Queen Creek

Reach 15050100-014A: Headwaters to confluence with the Town of Superior WWTP discharge
Reach 15050100-014B: Confluence with the Town of Superior WWTP discharge to the confluence with Potts Canyon
Reach 15050100-014C: Potts Canyon confluence to the Whitlow Dam

Arnett Creek

Reach 15050100-1818: Headwaters to the confluence with Queen Creek

Unnamed Drainages

Reach 15050100-1000: Headwaters to the confluence with Queen Creek
Reach 15050100-1843: Headwaters to the confluence with Queen Creek

Total Maximum Daily Loads (TMDL)

For

Dissolved Copper

Arizona Department of Environmental Quality

September 18, 2017

Publication number: OFR-17-03

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AAC	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
AgL	Agriculture-Livestock watering
ADOT	Arizona Department of Transportation
ARS	Arizona Revised Statutes
AZPDES	Arizona Pollution Discharge Elimination System
A&Wedw	Aquatic and Wildlife-effluent dependent water
A&Ww	Aquatic and Wildlife-warm water
BLM	Bureau of Land Management
BMP	Best Management Practice
cfs	cubic feet per second
CGP	Construction General Permit
EDW	Effluent-dependent water
EPA	Environmental Protection Agency
ft.	feet
FC	Fish consumption
FBC	Full Body Contact
GIS	Geographic Information System
kg/day	kilograms per day
LA	Load Allocation
MGD	Million Gallons per Day
µg/L	micrograms per liter
mg/L	milligrams per liter
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System Permit
MSGP	Multi-Sector General Permit
NB	Natural background
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
PBC	Partial Body Contact
QAQC	Quality Assurance / Quality Control
RCC	Resolution Copper Company
SWPP	Stormwater Pollution Prevention Plan
TMDL	Total Maximum Daily Load
TNF	Tonto National Forest
TSD	Technical Support Document (for Water Quality-based Toxics Control)
UAA	Use Attainability Analysis
USFS	United States Forest Service
USGS	United States Geological Survey
WIP	Watershed Improvement Planning
WLA	Waste Load Allocation
WQBEL	Water Quality Based Effluent Limit
WRCC	Western Regional Climate Center
WWTP	Waste Water Treatment Plant

1.0 INTRODUCTION

A Total Maximum Daily Load (TMDL) is the maximum amount, or load, of a water quality parameter which can be carried by a surface waterbody, on a daily basis, without causing an exceedance of surface water quality standards. TMDL calculations are made for waters listed as impaired on the state's 303(d) List. Data collection for the TMDL helps to identify if the impairment to water quality still exists. If the impairment is still present, the data can be utilized to identify the possible source(s) of the pollutant(s) and whether the source is due to human activity, or is due to natural background conditions. The Clean Water Act requires that every two years, states submit a list of impaired waters and a schedule to establish TMDLs to the Environmental Protection Agency (EPA). The EPA reviews and approves the 303(d) Lists and schedules. EPA also approves or disapproves of any TMDLs that the state may propose. Queen Creek has been divided into the following three hydrologic reaches: 15050100-014A (Headwaters to confluence with the Town of Superior WWTP discharge), 15050100-014B (Town of Superior WWTP discharge to the confluence with Potts Canyon), and 15050100-014C (Potts Canyon to the Whitlow Dam). Arnett Creek has the same reach number from its headwaters to its confluence with Queen Creek: 15050100-1818. Two unnamed drainages, 15050100-1000 and 15050100-1843 are tributary to Queen Creek in the upper Queen Creek Canyon area just downstream of Oak Flat. All six reaches are currently found in Arizona’s 2012/2014 303(d) list of impaired waters for exceedances of dissolved copper standards. Reach 014A was originally listed in the Arizona 303(d) list of 2002, and 014B was added to the 303(d) list of 2004. Reaches 014C, 1818, 1000, and 1843 were listed as impaired for dissolved copper in Arizona’s 2010 305(b) report.

Work on the Queen Creek TMDL was initiated in late 2002/early 2003 by Arizona Department of Environmental Quality (ADEQ) personnel as a part of the TMDL planning process. This initial work involved monitoring programs and modeling studies that were designed to identify and to quantify the various sources of copper within the watershed. In February of 2010, personnel from the TMDL Unit completed the calibration and validation of the preliminary modeling for dissolved copper in the Queen Creek watershed. This initial early work was followed up by the collection of more water samples, plus the addition of soil and rock samples. Discharge data was collected, and rain gauges were used to collect rainfall information from the top and bottom of the watershed. Data regarding climatic conditions was also collected by a remote weather station established by ADEQ near the top of Pinal Peak. Resolution Copper Company (RCC) also supplied metrological data from two weather stations that the company operates within the project area. In late 2011 a contractor was hired to handle the last portions of the modeling process. Modeling of the additional data exhibited an acceptable hydraulic and pollutant calibration and indicated that natural background in bedrock and soils, semi-active mines, and suspected historic smelter fallout, constitute the main sources of copper in the Queen Creek watershed.

The goal of the Queen Creek TMDL project was to develop the site characterization and water quality data set needed to calculate the TMDLs for dissolved copper in the listed reaches of Queen Creek, Arnett Creek, and the unnamed drainages. The sampling and modeling results have been used to accomplish the following:

1) Identify sources of pollutant loading, including natural background, nonpoint and point source contributions.
2) Identify the critical condition(s) for loading.
3) Calculate the pollutant loads and allocations for the identified load sources.
4) Calculate the required load reductions.

A by-product of sampling at various sites throughout the project watershed was the ability to assess whether other pollutants were also appearing with enough frequency to be considered an issue. Results of the sampling, combined with existing historical data, triggered the 303(d) listing of Reach 15050100-014A (Queen Creek; Headwaters to the confluence with Superior WWTP discharge) in 2010 for lead, and in 2012 for selenium. The older historic issue of dissolved copper is addressed in this TMDL document. Once the dissolved copper TMDL has been established for the impaired reaches, a schedule for the lead and selenium TMDLs will be developed.

2.0 Physical Setting

2.1 Physiographic Setting

Queen Creek is a sub-basin of the Middle Gila River watershed. Appendix B of Arizona's surface water standards (Arizona Administrative Code, Title 18, Chapter 11, Article 1 [AAC-18-11]) divides the Gila River into the following three watersheds: the Upper Gila, the Middle Gila and the Lower Gila. The Middle Gila watershed begins at the San Carlos Reservoir / Coolidge Dam (spillway elevation approximately 2,500 feet) and ends downstream at the Painted Rock Reservoir dam (elevation approximately 600 feet). In total, the Middle Gila watershed drains an area of approximately 12,250 square miles, and includes the lakes and drainages of the Phoenix metro area. In the past, Queen Creek drained directly to the Gila River near the northern boundary of the Gila River Indian Reservation. Currently the drainage has been engineered to flow into the Roosevelt Water Conservation District (RWCD) canal, where it will ultimately drain into the Gila River. The entire Queen Creek watershed covers an area of approximately 250 square miles.

The Queen Creek TMDL project area, as seen in **Figure 1**, is located within the Basin and Range Lowlands province. A portion of the northern most part of the watershed and a small section of the eastern tip are located in the Central Highlands province. The reaches of Queen Creek above Superior are best described as falling in the transition zone between the two provinces. All reaches below this point are located within the Basin and Range Lowlands province.

The headwaters of Queen Creek are located in the Pinal Mountains, specifically the northeastern slope of Fortuna Peak (elevation approximately 5,000 feet). The channel flows southeast for approximately three miles before turning slightly and flowing south for about 0.5 miles. At this point the channel turns back and begins draining in a southwesterly direction towards Superior. About 4.5 miles below the headwaters, the channel passes beneath US Highway 60 and drains southwest through the narrows of Queen Creek Canyon for about 2.8 miles. It is at this point, approximately 7.3 miles below the headwaters that the channel exits the foothills just north of the Apache Leap formation at the northern end of the Dripping Springs Mountains and proceeds through Superior in a west, southwesterly direction. At approximately 8.4 river miles below the headwaters, the channel passes under US Highway 60 a second time, and continues on for about another 1.2 miles where it begins receiving treated effluent from the Superior WWTP. The channel drains west, flowing along the northern base of Picketpost Mountain to the confluence of Arnett

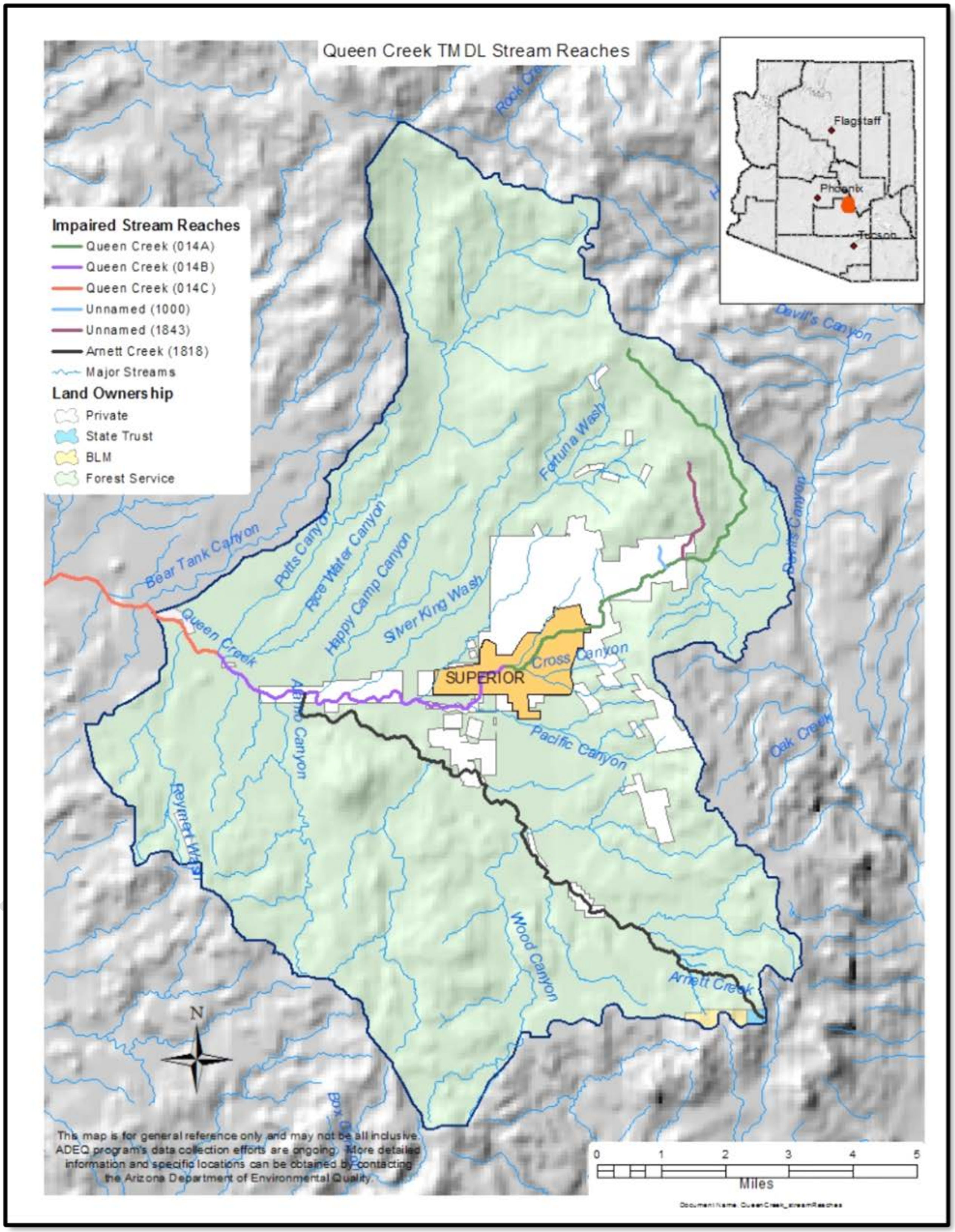

Figure 1: General Map of the Queen Creek Project Area

Creek (a distance of approximately 3.5 miles). About 0.15 miles downstream of the mouth of Arnett Creek, Queen Creek passes under US Highway 60 a third time. It then drains in a northwesterly direction for approximately 1.6 miles to the confluence with Potts Canyon (elevation approximately 2200 feet). Below Potts Canyon the channel drains in a westerly direction for about 5.5 miles towards the Whitlow Dam flood control structure (elevation approximately 2080 feet).

Those reaches of Queen Creek that lie above the city are typically narrow, reaching widths of about 30 feet or less. As the drainage runs through town, the channel width begins to increase. Below the confluence of Arnett Creek, the channel once again begins to widen and by the time it reaches its confluence with Potts Canyon the channel of Queen Creek has widened substantially. Aerial views show the presence of overflow side channels and braiding in the main channel. Cobble bars and mid-channel bars were observed in Queen Creek from the mouth of Potts Canyon to the sample site downstream at Queens Station during field sampling visits. At Queens Station the channel width has increased to over 100 feet in some areas. Flow measurements at this site were often impossible to perform during run-off events due to the depth, velocity and width of the active channel.

The Queen Creek watershed is located in an area of the state that has generally sparse population numbers. The entire watershed is located in Pinal County. Pinal County has a population of approximately 376,000, making it the third-most populous county in Arizona. Casa Grande is the largest city in the county with a population of about 49,000 (U.S. Census Bureau, 2010). The Town of Florence has about 25,500 (U.S. Census Bureau, 2010) people and is recognized as the county seat of Pinal County. Superior is the largest town within the Queen Creek sub-basin, with a population of about 2800 people (U.S. Census Bureau, 2010).

2.2 Climatic Setting

Like the majority of Arizona, hot summer temperatures and mild winter conditions typify the climatic conditions of the Queen Creek basin. Superior is located at an elevation of about 3000 feet. The higher elevation keeps Superior cooler on average than Phoenix and the other urban areas of the valley. Summer temperatures in the lower elevations of the project watershed can still reach into the 100's.

The higher elevations of the upper reaches will tend to be somewhat cooler throughout the year, and though snow fall is not common in this area it does occasionally occur when cycles of wet, cold weather move through the watershed. Data from the Western Regional Climate Center (WRCC) indicates that in February of 2001, 4.00 inches of snowfall was recorded at the Superior monitoring site. However, records show that prior to February 2001, the last recorded snowfall occurred in 1975-76, a stretch of approximately 24 years. This time frame of consecutive years without recorded snowfall in Superior is the longest since data collection had been initiated in July of 1919. Areas of the upper Queen Creek Canyon at elevations above 3000 feet will receive winter snowfall when conditions of moisture and temperature occur in the proper combination. Snow was observed during the winter rain sampling of late 2007 and early 2008 period on the peaks just north of the Oak Flat area. Late winter storms in 2016 deposited several inches of snow in the upper elevations of the Queen Creek Canyon area.

Rainfall in this area follows a pattern similar to much of Arizona. During the early warming period of summer the hot dry air in the lower elevations of the state begins to rise into the upper atmosphere. As the heated air rises, moist tropical air is pulled mainly from the Gulf of California (also known as the Sea of Cortez), and a small portion is pulled west from the Gulf of Mexico. The heavier moist air fills the void produced by the rising dry air. This invasion of very wet, warm air creates ideal conditions for localized storms of short duration and sometimes very large volumes of rain. Winter storms tend to be much longer in duration with considerably less intensity. During these cooler months the prevailing east winds off the Pacific Ocean push mid-latitude cyclonic storms across California and Arizona. The volume of rainfall produced by the different types of seasonal storms may be similar, but the duration and spatial extent are usually quite different. **Table 1** shows Western Regional Climate Center (WRCC) precipitation data for the Superior area for the period of 1920 to 2006.

Seasonal means indicate that the winter and summer months do receive the most moisture, but that the spring and fall months, which are sometimes described as dry months, also account for a significant amount of the annual mean. Inquiries to the WRCC indicate that more current information is still being reviewed for approval so that it can be released to the public.

Table 1: Precipitation data for the town of Superior, AZ

SUPERIOR, ARIZONA

Period of Record General Climate Summary - Precipitation

Station:(028348) SUPERIOR

From Year=1920 To Year=2006

	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	2.00	11.29	1993	0.00	1924	2.56	24/1943	5	4	2	0	0.3	6.4	1933
February	1.98	7.34	2005	0.00	1924	2.53	13/2005	5	4	1	0	0.5	7.5	1939
March	2.02	7.48	1992	0.00	1933	3.66	22/1954	5	4	2	0	0.3	6.0	1922
April	0.80	3.89	1952	0.00	1937	1.49	02/1999	3	2	1	0	0.1	2.5	1921
May	0.34	2.60	1992	0.00	1929	1.73	02/1941	2	1	0	0	0.0	0.0	1921
June	0.26	2.06	1955	0.00	1923	1.24	23/1972	1	1	0	0	0.0	0.0	1921
July	1.91	5.84	1921	0.04	1995	2.00	18/1976	7	4	1	0	0.0	0.0	1921
August	2.80	11.03	1963	0.47	1952	3.80	14/1990	8	5	2	1	0.0	0.0	1920
September	1.48	5.36	1983	0.00	1928	2.75	18/1946	4	3	1	0	0.0	0.0	1920
October	1.18	8.68	1972	0.00	1934	3.72	30/1959	3	2	1	0	0.0	0.0	1920
November	1.43	5.85	1931	0.00	1929	2.66	13/1941	4	3	1	0	0.0	3.0	1964
December	2.13	10.43	1965	0.00	1929	2.92	15/1967	5	4	2	1	0.2	4.5	1968
Annual	18.34	35.77	1978	4.90	2002	3.80	19900814	54	35	13	4	1.4	8.0	1976
Winter	6.11	23.65	1993	0.92	1964	2.92	19671215	16	11	5	1	1.0	9.0	1969
Spring	3.16	11.57	1941	0.01	1955	3.66	19540322	10	6	2	1	0.4	8.0	1976
Summer	4.97	11.22	1990	0.81	2002	3.80	19900814	16	10	3	1	0.0	0.0	1921
Fall	4.09	12.21	1972	0.20	1938	3.72	19591030	11	8	3	1	0.0	3.0	1964

Table updated on Jul 14, 2008
For monthly and annual means, thresholds, and sums:
Months with 5 or more missing days are not considered
Years with 1 or more missing months are not considered
Seasons are climatological not calendar seasons
Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

2.3 Hydrogeology

The watershed area for the Queen Creek/Arnett Creek project area is approximately 99 square miles. This figure was calculated using the farthest downstream sampling site on Queen Creek (MGQEN030.06), which is located at 33°17’48.459’’N / 111°12’39.236’’W in reach 014C. The sample site is 1.3 miles downstream of the reach break between 014B and 014C. Neither Arnett Creek, the three reaches of Queen Creek nor the two unnamed drainages being addressed in this TMDL meet ADEQ’s definition of a perennial water (“a surface water that flows continuously throughout the year”). Short reaches of spatially intermittent flow have been observed in the narrow reaches of Queen Creek that flow through Queen Creek Canyon, and in the lower reaches of Arnett Creek. Most of Queen Creek and its tributaries flow through sparsely inhabited areas of the watershed. A reach of approximately two miles in the middle section of the main channel does run through Superior. There are no perennial tributaries to Queen Creek, although small stretches of flow have been observed from seeps that occur near the channels. Most of these only flow for short distances due to the small amounts of water being discharged. Some of the sub-watersheds of Queen Creek which have been sampled for this TMDL include Potts Canyon, Whitford Canyon, Rice Water Canyon, Alamo Canyon, Arnett Creek, Happy Camp Canyon, Silver King Wash, Telegraph Canyon, Wood Canyon, Pacific Canyon, Belmont Canyon, Donkey Canyon, Cross Canyon, and numerous unnamed drainages either flowing into the sub-watersheds or directly into Queen Creek.

As noted earlier, the reach of Queen Creek from the Superior WWTP discharge to the confluence of Potts Canyon is listed in Appendix B of Arizona's Water Quality Standards for Surface Waters (AAC 18-11) as an effluent-dependent water (EDW). ADEQ defines an EDW as a surface water that would be ephemeral if not for the discharge of treated wastewater to the channel. Currently the Superior WWTP is not discharging at its maximum capacity, which limits the downstream extent of the EDW reach. The arboretum utilizes the effluent for watering vegetation throughout the site, and typically marks the channel with signs advising that the water in the stream is non-potable and unfit for drinking.

Pump Station Spring is located at N 33°20'23''/W 111°03'48'', which is approximately 1.9 miles downstream of the headwaters near the Omya Inc. pit. United States Geologic Survey (USGS) topographic maps show this as the only named spring located near the main stem of Queen Creek. Discharge from this spring is minimal, although it may help to maintain soil saturation just downstream of its location. Work by the U.S. Forest Service (USFS) indicates that although there are springs present within the watershed, the amount of water being discharged to the surface is in most cases minimal.

Many of the drainages in the upper reaches of Queen Creek will sometimes flow intermittently after periods of wet weather due to the presence of exposed or shallow bedrock within the channel. The lack of a significant alluvial layer in these areas of Queen Creek Canyon limits the ability of runoff to infiltrate as deeply as it does in the other sections of the main channel. Reaches of the main stem in Queen Creek Canyon and portions of the creek bed as it enters Superior (**Figure 2**) also show areas of relatively thin alluvial deposition over the exposed Gila Formation bedrock. The highest rate of stream flow loss due to infiltration occurs at the point where the channel exits Queen Creek Canyon (Jones & Stokes 2000).

Figure 2: Looking upstream from the Magma Avenue Bridge

The valley below Queen Creek Canyon consists of cemented sandstones and conglomerates of the Gila Formation covered by a layer of unconsolidated sediments of varying sizes. **Figure 2** illustrates the bedrock layer and large boulders that are present in the channel upstream of the Magma Avenue Bridge, approximately 0.4 miles below the point where the channel exits the narrow confines of the Queen Creek Canyon. As the channel progresses downstream the sediment size decreases and the depth of the alluvial material gradually begins to increase. Flows downstream of the canyon become more intermittent and short lived as the infiltration of surface water into the alluvium below the channel begins to occur more rapidly. The channel constricts as it drains westward along the north-facing base of Picketpost Mountain, a large fault-block feature that lies between Queen Creek and the Arnett Creek drainage. Below this constriction point flows in the creek become more ephemeral in nature, as the depth to bedrock (or other impermeable layers) increases significantly.

2.4 Land Management and Ownership

The majority of the land in the Queen Creek TMDL project area is public land, under the management of the USFS (see **Figure 1**). This forest service land makes up approximately 90 percent of the TMDL project watershed. It is administered by the Tonto National Forest, (TNF). TNF oversees the public grazing of cattle that occurs within the watershed, and also manages the harvesting of vegetation for commercial and private use.

Although timber harvesting is a viable commercial enterprise in other areas of Arizona’s national forests, the removal of timber in the TMDL project area is uncommon. The presence of mainly scrub vegetation throughout much of the area makes timber harvest financially challenging. Although commercially valuable types such as Ponderosa Pine are found in the higher elevations of the project area, they do not occur in the large stands found in other parts of the state. As with most public land, outdoor recreational activities such as camping, off-road recreational vehicle operation, hunting, etc., are also quite popular. For many years the Queen Creek Canyon area has been a popular site for rock climbing.

A very small portion of land managed by the Bureau of Land Management (BLM) is located near the headwaters of Arnett Creek, and an even smaller piece of land managed by the State Land Department is located adjacent to and east of the BLM parcel. Together these two pieces of land make up less than 0.5 percent of the project area. The rest of the land within the project area is privately owned, the majority of which falls within the boundaries of the Town of Superior. Land owned by mining interests makes up the second largest portion of private land. Historically, one of the largest employers in the area has been the mining industry. Mining does not employ the large numbers of people in this area that it has in the past, but it is still recognized as one of the important industries that help to fuel Arizona's economy. Mining is discussed in greater detail in Section 4.2.5.

2.5 Geology

The geology along Queen Creek from its headwaters to the Town of Superior consists of mineralized Precambrian metamorphic and igneous outcrops throughout the region which are overlain by upper Precambrian and Paleozoic sedimentary rocks (**Figure 3**). The Precambrian rocks are extensively intruded by diabase. Several intrusive bodies of granitic composition are of late Mesozoic and early Tertiary age. Large areas are covered by unmineralized Tertiary volcanic rocks known as Apache Leap Tuff. Sedimentary rocks have been tilted and the area has been extensively broken by block faults of several different ages. The geology from Superior to the confluence with Potts Canyon is predominantly Quaternary Alluvium with Gila Conglomerate.

Fortuna Peak, a Quaternary Dacite Conglomerate formation, overlies the Precambrian Diabase and Pinal Schist formations. Queen Creek, originating on the slopes of Fortuna Peak, flows southeast through the Paleozoic units, the Cambrian Bolsa Quartzite, the Devonian Martin Limestone, the Mississippian Escabrosa Limestone and the Pennsylvanian Naco Limestone. These units, having been exposed due to the extensive folding and faulting within the area, help form and direct the path of Queen Creek. Queen Creek continues its path through the Tertiary Rhyolite and Apache Leap Tuff formations. East of Superior, Queen Creek flows once again through the exposed and faulted Paleozoic formations previously listed. The Concentrator Fault separates the Paleozoic formations from the Quaternary Alluvium deposit which encompasses the remainder of Queen Creek's path to Potts Canyon.

Copper deposits in the Superior area are a by-product of volcanic activity in Arizona that occurred approximately 15 to 40 million years ago, during a period referred to as the Mid-Tertiary. Geologists agree that this is one of several volcanic periods in Arizona's history and believe that the eastward movement of the episode was caused by a decrease in the angle of the sub-ducted oceanic plate beneath the region. Middle Tertiary volcanic deposits are common and fairly widespread throughout the Basin and Range Province. Volcanism during this period was locally

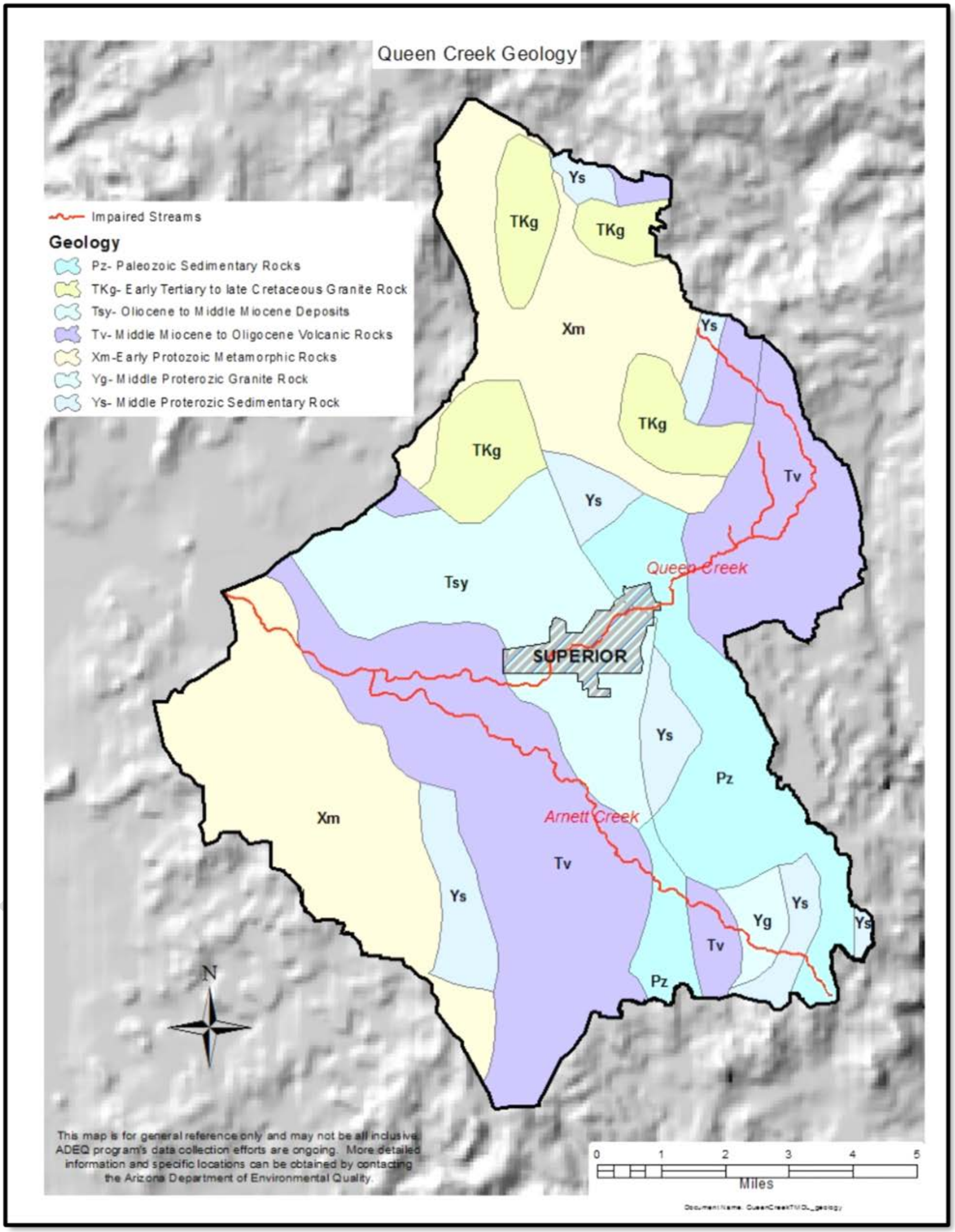

Figure 3: Geologic Map of the Queen Creek Project Area

accompanied by deposition of precious and base-metal veins from hot fluids that circulated near the centers of the volcanic activity and also along major fault lines.

The geologic make-up of the various sub-watersheds directly effects the total hardness present in various reaches of Queen Creek's main stem and also the tributaries that feed into it. The Oak Flat area consistently produces fairly low total hardness sample results. The volcanic tuff that makes up a great deal of the sub-watershed is relatively young in geologic terms, and has not been subjected to the erosional effects that other geologically older areas have been. The area typically has a thin alluvial layer, and in some spots the tuff is completely exposed. Rain water runs off very quickly, with little opportunity to soak through what little alluvial material is present. Without the ability to percolate through sufficient alluvial material the rain water cannot acquire the mineral carbonates that contribute to the levels of total hardness. Other sub-watersheds with better developed alluvial deposition will typically show higher levels of total hardness, in some cases over ten times higher than those seen in certain drainages of the Oak Flat area. Sample collection and geologic data has also shown the volcanic tuff in the project area to be one of the biggest contributors of copper when compared to other geologic features.

2.6 Vegetation and Wildlife

The vegetation within the Queen Creek project area varies most notably by differences in elevation. Arizona Sycamore, Arizona walnut and velvet ash are common within the riparian corridor of the headwaters area of Queen Creek. As the channel drops in elevation, the vegetation along the stream channel transitions into a mixed riparian woodland that includes cottonwood, willow, ash, seepwillow, desert broom, and netleaf hackberry. The upper banks of the channel are inhabited by a shrubby mesquite bosque through the Town of Superior. In lower portions of the channel around and below Superior, the invasive saltcedar tree (*Tamarix*) is not an uncommon sight. In the upland portions of the watershed the conditions are cool and moist enough to support areas of Madrean Evergreen Woodland. This type of woodland usually occurs below montane conifer forest, and is often recognized as a transitional step to pine forests. The most common trees for this type of woodland are evergreen oaks (several species), Alligator Juniper, One-seed Juniper and Mexican Pinyon Pine.

Below this woodland the vegetation changes to a scrubland assemblage referred to as Interior Chaparral. Arizona chaparral is normally found at mid-elevations of 3,445 to 6,560 feet. Shrub Live Oak is the most prevalent chaparral species and sometimes occurs in almost pure stands. It is more commonly found with shrubs like Birchleaf Mountain-mahogany, Skunkbush Sumac, Silktassel Bush, Wright Silktassel, and Desert Ceanothus, all of which may locally become the dominant vegetative component if the proper conditions are present. Hollyleaf Buckthorn, Cliffrose, Desert Olive, Arizona Rosewood, Lowell Ash Barberry and Manazanita are all less common, but are still considered an important component of Arizona chaparral. At the lower boundaries of the chaparral component lies the Sonoran Desertscrub community. The Sonoran Desertscrub region has been subdivided by Shreve (1951) into seven distinct components, two of which are present in the project area: Arizona Upland and Lower Colorado River Valley. Arizona Upland covers the majority of the lower Queen Creek project area. This biotic community derives its name from the fact that over 90 percent is located on broken or sloping ground, and on multi-dissected sloping plains commonly found in the transition zone between Interior Chaparral and

Sonoran Desertscrub. Within the Queen Creek project area two differing sub-divisions of the Arizona Upland occur, the Paloverde-Cacti-Mixed scrub series and the Jojoba-mixed Scrub series. Below the Arizona Upland community at the lowest elevations of the Queen Creek valley is the Lower Colorado River Valley subdivision. This community is normally found on the broad, flat, dry floor of the valley and occurs in two sub-divisions: the Creosote-White Bursage series and the Saltbush series. Creosote bush does tend to intrude on the slopes depending on moisture availability, while White Bursage tends to be limited to the valley floor. Dry drainages found within the Sonoran Desertscrub tend to be areas of water accumulation, and are usually areas where less xeric types of plants such as Seepwillow can be found.

Wildlife includes rock, cactus and canyon wrens, verdins, gnatcatchers, and white-winged and mourning doves. Beechey ground squirrel, desert cottontail, black-tailed jackrabbit, raccoon, gray fox, stripped skunk, deer and javelina have been observed near Queen Creek (Jones & Stokes, 2000).

2.7 Land Cover and Use

USGS data indicates that shrub and brush rangeland total 97.51 percent of the watershed area. Some of the more common sources of copper, including strip mines, quarries, and gravel pits, only make up 0.03 percent of the watershed area. **Table 2** breaks down the various land types and use classifications according to the USGS National Land Cover Dataset.

Table 2. Land Use Classification of the Queen Creek TMDL project watershed

Land Use	Total Area, meter^2	Total Area, mile^2	Percentage
Shrub & Brush Rangeland	237,129,864.7	91.56	97.51%
Residential	2,267,111.4	0.88	0.93%
Industrial	1,759,441.9	0.68	0.72%
Evergreen Forest	980,544.1	0.38	0.40%
Commercial & Service	400,335.2	0.15	0.16%
Other Urban Or Built-Up Land	164,889.8	0.06	0.07%
Transportation & Communication & Utility	163,375.1	0.06	0.07%
Bare Exposed Rock	127,600.6	0.05	0.05%
Sandy Areas Other Than Beaches	112,185.7	0.04	0.05%
Strip Mines & Quarries & Gravel Pits	69,994.8	0.03	0.03%
Total:	243,175,343.5	93.89	100.0%

3.0 Numeric Targets

3.1 Clean Water Act Section 303(d) List

ADEQ first listed 15050100-014A (Queen Creek – headwaters to the confluence with the Town of Superior WWTP discharge) as impaired for non-attainment of the Aquatic and Wildlife-warm water (A&Ww) designated use in 2002 due to dissolved copper exceedances. Reach 014B (Queen Creek – from the confluence with the Superior WWTP discharge to the confluence of Potts Canyon) was listed as impaired for copper in 2004. Reach 15050100-014C (Queen Creek – Potts Canyon to the Whitlow Dam), reach 15050100-1818 (Arnett Creek – headwaters to the confluence with Queen Creek), and the two unnamed drainages (15050100-1000 & 15050100-1843) were all listed as impaired for dissolved copper in 2010. TMDL allocations must be developed for those waters listed on the 303(d) list. TMDLs determine the amount of a given pollutant(s) that the water body can withstand without creating an impairment of that surface water's designated use(s). The most recent 305(b) report on the assessment of Arizona's surface waters (2012/2014) indicates that reaches 014A, 014B, and 014C of Queen Creek, Reach 1818 of Arnett Creek, and the two unnamed drainages remain listed as impaired for dissolved copper.

3.2 Beneficial Use Designations

ADEQ codifies water quality regulations in AAC 18-11. Designated beneficial uses, such as fish consumption, recreation, agriculture, and aquatic biota, are defined in AAC 18-11-101 and are listed for specific surface waters in AAC 18-11, Appendix B. AAC 18-11-104 describes the different designated uses that ADEQ recognizes, and how they are used for the protection of surface water quality

The designated uses for the listed reaches of Queen Creek in Arizona's water quality standards for surface waters are as follows:

014A - Headwaters to the confluence with the Town of Superior WWTP discharge at 33°16'33"/111°07'44" = Aquatic and Wildlife, warm water (A&Ww), Partial Body Contact (PBC), and Agricultural Livestock watering (AgL)

014B - Confluence with the Town of Superior WWTP discharge to the confluence with Potts Canyon at 33°17'17"/111°11'36" = Aquatic and Wildlife, effluent dependent water (A&Wedw), and PBC

014C - Potts Canyon confluence to the Whitlow Dam = A&Ww, Full Body Contact (FBC), Fish Consumption (FC), and AgL

1818 - Arnett Creek; Headwaters to the confluence with Queen Creek = A&Ww, FBC and FC

1000 - Unnamed drainage; Headwaters to confluence with Queen Creek = A&We and PBC

1843 - Unnamed drainage; Headwaters to confluence with Queen Creek = A&We and PBC

Arnett Creek and the two unnamed drainages are not currently listed in Appendix B of Arizona's surface water quality standards. In cases where a water body is not listed in Appendix B, but it is a tributary to a listed surface water, standards are determined through the application of the tributary rule found at AAC 18-11-105. The rule states that A&Ww, FBC, and FC standards apply to an unlisted tributary that is a perennial or intermittent surface water and is below 5000 feet in elevation. Arnett Creek meets the criteria in that it is spatially intermittent in lower reaches of the drainage and that its channel lies entirely below the 5000 foot elevation cut-off. AAC 18-11-105 states that the aquatic and wild life ephemeral (A&We) and PBC standards apply to an unlisted tributary that is an ephemeral water. The two unnamed drainages meet the criteria in that they only flow in response to storm water and their channels always lie above the ground water table.

The three reaches of Queen Creek, Arnett Creek, and the two unnamed drainages are all impaired due to the exceedance of the dissolved copper standard for the Aquatic and Wildlife designated uses, even though they represent different habitat types. Aquatic and Wildlife, warm water, is defined by ADEQ as the use of a surface water by animals, plants, or other warm-water organisms, occurring at an elevation of less than 5000 feet for habitation, growth, or propagation. The A&Wedw designated use is applied to those surface waters, classified under AAC 18-11-113, that owe their existence to a point source discharge of wastewater. The A&We designated use protects those organisms that use an ephemeral water body for habitation, growth, or propagation.

3.3 Applicable Water Quality Standards

The dissolved copper standards for all the impaired reaches are total hardness based, which is expressed as calcium carbonate in milligrams per liter (mg/L). Total hardness is analyzed from the corresponding water sample and is the sum of the dissolved molar concentrations of Ca^{2+} and Mg^{2+}, the two most common divalent metal ions found in the environment. The A&Ww copper standard has both acute and chronic limits. Ephemeral water bodies are only subject to the acute criteria, because they do not experience the long term flows that are needed to define chronic exposure. Chronic criteria for dissolved copper can range from 0.18 µg/L at a total hardness of 1 mg/L to 29.28 µg/L at a total hardness of 400 mg/L. Although the two unnamed drainages meet ADEQ's definition of an ephemeral water, the A&Ww chronic dissolved copper standard is being applied to determine loading and reductions due to the fact that both drainages are direct tributaries to the main stem of Queen Creek.

3.3.1 Total Hardness Data

While reviewing the total hardness data that had been supplied by ADEQ to the modeling team it was discovered that some of the data were inaccurate. The revised total hardness data set was statistically re-analyzed and the results were used to revise two tables located within the final modeling report (The Louis Berger Group, Inc., 2013): Table 3.4; Existing Conditions 24-hour Average Dissolved Copper Concentrations (µg/L) and Table 3-6; Existing Conditions Scenario Dissolved Copper Allocation Analysis. The revised tables can be found in Section 5.3 of this report.

The original total hardness values were not used in the modeling of the dissolved copper, and the updated values do not affect the modeling results. The function of the model is to predict the amount of dissolved copper being contributed by each modeling basin, utilizing both the sampling data and the meteorological data of the entire project watershed. The historical total hardness data, and the data collected just prior to the running of the model were used to determine the average total hardness value, solely for the purpose of establishing what the average dissolved copper standard should be at the pour point of the individual modeling basin. By determining the applicable standard, a target value is confirmed, allowing the TMDL calculations to go forward.

4.0 Source Assessment

4.1 Summary of Point Sources

Omya Inc., Superior, AZ, a limestone quarry, has been operating since 1999. Its quarry is adjacent to Queen Creek in the headwaters area, approximately 3.5 miles north of Highway 60 with its processing facility located within Superior. The quarry produces limestone for use in high-grade food and pharmaceutical products. Omya Inc. produces approximately 100,000 tons per year of calcium carbonate with 60 percent used for industrial purposes and the remaining 40 percent for food products. Omya's Arizona Pollution Discharge Elimination System (AZPDES) Multi-sector General Permits (AZMSG) include AZMSG-63038 for the quarry site and AZMSG-63037 for the in-town processing site. Discussions with the compliance section of ADEQ have indicated that currently only the in-town site is active, processing material shipped from their operations in California.

Imerys Perlite USA, Inc., a perlite mining facility, lies approximately 2 miles south of Highway 60. The main offices for the operation are located north of Highway 60, just off of Forest Service Road 229. The facility has been operating since 1950 and covers an area of approximately 6 acres with 160 filed claims. Two artesian wells are located on the facility site and they periodically discharge into Queen Creek. Imerys currently has an MSGP, AZMSG-61700.

Resolution Copper Company is in the initial stages for the opening of its east plant operations. In 1995, exploratory drilling by the Magma Copper Company discovered the "Resolution Deposit". The deposit lies about 7,000 feet deep and has been estimated at approximately 1.7 billion metric tons, and contains approximately 1.52 percent copper. The company plans on reaching production by 2020. RCC's permits include AZMSG-63061 for the east plant operations and AZMSG-62880 for the west plant operations. The west plant operations are located just north of Superior at the site of the old Magma Copper Company. The west plant operations have an existing AZPDES permit, AZ0020389 – outfall 001 & 002. Both outfalls are permitted to discharge to Queen Creek, but do not discharge on a continual basis.

The Silver King Mine has been mining silver intermittently since 1875. The most productive years were from 1875 to 1889. For the next 100 years small scale operations would occasionally come in and work the site. The mine was inactive when the TMDL was initiated, but is currently active again. The Silver King Mine has an MSGP, AZMSG-83151. The mine site is located in the headwaters of the Silver King Wash watershed, a sub-watershed of the Queen Creek watershed. Silver King Wash flows into Queen Creek, just west of Superior near the Boyce Thompson Arboretum.

Kalamazoo Materials Inc. is a small sand and gravel mining operation that is located about 3.5 miles south, southeast of Superior. The site covers approximately 220 acres and sits at the top of an unnamed ephemeral drainage that is a tributary of the upper Arnett Creek sub-watershed. The facility currently has an MSGP, AZMSG-100816.

The Town of Superior WWTP is a publicly owned facility that receives domestic wastewater from both residential and commercial sources. Currently, the only industrial discharger that is connected to the system is the Omya processing plant. The plant's treatment process involves influent screening, grit removal, activated sludge biological treatment, solids settling in secondary clarifiers, tertiary filtration, chlorination, and de-chlorination. The sludge that is produced is processed for moisture removal through the use of drying beds before being taken from site for disposal. The current individual Arizona Pollutant Discharge Elimination System (AZPDES) permit, AZ0021199, authorizes discharges of treated effluent to Queen Creek.

4.2 Summary of Nonpoint Sources

Nonpoint source pollution occurs as water flows through geologic features and over the lands surface. As the water flows, it picks up both natural and man-made pollutants which can then ultimately make their way into lakes, rivers, wetlands, coastal waters and groundwater sources. Sampling can sometimes show that naturally occurring sources of pollutants can be contributing in amounts that may be the major source of on-going exceedances. In other cases human activities such as road construction can expose pollutant sources, which can then become a significant source each time a rain event occurs. Certain geologic features may contain naturally high levels of a specific parameter, or parameters, which simply through the act of erosion are present in concentrations that are sufficient to trigger exceedances of the applicable water quality standards. Some common anthropogenic nonpoint sources of copper to surface waters include impacts from mining (storm water run-off, smelter deposition, etc.), copper plumbing fixtures, automobile brake pads, copper roofs and gutters, copper-containing pesticides and industrial sources such as automotive repair shops. The lack of large scale agriculture in the area means that copper-containing pesticides are not a common source for this area. Most structures in the watershed use asphalt or ceramic shingles, so copper run-off from roofs and gutters is also not a significant problem. There are a few auto repair shops located in the project watershed, but the number is small. Copper plumbing fixtures are probably present in some of the older structures, but the number of buildings and the possible contribution are unknown at this time. Copper from brake dust is also a source due to the amount of traffic that uses Highway 60 for travel, and its proximity to the channel of Queen Creek. The contribution of copper from brake dust is also unknown at this time. In this watershed the most obvious anthropogenic sources of dissolved copper are from mining impacts.

4.2.1 Agriculture

There is currently no large scale agricultural activity occurring within the Queen Creek TMDL project area.

4.2.2 Forest

Evergreen forest areas comprise only 0.40 percent of the total watershed area and are located at the higher elevations present along the northern edges of the watershed. This land is under the management of the USFS and falls completely within the boundaries of the Tonto National Forest. These areas are used more for recreation than for lumber production and are not recognized as traditional sources of copper.

4.2.3 Roads

An issue which has been researched in both California and Washington is the impact on surface waters from brake pads that contain copper. Manufacturers have utilized copper in the production of brake pads because it effectively transfers frictional heat that is produced when the brake pad makes contact with the rotor. Each time a driver applies the vehicles brakes, a small amount of copper dust is deposited on the surface of the roadway. Subsequent storm events then wash the material into the nearest drainage where it has the potential to negatively impact water quality. Unpaved roads in sparsely populated areas are not normally considered as a significant source due to light use of these roadways and a road surface that is typically graded dirt which is much more porous than a heavy-use, hard surface road. Highway 60 which runs parallel to Queen Creek through a good portion of the Queen Creek Canyon is subject to high traffic use at times and also has sections where the incline of the road has the potential for heavy brake use by motorists.

4.2.4 Urban/Developed

The copper impacts from the lightly developed areas in the Queen Creek watershed are slight. As noted previously, copper impacts from urban areas come mainly from water systems that utilize copper piping and from buildings that use copper in the architectural design of the house (copper roofs, etc.). Given the relative small footprint of Superior and the other small communities found in the watershed, and the low intensity of development in these areas, urban development is a minor contributor to copper issues in the project area. Recent development and future plans utilize home construction methods that are designed to minimize the influence of copper impacts.

4.2.5 Mining

The Globe-Miami Mining District has long been an area of metal mining due to the highly mineralized geology present in the area. Historically, the discovery of silver was the trigger for the mining boom in the area. The Silver King Mine, mentioned previously, operated from 1875 to 1889 and began producing again from 1918 to 1928. The amount of silver extracted during the two time frames represents a total of approximately 6.2 million troy ounces of silver. In the early 1900's the price of silver began to decline, as interest in the copper found in the area began to pick-up. In 1910, William Boyce Thompson had just purchased the Inspiration mine in Globe and was also looking at mining claims in the Superior area. After Thompson purchased the Silver Queen mining properties for 130,000 dollars, he and his partner George Gunn formed the Magma Copper Company. Magma mined copper and produced dependably for the next fifty years. In the 60's, Magma began cutting back on its production and by 1995 it had stopped production. At present the mine is owned by RCC. Small to large sized mining operations can be found within the project area, although not all are currently active. Some exist as claims yet to be worked. Those facilities with AZMSGP permits are located on private land with the exception of the open pit mine location for Omya Inc., which is located near the headwaters of Queen Creek on forest service land. The locations of mines identified by the U.S. Bureau of Mines are illustrated in **Figure 4**. The mine locations have been grouped into four categories:

DEVEL DEPOSIT – the resource has been defined and development has been initiated
EXP PROSPECT – the resource has been defined by exploration methods
PAST PRODUCER – a previously operating mineral property, where the equipment or structures have been removed or abandoned
PRODUCER – a currently operating mineral property.

An unknown number of historically old, relatively small hand dug mines exist throughout the project area. Soil samples were collected from the tailing piles of some of these old workings to try and characterize the soils and geology of these areas. The majority of these small, abandoned hand dug mines are located on USFS land. These abandoned mines that lack any type of permit coverage and/or pollution controls are good examples of nonpoint source impacts from mining. There are typically no mechanisms in place to control contributions of copper from storm events. Mines with permit coverage and BMP's in place, whether they are active or inactive, are more rightly recognized as point sources of pollutants. Mining activities have the potential to contribute as either point source or nonpoint source based on the circumstances.

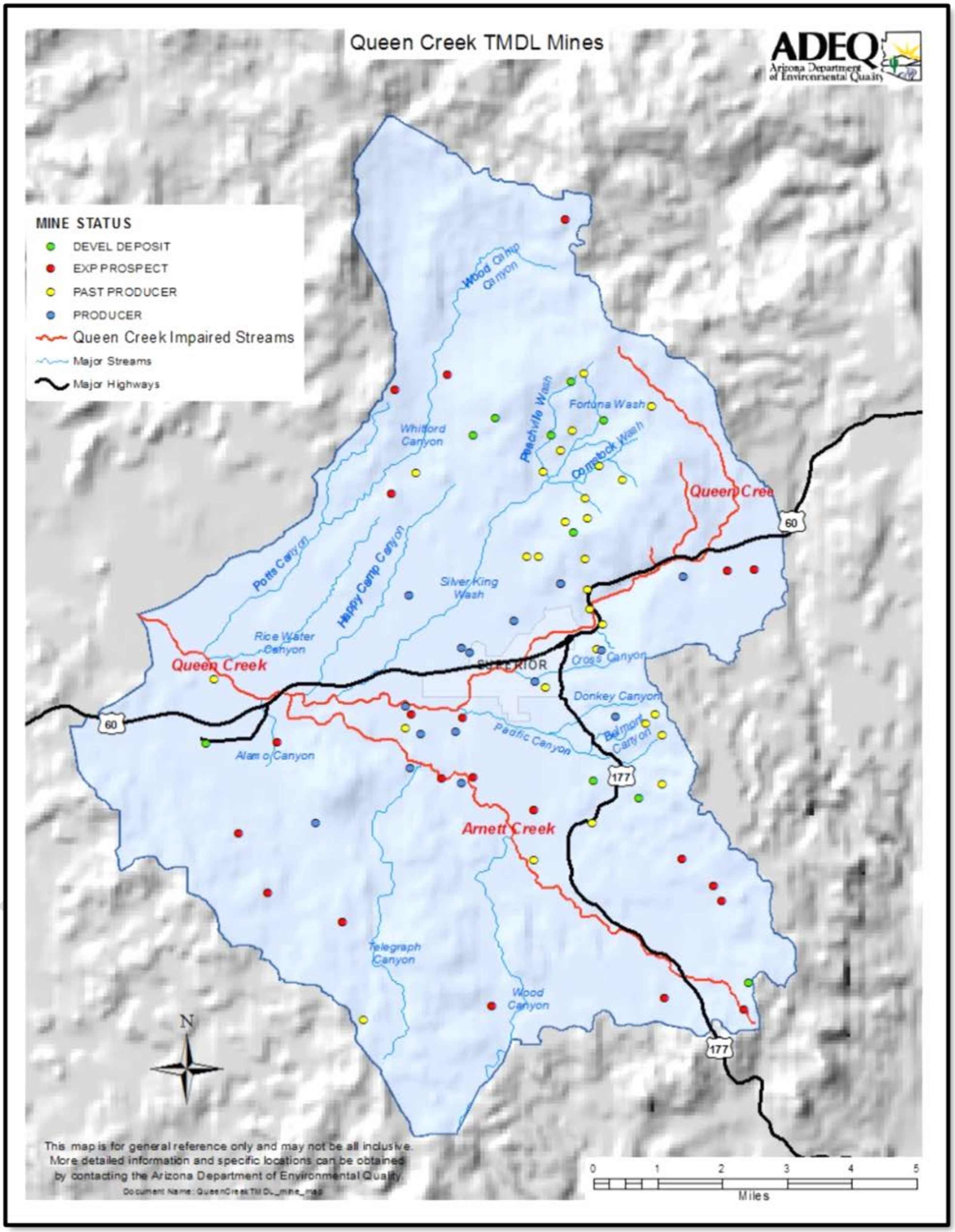

Figure 4: Documented Mine Locations within the Queen Creek Project Area

The removal of the ore and the subsequent crushing and milling process produce dust containing microscopic-sized copper particles. This dust is then spread by the movement of the wind until it ultimately settles to the ground. Subsequent storm runoff has the potential to wash the copper-contaminated dust into the nearest water body. Liquid and gaseous waste containing copper are both produced during the smelting phase of copper production. The waste water and sludge produced by the smelting process can contain traces of copper, and the extreme heat of the procedure produces gaseous emissions such as sulphur dioxide, nitrous oxide, and a number of toxic metal fumes. Deposition of particulate matter from older smelters that operated prior to being regulated for omissions has also been documented as a non-point source of copper and other metals.

Drainage or runoff from abandoned mining operations and prospect shafts can also be a contributor to nonpoint sources of copper and other metals. Tailings piles and remnants of acid leaching operations are normally the largest contributors from abandoned mining operations. Overburden material found near the mouths of prospect shafts and excavated mines are not usually as common a source for copper as tailings and waste rock material. Overburden material is typically coarse and not finely crushed like tailing and waste rock material, so it is not as easily erodible. If the overburden material does have high sulphur content the possibility of weak sulfuric acid leaching can increase as rain water flows over the material. Work around the state at various mine sites has shown that the contribution of metals from tailings piles can in some cases be significant. The active facilities have made physical changes at the sites to control storm water run-off from tailings. This typically involves physical alteration of the boundaries around the facility to stop any run-off generated on the site to be contained on the site. The number of abandoned mines in the project area is unknown, but most are small hand dug operations with a small amount of tailings usually located near the mouth.

4.2.6 Grazing

There are two grazing allotments in the project area. The Superior allotment covers an area of approximately 99 square miles and includes the lower and mid reaches of the project. The Devils Canyon allotment covers an area of about 33 square miles and encompasses most of the upper reaches of Queen Creek. Grazing impacts that accelerate erosion can lead to increased copper loading through loading of sediment into the stream. Observations of grazing impacts around the sampling sites did indicate that grazing impacts in the watershed appear to be slight, and are considered a minor source of copper loading.

5.0 Modeling of the Data

The term computer modeling is a phrase that refers to the use of a software program that is designed to simulate what might occur in a given situation based on the input of known data to help drive the simulation in the correct direction. Some computer-based models can be looking at things on a global scale, such as weather forecasting and climate change. Other types such as water quality modeling have the ability to work with large watersheds like the Amazon or Mississippi Rivers, but can also be applied to watersheds with drainage areas less than one square mile in size. Water quality models are typically designed to simulate the movement of parameters such as dissolved copper, from the source to the ultimate endpoint. In the natural environment, chemical, physical, and biological processes can affect both the transformation and the transportation of parameters such as dissolved copper. A good water quality model will have the ability to analyze the primary variables such as the hydraulic nature of the watershed, the potential loading sources, and the meteorological factors when simulating the fate of the parameter(s) in question. These separate factors are normally addressed within the model by individual modules that employ an algorithm to adjust factors such as air temperature versus evapotranspiration, pH changes, etc.

When personnel from ADEQ first began considering the agency's modeling approach to the Queen Creek watershed data, the decision was made to use the Hydrologic Simulation Program FORTRAN (HSPF) to simulate the hydrology and the transport of dissolved copper in the main stem of Queen Creek above sample site MGQEN030.06. This includes all of reaches 014A & 014B, and 1.3 stream miles of reach 014C. The fact that it is developed and supported by the USGS and EPA, and has been successfully applied in the TMDL analysis of complex watersheds throughout the country made it a logical choice. The modeling was also applied to those sub-watersheds of the project watershed where water quality data had been collected (ADEQ, 2010). The HSPF program is an element of the exposure assessment model developed by the USEPA referred to as the Better Assessment Science Integrating point & Non-point Sources, or BASINS (USEPA, 2001). The USEPA designed BASINS as a tool for both watershed management and TMDL development that can be used freely by any agency or organization dealing with issues of water quality. It works by incorporating a geographic information system (GIS) with data analysis and analytical modeling tools. The *ADEQ Queen Creek TMDL Modeling Report* is available for review through ADEQ. It was finalized in 2013 by the Louis Berger Group, located in Washington D.C.

The HSPF component of BASINS is a wide-ranging model dealing with watershed hydrology and water quality, which has the ability to simulate the pollutant run-off from various geologic formations within the watershed. It accounts for the specific watershed characteristics such as physical conditions, variations in rainfall and climate, etc., and it also predicts point and non-point sources of dissolved copper within the project watershed, along with the contribution of the various sources. By simulating the source and fate of dissolved copper, along with the in-stream hydraulic and sediment-chemical interactions, the modeler is able to produce a predicted time history of water quantity and quality at any point in the watershed that can be directly compared to the applicable water quality standard. Because the model has been calibrated hydrologically, the modeler is also able to predict the in-stream pollutant concentrations and loading under various hydrologic situations.

5.1 Modeling Implementation

BASINS was first utilized to delineate the watershed into 95 smaller modeling basins. The model was then able to use both the physical data and the land use data to develop a more detailed description of the characteristics of each modeling basin, which works to improve the over-all accuracy of the HSPF model. The modeling basin delineation is based on topographic characteristics, land use, and geology. The basins were created using a Digital Elevation Model (DEM), stream reaches obtained from the National Hydrography Dataset (NHD), and both stream flow and in-stream water quality data. The furthest downstream point in the modeling basin is typically referred to as the pour-point of the basin. This is the point where the model predicts the loading from the basin into the receiving surface water, based on the discharge data and the water

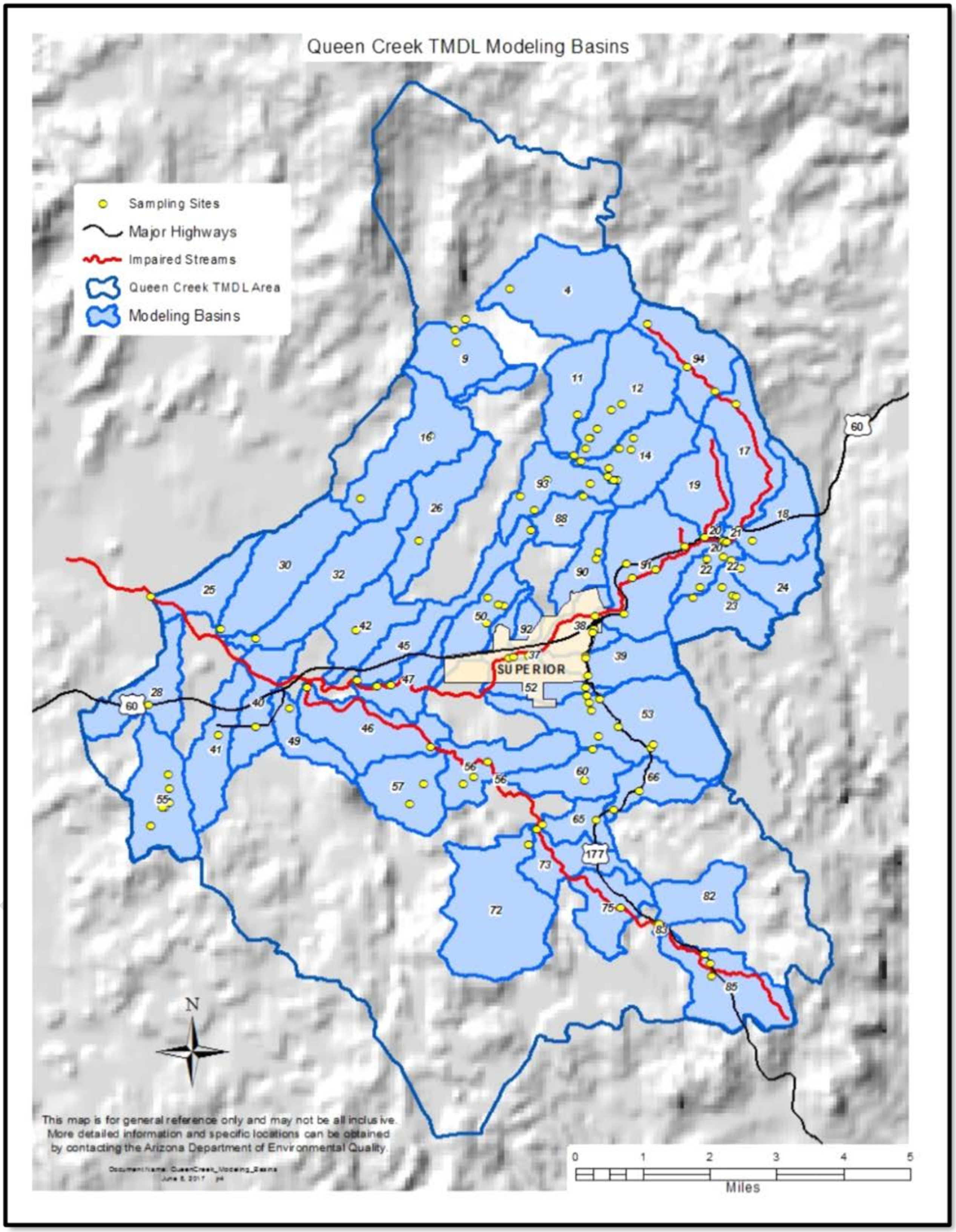

Figure 5: Modeling Basins that have Water Quality Data

quality sampling data from the sites located within the basin. **Figure 5** shows the location of those modeling basins that have available water quality data and were used in the modeling process.

5.2 Hydrologic Calibration

Once the modeling basins have been established the stream discharge data and the weather data can be utilized to establish calibration of the watershed hydrology. In hydrologic terms, Queen Creek flows tend to be storm driven and are usually short in duration. Flows in Arnett Creek tend to be similar in nature. Based on the assumption that these flows represent the normal hydrologic conditions, plus the availability of high frequency stream stage data collected by the pressure transducers stationed at sites throughout the watershed, and readily available local meteorological data, the decision was made to establish the time-step intervals for the model to be set at fifteen minutes. Calibration of the model can be a lengthy process, due to the fact that the modules which simulate different aspects of the hydrologic cycle must be continually adjusted each time the model is run. The results of the modeling runs are compared to the recorded discharges from the various sample sites to gauge the similarity between the simulated flows, and the actual observed in-stream flows. A large amount of data is needed to statistically gauge calibration results. Even though a large amount of data was collected at sites throughout the watershed, it was still not enough for statistical methods to be applicable. Visual agreement of the results must be utilized. The hydrologic calibration results for the various modeling sub-watersheds indicate acceptable visual agreement between the observed and the simulated surface water flows. Sensitivity analysis is always performed during the calibration process where input parameters are adjusted until the modeling results are acceptable, which includes agreement between the model output and the observed flow data. **Figure 6** illustrates the hydrology calibration for modeling basin # 46 – Arnett Creek, and indicates an acceptable visual agreement between observed and simulated flows.

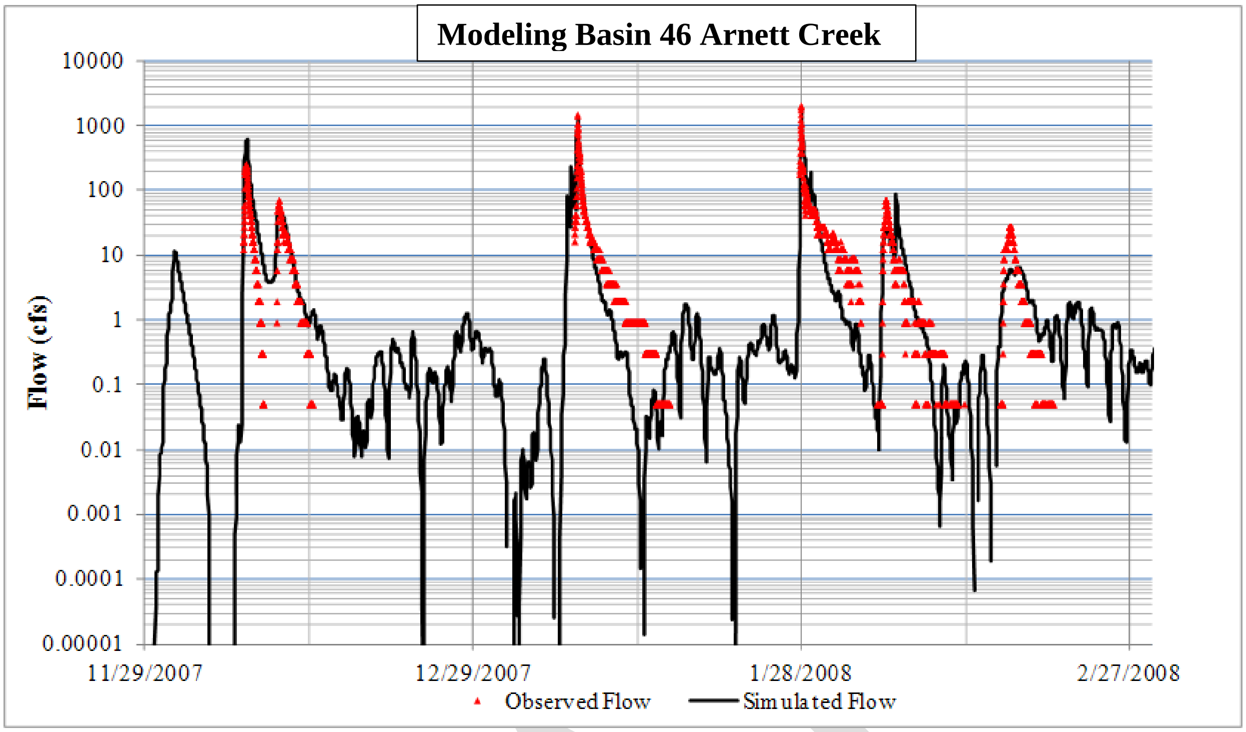

Figure 6: Observed vs Simulated Flows in Modeling Basin 46- Arnett Creek

5.3 Dissolved Copper Calibration of the Model

Calibration of dissolved copper is similar to the hydrologic calibration in that the observed in-stream sample data is compared to the simulated in-stream concentrations. In the case of dissolved copper, the modules of the model are used to simulate the sources of copper and also the environmental factors that are important in determining where in the watershed it is transported to. Like the hydrologic calibration, the dissolved copper calibration can be a time consuming process. Because the model is dealing with modeling basins of differing geologic features, run-off potentials, etc., the fate of dissolved copper can vary from one modeling basin to another. The water quality calibration proceeded from the most upstream reach (basin 94) to the furthest downstream reach (basin 25). Further modeling refinements were made at several monitoring stations (using the hard rock copper data as a guide) to achieve a better fit between observed and simulated average dissolved copper concentrations. The water quality calibrations were performed at each monitoring station located at each modeling basin outlet, and at several monitoring stations located in the main stem of Queen Creek. The calibration process compares the simulated copper time-series and the observed dissolved copper observations during the period spanning from November 29, 2007 to February 27, 2008. **Figure 7** depicts the dissolved copper calibration at modeling basin 46 – Arnett Creek, the same modeling basin sited in the previous figure. The dissolved copper calibration results from this basin and others within the project watershed indicate acceptable agreement between observed and simulated concentrations of dissolved copper.

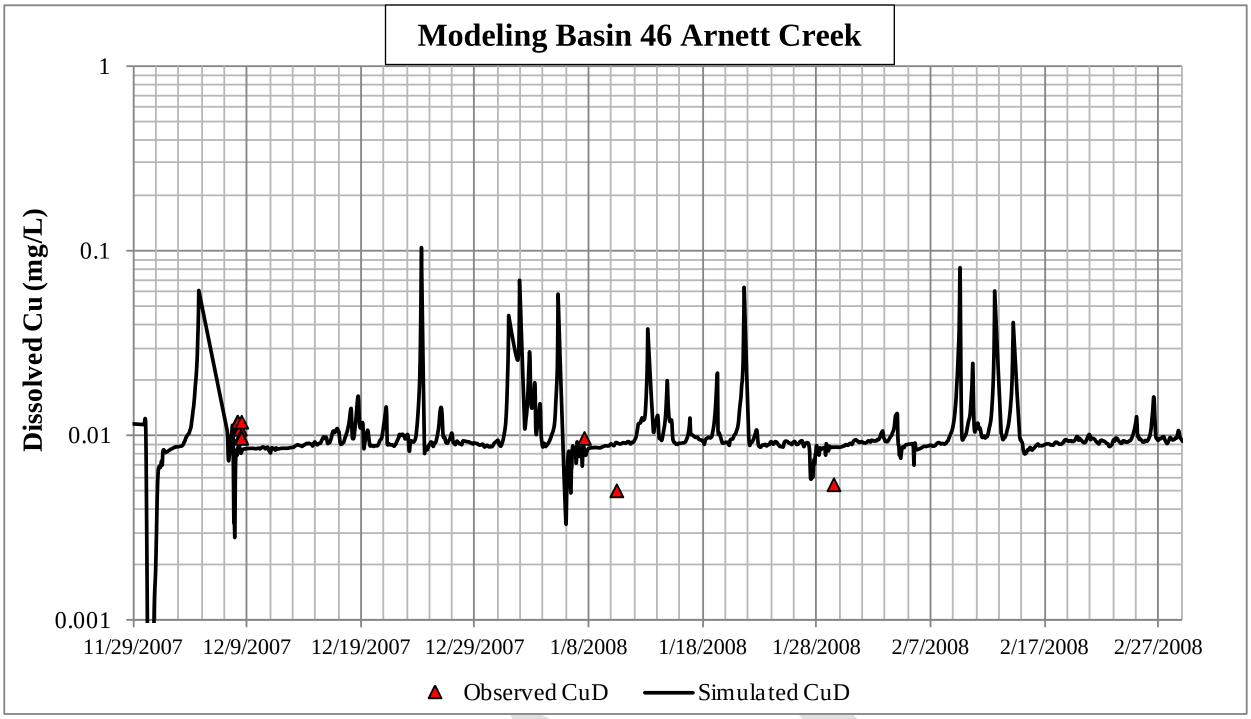

Figure 7: Observed vs Simulated Dissolved Copper in Modeling Basin 46 - Arnett Creek

5.4 Existing Conditions Scenario

When the HSPF model has been calibrated for both hydrology and dissolved copper it is then used to estimate pollutant loads under a number of different simulations. Typically the running of existing conditions scenarios is the first step in the process. An important aspect of running any type of scenario in the TMDL development process is how to define the critical conditions for a receiving waterbody. In streams like Queen Creek and Arnett Creek, critical conditions are defined as storm water run-off flows, and use an event based approach. To determine which storm type produces the highest amount of dissolved copper loading, a series of synthetic storms were modeled utilizing the calibrated hydrology and copper data. Five storm types were modeled; the 2-year 1-hour storm event typical of summer monsoon storms, and four other winter storm types: 2-year 24-hour, 10-year 24-hour, 25-year 24-hour and the 100-year 24-hour event. Each storm type has an average and maximum 24 hour flow predicted to be generated at the pour point of the various modeling basins. This data is used to calculate the loading of dissolved copper by storm type, which helps to determine the critical storm conditions used in calculating the TMDL.

Data on precipitation depths and distributions for the synthetic storms presented in **Table 3** were obtained from the National Oceanic and Atmospheric Administration (NOAA). The Soil Conservation Service (SCS) precipitation distribution type identifies whether the storm event is classified as a summer storm or a winter storm. Type II refers to summer storms, type IA refers to winter storms. In addition to rainfall data, the HSPF model requires additional data such as potential evapotranspiration, air temperature, etc.; these additional meteorological data were extracted from similar time periods from the ADEQ 2007 weather data set used for the calibration.

Similar to the HSPF model calibration, the synthetic storm weather data was distributed to each modeling basin based on proximity to the rain gage and elevation. The synthetic storms conditions were then imposed on the calibrated HSPF model to implement the existing conditions scenario.

Table 3: Characteristics of the Synthetic Storms

Storm Event Return Period and Duration	SCS Precipitation Distribution Type	Omya Rain Gage Precipitation Depth (inches)	Boyce Rain Gage Precipitation Depth (inches)
100-yr, 24-hr	IA	6.20	4.64
25-yr, 24-hr	IA	4.89	3.67
10-yr, 24-hr	IA	4.08	3.06
2-yr, 24-hr	IA	2.78	2.08
2-yr, 1-hr	II	1.18	0.99

The resulting 24-hour average dissolved copper concentrations and the 24-hour loads are depicted for each sub-basin and synthetic storm in **Tables 4** and **5** respectively. Under each synthetic storm condition, attainment with the A&Ww chronic criteria was assessed at the pour point of each representative modeling basin using the average observed total hardness and the 24-hour average predicted copper concentration (**Table 4**).

Table 4: Existing Conditions 24-Hour Average Dissolved Copper Concentrations (μg/L)

Modeling Basins	[(1)]Average Hardness (mg/L)	Acute Criterion (ug/L)	Chronic Criterion (ug/L)	Existing Conditions				
				2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H
Oak Flat Basin 22	34	4.86	3.56	35.1	32.7	33.2	33.6	35.0
QC Hwy 60 Basin 17	105	14.07	9.34	20.6	18.6	18.8	18.8	19.2
QC Magma Avenue Basin 91	63	8.70	6.03	23.4	22.9	22.1	22.8	23.6
QC Mary Avenue Basin 38	106	14.20	9.41	22.3	13.5	16.9	17.3	18.6
QC blw Mine Disch. Basin 92	96	12.93	8.65	12.5	0.8	12.3	14.1	15.4
Apex Wash Basin 50	182	23.63	14.94	13.1	3.9	11.4	13.0	14.5
QC Arboretum Basin 47	358	44.69	26.63	4.7	7.0	11.5	12.6	13.7
Silver King Wash Basin 45	262	33.30	20.40	14.3	9.1	10.1	10.3	10.5
Happy Camp Canyon Basin 42	460*	49.62	29.28	10.2	10.6	13.0	14.5	15.3
Arnett Creek Basin 46	98	13.19	8.80	9.0	4.3	5.7	5.9	6.3
Alamo Canyon Basin 49	116	15.46	10.17	6.8	6.9	8.0	8.6	8.8
Potts Canyon Basin 30	129	17.08	11.13	10.6	6.0	7.3	7.3	7.4
Reymert Wash Basin 28	432*	49.62	29.28	5.7	6.8	7.8	8.5	8.9
QC Outlet Basin 25	131	17.33	11.28	14.4	12.4	12.1	12.3	12.4

Average Concentration Exceeds Chronic Criterion (shaded cells)

* = Use cap of 400 mg/L total hardness

(1) – Average Hardness represents updated values from the original table based on a review of available total hardness data as discussed in Section 3.3.1

The dissolved copper attainment analysis found in **Table 4** is performed at each basin outlet and across representative monitoring stations (model basins) along the Queen Creek main stem. The resulting water quality at each modeling basin outlet is considered representative of the water quality conditions within the whole sub-basin. The concentrations and loads at modeling basin 22 (Oak Flat Sub-basin) take into account all the hydrologic and water quality processes occurring in all the upstream sub-basins including modeling basins 23, and 24 that feed into modeling basin 22. Presenting the modeling results at the outlet of a sub-basin or a watershed is the recommended approach to use in watershed-based studies. (Louis Berger, 2013)

The dissolved copper concentrations and loads resulting from the five synthetic storms are presented at the outlet of each sub-basin and at several representative modeling basins in the main stem of Queen Creek including the watershed outlet (modeling basin #25). The analysis indicates that under all five synthetic storm conditions, the upper reaches (modeling basins 22, 17, 91, and 38) of Queen Creek will exhibit exceedances of the chronic dissolved copper criteria.

Table 5: Existing Conditions 24-Hour Average Dissolved Copper Loads (kg/day)

Modeling Basins	Existing Conditions				
	2Y-1Hr	2Y-24Hr	10Y-24Hr	25Y-24Hr	100Y-24Hr
Oak Flat Basin 22	0.197	0.243	1.372	2.356	3.950
QC Hwy 60 Basin 17	0.040	0.080	0.704	1.318	2.306
QC Magma Avenue Basin 91	0.259	0.330	2.220	4.166	7.573
QC Mary Avenue Basin 38	0.255	0.300	2.151	4.070	7.472
QC below Mine Discharge Basin 92	0.079	0.003	1.118	2.906	6.230
Apex Wash Basin 50	0.023	0.004	0.086	0.236	0.569
QC Arboretum Basin 47	0.008	0.001	0.352	1.549	4.861
Silver King Wash Basin 45	0.021	0.004	0.060	0.148	0.524
Happy Camp Canyon Basin 42	0.028	0.004	0.031	0.161	0.673
Arnett Creek Basin 46	0.024	0.005	0.164	0.766	2.528
Alamo Canyon Basin 49	0.017	0.003	0.025	0.116	0.484
Potts Canyon Basin 30	0.097	0.006	0.370	0.723	1.745
Reymert Wash Basin 28	0.008	0.002	0.013	0.061	0.259
QC Outlet Basin 25	0.101	0.007	0.356	1.497	6.958

Because of the significant transmission losses of flow and pollutant loads in the Queen Creek watershed, the intensity, duration, and return period of each synthetic storm affect the dissolved copper loads at downstream model sub-basins in the main stem of Queen Creek differently. **Tables 4 and 5** are used to estimate the magnitude of the allowable loads and the related load reductions required at each sub-basin outlet and modeling basin in the main stem of Queen Creek. **Table 6** presents the allowable dissolved copper loads and the corresponding reduction using the most stringent chronic criterion for dissolved copper.

Table 6: Existing Conditions Scenario Dissolved Copper Allocation Analysis

Modeling Basins	[(1)]Maximum Allowable 24-Hour Load (kg)					Estimated Dissolved Copper Reductions to Comply with the Maximum Allowable Load (%)				
	2Y 1Hr	2Y 24Hr	10Y 24Hr	25Y 24Hr	100Y 24Hr	2Y 1Hr	2Y 24Hr	10Y 24Hr	25Y 24Hr	100Y 24Hr
Oak Flat Basin 22	0.020	0.026	0.147	0.249	0.402	89.9	89.3	89.3	89.4	89.8
QC Hwy 60 Basin 17	0.018	0.041	0.350	0.656	1.120	55.0	48.8	50.3	50.2	51.4
QC Magma Avenue Basin 91	0.066	0.087	0.605	1.100	1.937	74.5	73.6	72.7	73.6	74.4
QC Mary Avenue Basin 38	0.108	0.210	1.199	2.212	3.783	57.6	30.0	44.3	45.7	49.4
QC blw Mine Disch. Basin 92	0.055	0.036	0.789	1.782	3.500	30.4	0	29.4	38.7	43.8
Apex Wash Basin 50	0.026	0.015	0.113	0.271	0.588	0	0	0	0	0
QC Arboretum Basin 47	0.046	0.003	0.814	3.284	9.447	0	0	0	0	0
Silver King Wash Basin 45	0.030	0.010	0.120	0.294	1.023	0	0	0	0	0
Happy Camp Canyon Basin 42	0.079	0.007	0.072	0.330	1.289	0	0	0	0	0
Arnett Creek Basin 46	0.024	0.009	0.256	1.150	3.559	2.1	0	0	0	0
Alamo Canyon Basin 49	0.025	0.005	0.032	0.137	0.557	0	0	0	0	0
Potts Canyon Basin 30	0.103	0.011	0.569	1.108	2.636	0	0	0	0	0
Reymert Wash Basin 28	0.043	0.007	0.050	0.208	0.845	0	0	0	0	0
QC Outlet Basin 25	0.080	0.006	0.334	1.374	6.323	20.8	14.3	6.2	8.2	9.1

(1) – Loading targets represent updated values from the original table based on a review of available total hardness data as discussed in Section 3.3.1

The dissolved copper reductions presented in **Table 6** were developed using the estimated allowable dissolved copper load that will meet the most stringent criteria, and the loads developed under the existing conditions scenario. These estimated reductions address dissolved copper loads from the mining operations, soil contamination in the Oak Flat modeling basin due to historic smelter operations, and the copper loads present as natural background from normal erosion.

The existing conditions scenario modeling results indicate that dissolved copper concentrations and loads are elevated at the outlet of the Oak Flat modeling basin contributing significant dissolved copper loads to Queen Creek. It has been theorized that the elevated levels of dissolved copper are due to past emissions from mining process operations, such as historic smelting operations and elevated natural background levels contributed by the exposed volcanic tuff material which has been shown to have a high copper content (see table 3-2; The Louis Berger Group, Inc., 2013). Soil contamination in this case is suspected to be from historic smelting operations emissions that occurred at the west plant site and were carried up Queen Creek Canyon by the prevailing winds. These same winds also had the ability to carry other sources of copper, such as contaminated dust from the tailings piles, into the upper reaches of Queen Creek.

5.5 Dissolved Copper Mining Background Scenario

Once the existing conditions scenario has been used to determine what reductions are needed at the various modeling basins, the model can then be utilized to help determine the loading attributable to the suspected sources. The first suspected source of copper to be modeled was the possible contribution by past and present mining activities. To assess the contribution of the land-based mining loads, a modeling scenario was implemented using the assumption that all the land-based mining-related copper loads are eliminated in the Queen Creek watershed. **Table 7** depicts the mining-areas identified by ADEQ and included in the Queen Creek HSPF model. A total of

772 acres, representing the footprint of abandoned, inactive, and semi-active mines, were included in the Queen Creek dissolved copper HSPF model. As the table indicates, the total mining acres make up only 1.3 percent of the watershed drainage area, a relatively small portion when considering the entire watershed. The five synthetic storms were each modeled utilizing a simulation where the copper contributions from the 772 acres located within the modeling basins listed in **Table 7** were set to zero. By turning these acres to zero contribution, the background contribution from the remaining area within the modeling basin was still being accounted for by the model. Only the background contribution from the mining area is being ignored, along with any contribution from the mining activity itself.

Table 7: Mining Areas in the Queen Creek Watershed Model

Sub-basin	Modeling Basin #	Acres
Oak Flat	22	26
Queen Creek	94	32
	91	6
	38	8
	53	11
Apex Wash	88	39
	89	176
	50	29
Silver King Wash	11	1
	12	1
	14	8
RCC Superior Wash	90	163
	36	73
	92	77
Arnett Creek	63	1
Potts Canyon	9	1
	16	1
Reymert Wash	55	119
	Total Mining Acres	**772**
	Percent of Watershed Drainage Area	**1.3%**

The results of the dissolved copper mining background scenario, expressed as a 24 hour dissolved copper load in kg per day for the modeling basins, can be seen in **Table 8.** It also illustrates the existing conditions scenario results for comparison. This scenario indicates that the dissolved copper loading from the mining areas identified within the 772 acres is not a major contributor and their complete removal will not impact the impairments predicted under the existing conditions scenario. In other words, the simulated dissolved copper mining loads are relatively small when compared to the other contributions such as the copper found in the native rock and soils, and the historic copper processing fallout in the Oak Flat sub-basin and to some extent the remnants of this same fallout in the entire Queen Creek watershed.

Table 8: Existing Conditions and No Mining-Background Scenarios - 24-Hr Dissolved Copper Loads (kg/day)

Modeling Basins	Existing Conditions Scenario					Mining-Background Scenario Without Land-Based Mining Loads				
	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H
Oak Flat Basin 22	0.197	0.243	1.372	2.356	3.950	0.195	0.240	1.356	2.328	3.904
QC Hwy 60 Basin 17	0.040	0.080	0.704	1.318	2.306	0.038	0.076	0.676	1.265	2.213
QC Magma Avenue Basin 91	0.259	0.330	2.220	4.166	7.573	0.255	0.324	2.175	4.083	7.428
QC Mary Avenue Basin 38	0.255	0.300	2.151	4.070	7.472	0.251	0.295	2.107	3.990	7.329
QC blw Mine Disch. Basin 92	0.079	0.003	1.118	2.906	6.230	0.077	0.003	1.096	2.843	6.080
Apex Wash Basin 50	0.023	0.004	0.086	0.236	0.569	0.004	0.001	0.013	0.037	0.091
QC Arboretum Basin 47	0.008	0.001	0.352	1.549	4.861	0.008	0.001	0.346	1.518	4.668
Silver King Wash Basin 45	0.021	0.004	0.060	0.148	0.524	0.020	0.004	0.055	0.137	0.484
Happy Camp Canyon Basin 42	0.028	0.004	0.031	0.161	0.673	0.028	0.004	0.031	0.161	0.673
Arnett Creek Basin 46	0.024	0.005	0.164	0.766	2.528	0.024	0.005	0.164	0.766	2.526
Alamo Canyon Basin 49	0.017	0.003	0.025	0.116	0.484	0.017	0.003	0.025	0.116	0.484
Potts Canyon Basin 30	0.097	0.006	0.370	0.723	1.745	0.097	0.006	0.370	0.723	1.743
Reymert Wash Basin 28	0.008	0.002	0.013	0.061	0.259	0.007	0.001	0.011	0.054	0.229

5.6 Oak Flat Dissolved Copper Scenario

One of the main issues illustrated by both the existing conditions scenario and the dissolved copper mining background scenario is that the majority of copper loading is occurring in the upper reach (014A) of Queen Creek, and more specifically from the Oak Flat modeling basin. The final copper modeling simulation run was the Oak Flat dissolved copper scenario. This scenario helps in evaluating the estimated contribution from the Oak Flat modeling basin and also helps gauge its impact on the downstream modeling basins. To run the scenario, the modules which imitate copper run-off from the Oak Flat basin were adjusted until the levels of dissolved copper at the pour point were meeting the applicable water quality standard. **Table 9** depicts the resulting simulated dissolved copper concentrations and attainment analysis under both the Oak Flat scenario and the existing conditions scenario. Reductions of the copper loads contributed by a mixture of natural background and possible copper processing fall out in the Oak Flat area will only impact those sub-basins located on the Queen Creek main stem downstream of the Oak Flat modeling basin which are noted. The table indicates that reductions of copper loads in the Oak Flat modeling basin will have a considerable impact on the downstream concentrations in the modeling basins located on the main stem of Queen Creek. It also illustrates that the reduction in copper from the Oak Flat basin is not significant enough to be the only cause of the impairment in the upper segments of Queen Creek. Even though the model predicts decreases in the 24-hour average concentrations in the modeling basins downstream of the Oak Flat basin (modeling basins 91, 38, and 92), the predicted levels are still not meeting the applicable water quality standards. It should be noted that basins 22, 91, 38 and 92 typically have lower total hardness values when compared to other modeling basins in the project watershed. The lower the average total hardness for the modeling basin, the stricter the applicable dissolved copper chronic criteria for waters with the A&W designated use.

Table 9: Existing Conditions and Oak Flat Scenarios - 24-Hr Average Dissolved Copper Conc (µg/L)

Modeling Basins	Existing Conditions Scenario					Oak Flat Scenario - Without Smelter Fallout & Background Loads				
	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H
Oak Flat Basin 22	35.1	32.7	33.2	33.6	35.0	2.72	2.71	2.76	2.78	2.90
QC Hwy 60 Basin 17	20.6	18.6	18.8	18.8	19.2	20.6	18.6	18.8	18.8	19.2
QC Magma Avenue Basin 91(1)	23.4	22.9	22.1	22.8	23.6	15.7	9.7	11.5	11.7	11.9
QC Mary Avenue Basin 38(1)	22.3	13.5	16.9	17.3	18.6	14.3	5.8	8.9	9.4	10.0
QC blw Mine Disch. Basin 92(1)	12.5	0.8	12.3	14.1	15.4	11.0	0.8	6.6	8.0	8.9
Apex Wash Basin 50	13.1	3.9	11.4	13.0	14.5	13.1	3.9	11.4	13.0	14.5
QC Arboretum Basin 47(1)	4.7	7.0	11.5	12.6	13.7	4.3	7.0	6.5	8.0	9.2
Silver King Wash Basin 45	14.3	9.1	10.1	10.3	10.5	14.3	9.1	10.1	10.3	10.5
Happy Camp Canyon Basin 42	10.2	10.6	13.0	14.5	15.3	10.2	10.6	13.0	14.5	15.3
Arnett Creek Basin 46	9.0	4.3	5.7	5.9	6.3	9.0	4.3	5.7	5.9	6.3
Alamo Canyon Basin 49	6.8	6.9	8.0	8.6	8.8	6.8	6.9	8.0	8.6	8.8
Potts Canyon Basin 30	10.6	6.0	7.3	7.3	7.4	10.6	6.0	7.3	7.3	7.4
Reymert Wash Basin 28	5.7	6.8	7.8	8.5	8.9	5.7	6.8	7.8	8.5	8.9
QC Outlet Basin 25(1)	14.4	12.4	12.1	12.3	12.4	14.4	12.4	12.1	11.7	11.7

Exceeds Chronic Criterion (shaded cells)

(1) Those modeling basins of Queen Creek that are downstream of the Oak Flat basin

Table 10: Existing Conditions and Oak Flat Scenarios - 24-Hr Dissolved Copper Loads (kg/day)

Modeling Basins	Existing Conditions Scenario					Oak Flat Scenario				
	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H
Oak Flat Basin 22	0.197	0.243	1.372	2.356	3.950	0.016	0.020	0.113	0.194	0.325
QC Hwy 60 Basin 17	0.040	0.080	0.704	1.318	2.306	0.040	0.080	0.704	1.318	2.306
QC Magma Avenue Basin 91(1)	0.259	0.330	2.220	4.166	7.573	0.078	0.115	0.975	2.021	3.976
QC Mary Avenue Basin 38(1)	0.255	0.300	2.151	4.070	7.472	0.077	0.102	0.936	1.966	3.922
QC blw Mine Disch. Basin 92(1)	0.079	0.003	1.118	2.906	6.230	0.031	0.003	0.477	1.460	3.489
Apex Wash Basin 50	0.023	0.004	0.086	0.236	0.569	0.023	0.004	0.086	0.236	0.569
QC Arboretum Basin 47(1)	0.008	0.001	0.352	1.549	4.861	0.007	0.001	0.126	0.763	2.967
Silver King Wash Basin 45	0.021	0.004	0.060	0.148	0.524	0.021	0.004	0.060	0.148	0.524
Happy Camp Canyon Basin 42	0.028	0.004	0.031	0.161	0.673	0.028	0.004	0.031	0.161	0.673
Arnett Creek Basin 46	0.024	0.005	0.164	0.766	2.528	0.024	0.005	0.164	0.766	2.528
Alamo Canyon Basin 49	0.017	0.003	0.025	0.116	0.484	0.017	0.003	0.025	0.116	0.484
Potts Canyon Basin 30	0.097	0.006	0.370	0.723	1.745	0.097	0.006	0.370	0.723	1.745
Reymert Wash Basin 28	0.008	0.002	0.013	0.061	0.259	0.008	0.002	0.013	0.061	0.259
QC Outlet Basin 25(1)	0.101	0.007	0.356	1.497	6.958	0.101	0.007	0.356	1.218	5.867

(1) Those modeling basins of Queen Creek that are downstream of the Oak Flat basin

Table 10 shows the 24-hour dissolved copper loads predicted under both the existing conditions scenario and the Oak Flat dissolved copper scenario. **Table 11** summarizes the percent contribution of dissolved copper loading by the five different storm types in the Oak Flat modeling basin and the modeling basins located downstream.

Table 11: Oak Flat Scenarios - Smelter Fallout & Background Dissolved Copper Load Contribution

Modeling Basins	2Y-1H	2Y-24H	10Y-24H	25Y-24H	100Y-24H
Oak Flat Basin 22	91.7%	91.7%	91.3%	91.3%	91.8%
QC Hwy 60 Basin 17	0.0%	0.0%	0.0%	0.0%	0.0%
QC Magma Avenue Basin 91[(1)]	69.7%	65.2%	55.8%	51.2%	47.5%
QC Mary Avenue Basin 38[(1)]	70.0%	66.0%	56.2%	51.5%	47.5%
QC below Mine Disch. Basin 92[(1)]	60.6%	0.0%	57.1%	49.5%	44.0%
Apex Wash Basin 50	0.0%	0.0%	0.0%	0.0%	0.0%
QC Arboretum Basin 47[(1)]	10.6%	0.0%	63.9%	50.5%	39.0%
Silver King Wash Basin 45	0.0%	0.0%	0.0%	0.0%	0.0%
Happy Camp Canyon Basin 42	0.0%	0.0%	0.0%	0.0%	0.0%
Arnett Creek Basin 46	0.0%	0.0%	0.0%	0.0%	0.0%
Alamo Canyon Basin 49	0.0%	0.0%	0.0%	0.0%	0.0%
Potts Canyon Basin 30	0.0%	0.0%	0.0%	0.0%	0.0%
Reymert Wash Basin 28	0.0%	0.0%	0.0%	0.0%	0.0%
QC Outlet Basin 25[(1)]	0.00%	0.00%	0.01%	18.6%	15.7%
Total All Segments	50.9%	64.2%	50.6%	44.2%	35.8%

(1) Those modeling basins of Queen Creek that are downstream of the Oak Flat basin

The numbers presented in **Table 11** indicate that the Oak Flat dissolved copper loads make up a significant proportion of the loads at the basins located downstream on the main stem of Queen Creek (modeling basins 91, 38, 92, and 47). Under the low return-interval type storms (2 year-1-hour and 2 year-24-hour) the copper loads from the Oak Flat modeling basin are not transported all the way down to the outlet of the watershed (modeling basin 25). Under the 10-year 24-hour storm the Oak Flat dissolved copper load has an insignificant impact on the load in the outlet of the watershed. Under the higher frequency storms (25-year 24-hour and 100-year 24-hour) the contribution of the Oak Flat dissolved copper load constitutes 16 to 19 percent of the dissolved copper load at the outlet of the Queen Creek watershed.

The Oak Flat scenario addressed the contribution of the anthropogenic contamination of the soils in the Oak Flat modeling basin and highlighted the magnitude of these loads and their impact on the downstream segments in the Queen Creek watershed. The conclusion that can be drawn from the Oak Flat scenario is that the copper content found in the soil and rocks of various locations other than the Oak Flat modeling basin, are still significant enough to cause exceedances of the dissolved copper criteria. The Mining-Background scenario indicated that the dissolved copper mining loads transported at the outlet of the sub-basins and in the main stem of Queen Creek are not a significant source of copper in the watershed.

Based on the implementation of the various dissolved copper scenarios, it is apparent that the copper content in soils and rocks is the dominant factor causing the exceedances of the dissolved copper criteria in the various segments of the Queen Creek watershed. This copper content in soils and rocks is believed to be a combination of the natural copper content of the local geology and the historic copper processing fallout present in the Queen Creek watershed.

6.0 TMDL Calculations

The term TMDL is defined as the maximum quantity of a parameter, in this instance dissolved copper, which a surface water can receive without exceeding the water quality standards for the applicable designated uses supported by the water body. As observed in the previous discussion of the modeling approach, when calculating the maximum loading value of a pollutant the quantities are normally referenced as kilograms per day (kg/day). These daily loads are normally determined using the average daily flow in cubic feet per second (cfs) and the average daily concentration of the parameter in question. The averages for the two factors are determined by utilizing all the available flow data and all dissolved copper data documented within the modeling basin. The formula for determining a TMDL is:

$$TMDL = \sum WLA + \sum LA + NB + MOS$$

$\sum WLA$: The sum of the waste load (point source) allocations

$\sum LA$: The sum of the load (nonpoint source) allocations

NB: Natural background levels

MOS: Margin of safety

6.1 Critical Conditions

Storm water run-off, or storm flow, constitutes the critical loading conditions to the intermittent and effluent dependent reaches of Queen Creek, and Arnett Creek. Storm flow also makes up the critical loading conditions for the ephemeral reaches of the unnamed drainages. The important issue is to determine which storm type contributes the highest level of dissolved copper loading. **Table 4** from the discussion of the existing conditions scenario illustrates that the critical loading conditions occur during run-off from the 2-year 1-hour type storm. Dissolved copper concentration results from the 100-year 24-hour storm type are almost identical when comparing the sums and the averages of the modeling basins with the 2-year 1-hour storm type. Overall, in those modeling basins where the dissolved copper levels are exceeding the chronic criterion, the majority are being affected more by the input from the 2-year 1-hour storm type than from any of the other storm types that were used in the existing condition scenario. Linking the TMDL analysis to the 2-year 1-hour storm type also makes any effectiveness monitoring that may occur later in the project easier to conduct. The 2-year 1-hour type storm (average of 1.08 inches) (National Oceanic and Atmospheric Administration, 2011) is common during summer monsoon season periods when the probability of a heavy, but short-lived storm will occur every year is 50 percent. The 100-year 24-hour storm type (average of 5.18 inches) (National Oceanic and Atmospheric Administration, 2011) typically has a longer return period between occurrences, which makes monitoring for the effects of this storm type more problematic.

6.2 Margin of Safety

The calculation of a TMDL looks at the contributions from the various point and nonpoint sources. It also includes a margin of safety (MOS) that is designed to address uncertainties in the TMDL process. If the MOS is allocated a numeric portion of the TMDL, it is referred to as an explicit MOS. An implicit MOS is commonly addressed by making environmentally conservative assumptions when calculating the TMDL. For the Queen Creek TMDL the largest source of dissolved copper is believed to be a nonpoint mix of natural background and deposition from the by-products of the copper extraction process. Applying an explicit MOS would be difficult in this project when the fractions contributed by each are unknown. However, the use of an explicit MOS to account for the impact of future sources associated with the expansion of mining activity in the area is applicable. Because much of the infrastructure is currently in place, the expansion will not have the impact that a new mine would have. Impacts from new roads, increased traffic and an increase in the population of the town are some of the expected future sources. The Queen Creek TMDL will adopt a 5 percent explicit MOS that will be applied solely to impacts from future growth within the watershed. An implicit MOS will be applied to the current sources and the predicted modeling impacts from dissolved copper.

While some Arizona TMDL projects that rely on storm water run-off can have trouble collecting a sufficient amount of data, the Queen Creek project was fortunate to have a number of both summer and winter type storms present during the data collection period for the model. A large number of both grab and automated samples were collected during this time frame. The data that was collected was then checked using established ADEQ quality assurance quality control (QAQC) procedures to verify that it was valid and of good quality. As noted in the prior discussions of the model calibration for both hydrology and dissolved copper, the results for the various reaches indicates acceptable agreement between the observed data and the modeled simulations.

As previously noted, an implied MOS is addressed through the use of various conservative assumptions within the framework of the model that are applied during the different modeling scenarios. A conservative assumption typically over estimates the concentration or loading of a parameter during the running of the various modeling scenarios. Listed below are the conservative assumptions that have been identified in the running of the HSPF model for the Queen Creek TMDL:

- **The Use of Chronic Criteria Versus Acute Criteria**

By applying the chronic criteria as the concentration that must not be exceeded within the different reaches of Queen Creek, the model is assuming the most stringent applicable dissolved copper criteria. As discussed previously, the hydrology of Queen Creek is primarily driven by storm water run-off. Other than the flow below the WWTP discharge, the only other extended flows of any type are short spatially intermittent stretches located in the upper reaches of the Queen Creek Canyon area. Even though these stretches may flow long enough that they cannot be defined as ephemeral, most will occasionally dry up during the year. However, storm flows may extend longer than four days. The application of chronic criteria is a more conservative approach than applying the acute criteria, which are typically 1.5 times greater than the applicable chronic criteria.

- **Overestimation of the Contribution from Small, Abandoned Mines**

During the process of identifying the various nonpoint sources of dissolved copper, the contribution from historic, mainly hand-dug mines was addressed. A few of the many locations were physically inspected by members of ADEQ who were involved in data collection for the TMDL. This allowed for a visual inspection of the disturbed area around the mine site. In the majority of cases the mines were identified using satellite images of the project watershed. The most accurate method of defining the disturbed area would be to either physically survey each mine site, or to delineate by hand using ArcMap software. Because of the large number of these types of mines identified in the project area, both approaches would have been difficult to perform given both the amount of work and time involved. To assess the impacts from these mines an approach was used that attempted to customize the disturbance footprint of some of the larger mines and also some of the mines that represented the most average size observed throughout the watershed. Areas of disturbance were created that would adequately assess the impacts from both large and average sized abandoned mines. The disturbance area for anything larger than an average size mine utilized the area determined for large mines. The disturbance area for mines meeting the definition of average or smaller used the footprint determined to fit the average size mine. By using this approach, the area of disturbance for some mines would be relatively accurate for fairly large and average size mines. For the majority of mine sites that do not fit into either category, the applied area of disturbance will be larger than the actual area of disturbance, resulting in over estimation of the dissolved copper being contributed by the disturbed areas around the mines.

- **Using the Average Flow Versus the Maximum Flow of the Synthetic Storms**

When running the scenarios to determine the loading of dissolved copper for the different modeling basins, the average flow generated by the five storms during a 24 hour period was used instead of the maximum flow generated by the storms during the same 24 hour period. The maximum flow generated represents the greatest discharge that can be produced at the pour point of the modeling basin based on the various attributes of the modeling basin. The concentrations of dissolved copper are typically going to be higher at the average flow due to the higher amount of dilution taking place at the maximum flow. The loading of dissolved copper occurs at a higher rate using the average flow because of the dilution present at the maximum flows. This conservative approach to flow types allows for the loading to be calculated utilizing the flow type with the higher concentration of dissolved copper.

- **Applying Rainfall Gathered at the High Elevation Gauge to the Entire Watershed**

Rainfall data was collected from two sources maintained by ADEQ and also from a gauge maintained by the RCC, located at the west plant site near Superior. When applying the rain gauge data to the model for the hydrologic and the dissolved copper calibration/validation, the rain gauge data from the upper elevation site was applied to the entire watershed down to the valley floor. The rainfall amounts at the upper gauge were larger than the other two sites, so by applying the larger amount to the calibration/validation simulations the model produces dissolved copper run-off concentrations that are higher than normally seen under real world conditions where the rainfall amounts in the mid to lower elevations of the watershed are typically going to be less than in the upper elevations. The predictive simulations utilize a synthetic weather record. As discussed previously, its base is a portion of the weather data from the calibration/validation period, but then the weather data is modified by “splicing-in” the five different design storm events.

6.3 TMDL Loads and Allocations

As noted previously, there are three reaches of Queen Creek, one reach of Arnett Creek, and two unnamed reaches that are located within the project area, all are impaired for dissolved copper:

1) 014A – Queen Creek; headwaters to the Superior WWTP outfall at 33°16’33’’/111°07’44’’
2) 014B – Queen Creek; Superior WWTP outfall to confluence with Potts Canyon

3) 014C – Queen Creek; Potts Canyon confluence to the Whitlow Dam
4) 1818 – Arnett Creek; headwaters to the confluence with Queen Creek
5) 1843 – Unnamed Drainage; headwaters to the confluence with Queen Creek
6) 1000 – Unnamed Drainage: headwaters to the confluence with Queen Creek

Although both 014A and 014C are large in stream miles compared to reach 014B, only about 1.25 miles of 014C is actually located in the project area. This includes the stream segment from Potts Canyon to the pour point of modeling basin 25. TMDLs have been calculated for the three points on Queen Creek that correspond to the changes in reach numbers, and also for Arnett Creek, and for the two unnamed drainages. Because there are no modeling basins for reach 014B of Queen Creek below basin 47 (QC Arboretum; **Table 11**) that have associated water quality data, the calculated TMDL for modeling basin 25 (QC Outlet; **Table 11**) will be applied to reach 014B and reach 014C of Queen Creek. The modeling work has shown that the main impacts are occurring within the upper reaches of Queen Creek, and field work has verified that there are no activities besides grazing that contribute to dissolved copper loading (through increased erosion), below the confluence of Potts Canyon. The required load reduction will allow both segments to attain the applicable dissolved copper water quality standards, so the application to both reaches is an acceptable approach.

6.3.1 Waste Load Allocations

Point source discharges to surface waters in Arizona are required to obtain an AZPDES permit. The permit establishes effluent limitations for pollutants discharged by the facility. The permit also stipulates the monitoring requirements that the facility must adhere to. At present there are two individual AZPDES permits, eight MSGP permits, and one MS4 permit located within the Queen Creek TMDL project watershed. There are also currently eleven facilities with Construction General Permits (CGP) within the TMDL project watershed. **Table 12** contains the names of permitted facilities within the project area, their permit number, the type of permit, and the type of WLA that the facility is required to meet. This can be either concentration based, which is referred to as a Water Quality Based Effluent Limit (WQBEL), or mass based. CGP permitted facilities are not listed in **Table 12** due to the fact that they are typically short-lived. Listing those that are current now may not accurately reflect what will be current when the TMDL has been finalized. Although CGP permits are not listed, current permits must meet a WQBEL waste load allocation. WQBELs are discussed in more detail in section 6.3.1.2.

ADEQ will assign load allocations, rather than waste load allocations, for the inactive and abandoned mine site sources located within the watershed that do not have permit coverage. If future data and information provide for the application of permit coverage to these mines then the mass based LAs assigned will be converted to WLAs and incorporated as WQBELs using the methods outlined in the EPA's *Technical Support Document for Water Quality-based Toxics Control* (TSD) (EPA, 1991). Such conversions must conserve or reduce loadings. Increases to loadings will require revision and resubmission of the TMDL for approval. Where inactive and abandoned mine sites meet the non-point source grant criteria, then Clean Water Act 319(h) funds may be available through the ADEQ Water Quality Improvement Grant Program. The CWA §319 grant funds from the EPA through ADEQ can be used for remediation purposes of non-point sources where, mining and extraction has ceased, mining will not foreseeably be restarted, and management projects will be maintained. Per grant condition, installed BMP's "shall be operated and maintained for the expected lifespan of the specific practice and in accordance with commonly accepted standards." Point source discharges will still receive a WLA and ADEQ will apply its full suite of regulatory tools to address the impacts from each site.

Table 12: Active AZPDES Permits

FACILITY	PERMIT NUMBER	PERMIT TYPE	WASTE LOAD ALLOCATION
Resolution Copper, LLC; Superior operations	AZ0020389 – outfall 001 & 002	Individual AZPDES	WQBEL
Town of Superior WWTP	AZ0021199 – outfall 001	Individual AZPDES	Mass Based = 0.024 kg/day
Resolution Copper, LLC; east plant operations	AZMSG-226925	MSGP	WQBEL
Resolution Copper, LLC; west plant operations	AZMSG-226848	MSGP	WQBEL
Imerys Perlite USA, Inc.	AZMSG-226183	MSGP	WQBEL
Omya Arizona	AZMSG-226914	MSGP	WQBEL
Omya Arizona; Quarry	AZMSG-226915	MSGP	WQBEL
Gila Rock Products, LLC	AZMSG-232797	MSGP	WQBEL
Silver King Mine	AZMSG-232850	MSGP	WQBEL
Kalamazoo Materials, Inc.	AZMSG-234018	MSGP	WQBEL
Arizona Department of Transportation	AZS000018-2015	MS4	WQBEL

6.3.1.1 Mass Based WLAs

Currently the Superior WWTP is the only facility of the two individual AZPDES permittees that has an outfall which discharges on a continual basis. As a result of its continual discharge, it is the only permitted mass based WLA within the Queen Creek TMDL project area. As noted in **Table 12**, the facility has one outfall. The confluence of the WWTP effluent discharge and Queen Creek marks the point at which the aquatic and wildlife designated uses change from A&Ww to A&Wedw, and it is also the point where reach 014A becomes reach 014B. The WLA of 0.024 kg/day for reach 014B of Queen Creek was derived by using the permitted monthly dissolved copper average of 8.6 µg/L, the maximum design discharge capacity of 0.75 MGD (= 1.16 cfs average/24 hours), and a conversion factor of 0.002445. Discharge records for January 2015 to April 2016 indicate an average monthly flow of approximately 173,000 gallons per day, or approximately 23 percent of the maximum design discharge capacity.

Resolution Copper has two outfalls covered by permit number AZ0020389. Outfall 001 is designed to be used as an emergency discharge release point only in the event that the holding capacity of the storm water holding facility is exceeded. On-site holding ponds at the west plant site contain storm water run-off from the facility, and are designed to withstand up to and including a 100-year, 24-hour type storm. If a storm event were to occur that had capacity to overwhelm the system, the 001 outfall would be used to discharge the run-off into Queen Creek. Outfall 002 is the discharge point for the mine's treated wastewater system. The treated wastewater is a by-product of pumped water from the East Plant location. This treated wastewater is normally used by irrigation districts in the Florence area. The 002 outfall is for the discharge of treated wastewater into Queen Creek on those occasions when the irrigation districts are unable to take the water. Because neither outfall is designed to discharge on a continual basis, the Resolution Copper outfalls are not assigned a mass based WLA, and are therefore subject to a concentration based WLA, as described in the following section.

Future WLAs for new or expanded individual AZPDES permits will be based upon the applicable chronic dissolved copper WQS and will be applied as WQBELs calculated using the methods outlined in the EPA *Technical Support Document for Water Quality-based Toxics Control* (TSD) (EPA, 1991).

6.3.1.2 Concentration Based WLAs

Concentration based WLAs will be applied, as a WQBEL, to all existing and future permittees covered under all sectors of the MSGP, CGP, and MS4 permits. Both the AZPDES Industrial Stormwater (MSGP) and the AZPDES Industrial Stormwater Non-Mining MSGP address run-off from operations that may have the potential to negatively impact surface water quality. MS4 permits aid in the management of stormwater runoff from urbanized areas into surface waters. For the permittees listed in **Table 12** with either an MSGP permit or an MS4 permit, the WLA will be based upon the applicable hardness based aquatic and wildlife chronic copper standard of the receiving water according to AAC R18-11 Appendix A, Table 11. The same WLA conditions will apply to the individual AZPDES permit for Resolution Copper. As mentioned previously, **Table 12** does not list the AZPDES CGPs associated with construction activity mainly due to the fact that these type of permits are normally short lived. This type of permit addresses storm water discharges from construction activities that have the potential of entering a surface water of the state. CGPs would also be required to meet concentration based WLAs for discharges that leave the site. As with MSGPs, the WLA will be also be based upon the applicable aquatic and wildlife chronic copper standard as dictated by the total hardness value of the receiving water.

Permittees can demonstrate compliance with the WLA by either direct sampling of outfall discharges or demonstrate that best management practices quantitatively reduce the discharge of pollutants to a level that meets the WQBEL. If sample results exceed the WLA, permittees should evaluate the effectiveness of BMPs, modify or implement new BMPs, or provide additional measures to improve water quality.

The discussion of the existing conditions scenarios in Section 5.4 involved analysis of whether the acute and chronic criterion were being met at the pour point of the modeling basins during each of the storm types. This also required the application of the average total hardness for the sampling data collected within the basin. An analysis of the average total hardness of the sub-basins used in the modeling of the Queen Creek water quality data demonstrates that as you move from the headwaters of the drainage to its mouth, the hardness increases. This is typical in most drainages that originate in mountainous terrain and flow into alluvial fill valleys. As the slope of the channel decreases, water velocity slows and the rate of sediment deposition increases. The total hardness levels increase as the water flows through more porous substrate, accumulating greater amounts of dissolved solids. **Table 13** illustrates the average total hardness for each reach of Queen Creek. The numbers were derived by determining which modeling basins make up the three separate reaches of Queen Creek and then using the total hardness measured under storm conditions. The results show that the application of WQBELs will be stricter in the upper reach of Queen Creek (014A) where the total hardness values are lower than the downstream reaches. This guarantees that daily loading requirements will not be exceeded in reaches 014B and 014C, where hardness values will be higher resulting in less strict WQBELs for permittees. Even though the total hardness in 014C is only slightly higher than 014B, the same situation is applicable, discharges by a permittee to 014B would still be stricter than if the discharge were to reach 014C.

Table 13: Average Total Hardness by Reach (Queen Creek)

	Reach 014A	Reach 014B	Reach 014C
Average Total Hardness; mg/L	98	123	131

Permittees must demonstrate compliance with the WLA as specified in their permits. If sample results exceed the WLA, permittees should evaluate the effectiveness of BMPs, modify or implement new BMPs, or provide additional measures to improve water quality.

6.3.2 Load Allocations

Once the WLAs have been established, the LA can be calculated. As previously noted, the TMDL is equal to the sum of the WLAs (point source), the MOS, NB, and the sum of the LAs (nonpoint sources). In the case of the Queen Creek TMDL, there is no method to differentiate what the amount of NB dissolved copper is versus what amount is due to historical nonpoint mining impacts. Because the two cannot be separated, the LA figures located in **Table 13** are essentially a combination of inputs from both nonpoint source impacts and natural background contributions. The Queen Creek TMDL has a single mass based WLA assigned to the City of Superior WWTP. For the reaches of the TMDL not impacted by this discharge (014A & 014C), the TMDL consists of the LA portion only. If discharges from MSGP facilities located within these reaches meet their concentration based WLAs, the daily loading of dissolved copper will not exceed the TMDL assigned to the reach. If any sources currently assigned load allocations are later determined to be point sources requiring AZPDES permits, the portion of the LAs applied to these sources are to be treated as WLAs for purposes of determining appropriate WQBELs pursuant to 40 CFR 122.44(d)(1). The two unnamed drainages had not been listed as impaired when the modeling for the TMDL was initiated. During the modeling of the five storm types under the various scenarios, simulated copper loading was not addressed in the two unnamed drainages. TMDL calculations expressed in **Table 14** for the two reaches were determined using the average values for flow, dissolved copper concentration, and total hardness that had been collected from all sampling sites located in the two drainages. Due to the lack of synthetic storm modeling simulation data on the two unnamed drainages, it is difficult to establish mass based WLAs and mass based load reductions. The best approach is to use the average total hardness value and the average dissolved copper for each drainage to represent the current existing condition and establish the reductions needed based upon the applicable downstream chronic standard for dissolved copper.

Table 14: TMDL Calculations by Surface Water Reach

REACH DESCRIPTION	REACH	TMDL[1] (kg/day)	WLA (kg/day)	LA[2] (kg/day)	5% MOS
Queen Creek: Headwaters to the confluence w/the Superior WWTP discharge (0.7 cfs)[3]	014A	0.055	0.0[(5)]	0.052	0.003
Queen Creek: Superior WWTP discharge to the confluence w/Potts Canyon (2.9 cfs)[3]	014B	0.080	0.024[(5)]	0.052	0.004
Queen Creek: Potts Canyon to the Whitlow Dam (2.9 cfs)[3]	014C	0.080	0.0	0.076	0.004
Arnett Crk: Hdwtrs to conf w/Queen Creek (1.1 cfs)[3]	1818	0.024	0.0	0.023	0.001
Unnamed Drainage (UQ2): Hdwtrs to the conf with Queen Creek (1.4 cfs)[4]	1000	0.014	0.0	0.013	0.001
Unnamed Drainage (UQ3): Hdwtrs to the conf with Queen Creek (8.4 cfs)[4]	1843	0.104	0.0	0.103	0.001

The WLAs for all reaches include the concentration based WLA described in section 6.3.1.2

1) Includes implicit margin of safety
2) The NB and LA have been summed into one allocation
3) Flow rate used in calculating the TMDL for each reach (2yr-1hr storm; 24 hr average)
4) Average flow rate used in calculating the TMDL for the unnamed tributaries
5) Includes concentration based WLAs

6.4 Load Reductions

In order for the impaired reaches of Queen Creek, Arnett Creek, and the two unnamed drainages to meet applicable water quality standards and the TMDL, reductions in the daily loading of dissolved copper must occur. The reaches and required reductions are shown in the following tables. Each table addresses the reductions needed for the individual modeling basins that contribute to the impaired reaches of Queen Creek, Arnett Creek, and the two unnamed drainages. **Table 15** covers Arnett Creek and the three reaches of Queen Creek, and includes the existing daily load and concentration for each basin, the target load and concentration for the basin, and the percent estimated reduction needed to meet the targets for each basin. The target concentration and target load are based on meeting aquatic & wildlife chronic dissolved copper criteria. Because the standard for dissolved copper is hardness dependent, both the target concentration and the target load are based on the average total hardness value derived from data collected at sites within the modeling basin. The table also represents the critical conditions of the 2-year, 1-hour storm type. As discussed in Section 6.3, the loading numbers for modeling basin 25 will be applied to both 014B and 014C. Because of this the load reductions required for each reach are identical. Within modeling basin 51 is the confluence of Queen Creek and the discharge from the Superior WWTP. This is the segmentation point from reach 014A to 014B, but the basin itself contains neither water quality or discharge data. Load reductions will be required at the pour point of modeling basin 92, located approximately 0.8 miles above basin 51.

Reach 014A shows the highest load reduction required of the four impaired reaches. As discussed in section 5.4, modeling of the existing conditions scenarios illustrated that the majority of the dissolved copper loading is occurring in the upper basins of reach 014A. **Table 6** of section 5.4 shows that large reductions are required above basin 92 for the 30.4 percent load reduction to be met. The load reduction required at the Oak Flat modeling basin is approximately 90 percent, about three times higher than basin 92. The necessary load reductions below the Oak Flat basin decrease as the channel moves down through the canyon, but the amount of load reduction needed at the pour point of basin 38 is 63.3 percent a figure that is twice as high as basin 92. Basin 38 is located only 0.2 miles upstream of basin 92. On the other end of the spectrum, **Table 15** illustrates how small the difference is between the existing load and the target load for Arnett Creek. The kg/day for both loads had to be expressed to four decimal places. Rounding it to three places as the other loads are expressed would have made the numbers identical. Because the two impaired unnamed drainages were not included in the various synthetic storm modeling scenarios, the estimated reductions illustrated in **Table 16** for the two drainages are based on the average total hardness of each reach.

Table 15: Load Reductions for the impaired reaches of Queen Creek and Arnett Creek

Model Description & Number	Existing Load kg/day	Target Load kg/day	Existing Conc µg/L	Target Conc µg/L	% Estimated Reduction (of daily load)
Queen Creek below Mine Disch; #92 (Reach 014A)	0.079	0.055	12.5	8.65	30.4%
Queen Creek Outlet; #25 (Reach 014B)	0.101	0.080	14.4	11.28	20.8%
Queen Creek Outlet; #25 (Reach 014C)	0.101	0.080	14.4	11.28	20.8%
Arnett Creek; #46	0.0242	0.0237	9.0	8.80	2.1%

Table 16: Dissolved Copper Concentration Reductions for the two Unnamed Drainages

Model Description & Number	Average Total Hardness mg/L	Average Dissolved Copper µg/L	Dissolved Copper Target Concentration µg/L	% Estimated Reduction (of Avg Dissolved Copper
Unnamed Drainage (UQ2): Hdwtrs to the conf with Queen Crk; Reach – 1000	41	42	4.18	90.1
Unnamed Drainage (UQ3): Hdwtrs to the conf with Queen Crk; Reach – 1843	51	19	5.04	73.5

7.0 TMDL Implementation

Currently there are no planned remediation projects to address the issue of dissolved copper present within the project area. The modeling scenarios have suggested that the source of the high levels of dissolved copper found in the upper reaches of Queen Creek are from a combination of natural copper from the native geology and historic copper processing impacts. Although the presence of abandoned, mainly historic hand-dug mines in the watershed have not been shown to be a significant contributor of dissolved copper, the remediation of some of the larger sites would help to decrease the amount of daily loading to either Arnett Creek or Queen Creek depending on the location of the mine. ADEQ will work with the US Forest Service and private landowners to investigate and address the possible implementation of remediation projects at these abandoned mine sites.

Because the RCC's operations have the potential to be a source of copper within the Queen Creek watershed, ADEQ will implement steps to monitor dissolved copper impacts from the facilities. This will involve the annual review by ADEQ of RCC's Stormwater Pollution Prevention Plan (SWPP) for dissolved copper levels, and the tracking of stormwater BMPs as RCC progresses through the various site developments.

In an effort to determine the impact from brake dust run-off from the highway into Queen Creek, ADEQ will discuss with the Arizona Department of Transportation (ADOT) the possibility of working cooperatively to monitor outfalls covered under their MS4 permit. This would consist of intercepting stormwater runoff from paved road surfaces and collecting water quality samples to try and characterize the degree of impact from this particular nonpoint source issue.

ADEQ will also conduct effectiveness monitoring after the plans for Resolution's east plant site have been implemented and the mine has been developed. This effectiveness monitoring will also target any other locations in the project watershed where remediation work has been performed in an effort to reduce dissolved copper loading. **Table 17** contains information regarding the anticipated milestones for the completion and implementation of the TMDL.

Table 17: Milestones for TMDL Completion and Implementation

Milestone	FY19	FY20	FY21
TMDL completed by ADEQ	X		
TMDL approved by EPA	X		
ADEQ to work with ADOT about possible cooperative monitoring of stormwater run-off from paved roads	X		
ADEQ to talk with potential grantees regarding funding for potential water quality improvement projects	X	X	
Implementation of grant funded water quality improvement projects	X	X	X
ADEQ conducts implementation effectiveness monitoring on grant projects & mine development	X	X	X
Annual SWPP review of permitted facilities	X	X	X

8.0 Public Participation

ADEQ has held public meetings in Superior to help spread information about the project and to also take questions from those interested in the outcome. The initial public meeting was held on June 14, 2005. The last meeting was held on January 11th of 2007, during the period when much of the water quality data was still being collected. ADEQ plans on holding at least one more additional public meeting in the Superior area for discussion of the draft TMDL for Queen Creek. If the need arises, additional public meetings may be scheduled.

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