

Ambient Groundwater Quality of the Salt River Basin: A 2001-2015 Baseline Study – June 2016

Introduction

The Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring Program conducted a baseline study to characterize the groundwater quality of the Salt River basin from 2001 to 2015. ADEQ carried out this task under Arizona Revised Statutes §49-225 that mandates monitoring of waters of the state including its aquifers. The fact sheet is a synopsis of the ADEQ Open-File Report 16-01.¹

Groundwater in the Salt River basin is generally suitable for drinking water uses based on the sampling results from this study.

The Salt River basin comprises 5,232 square miles within east-central Arizona and includes portions of Apache, Gila, Greenlee, Maricopa, and Navajo counties. The basin extends from the White Mountains located near the New Mexico border to the northeast of Phoenix where Stewart Mountain Dam forms Saguaro Lake (Figure 1).

The basin's population was 29,057 in 2000, most of who lived in the communities of Globe, Miami, Young, and in Fort Apache and Whiteriver on the White Mountain Apache Nation.²

Most land is used for recreation and livestock grazing, with major copper mines located in the Globe-Miami area.

Mid-to-high elevation mountain ranges, plateaus, and canyons characterize the basin. Land ownership consists of tribal lands of the White Mountain Apache and the San Carlos Apache nations (59 percent), federal lands managed by the

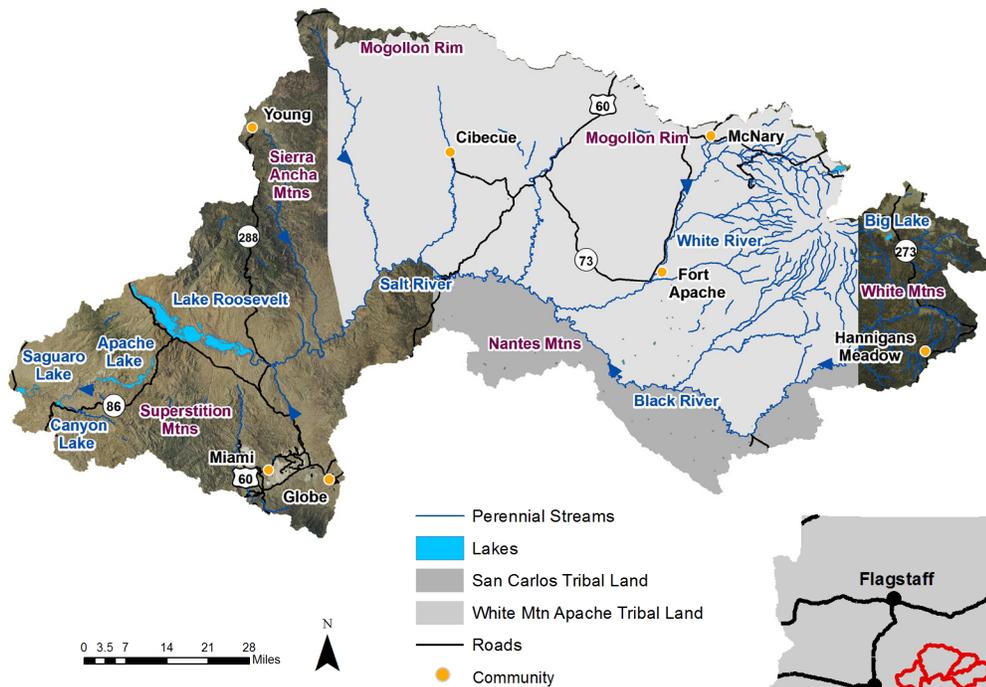


Figure 1 - Map of the Salt River Basin

*This map is for general reference only and may not be all inclusive. More detailed information and specific locations can be obtained by contacting the Arizona Department of Environmental Quality.

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Figure 2 - Theodore Roosevelt Lake with the new highway bridge that was completed in 1996.

U.S. Forest Service as part of the Tonto and Apache-Sitgreaves National Forests (39 percent), and private lands found in the Miami/Globe area and numerous in-holdings in the forest (two percent).³

Hydrology

The Salt River, a perennial stream that runs east to west, drains the basin and is formed by the confluence of the White and Black Rivers.

Four dams impound the Salt River within the Tonto National Forest starting with Theodore Roosevelt Dam, which forms the lake of the same name (Figure 2). Completed in 1911 and expanded in 1996, Theodore Roosevelt Lake has a storage capacity of 1.6 million acre-feet.

Downgradient is Horse Mesa Dam that forms Apache Lake, which has a storage capacity of 245,138 acre-feet. Mormon

Flat Dam, which forms Canyon Lake, holds 57,852 acre-feet. Furthest down-gradient is Stewart Mountain Dam, which forms Saguaro Lake that has a storage capacity of 69,765 acre-feet.⁴

Major tributaries to the Salt River within the basin include Cherry Creek, Canyon Creek, Cibecue Creek, Carrizo Creek, and Cedar Creek. The streams in the basin's drier western portion are mainly intermittent. High-elevation lakes include Sunrise, Big, Reservation, Crescent, Horseshoe Cienega, Cyclone, and Hawley lakes in the White Mountains.

The Salt River basin is characterized by a relatively narrow band of rugged mountains composed of igneous, metamorphic, and sedimentary rocks. Groundwater flows from springs in the higher elevations to supply perennial streams such as the Salt River, which serves as a

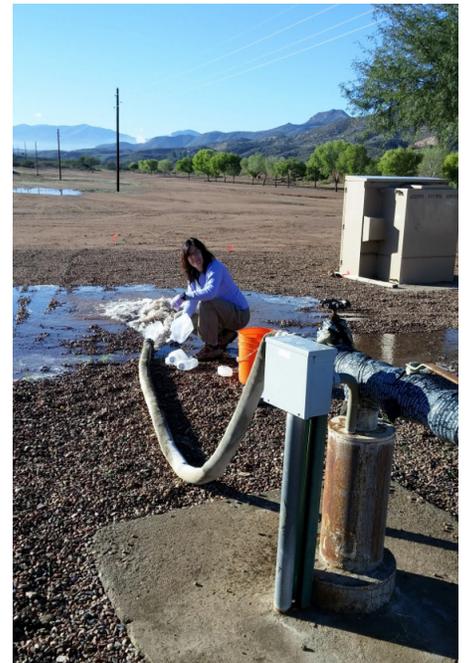


Figure 3 - ADEQ's Patti Spindler samples a domestic well near Pinal Creek located north of Globe. The sample met all water quality standards.



Figure 4 - ADEQ's Elizabeth Boettcher collects a sample from Crescent Spring, the flow of which contributes to Crescent Lake in the background.

significant water supply for the Phoenix metropolitan area.

The basin has minimal groundwater storage capabilities and high runoff because of the prevalence of bedrock and steep gradients. Groundwater resources depend on short-term recharge and are impacted by drought and well pumping.⁵

Important aquifers include recent stream alluvium, volcanic rock (the Pinetop-Lakeside Aquifer), and sedimentary rock (Gila Conglomerate; C and R aquifers). Well yields vary widely, ranging up to greater than 2,000 gallons per minute (gpm) based on 140 wells (Figure 3). Natural recharge to the basin is estimated to be 178,000 acre-feet per year. An estimated 8.7 million acre-feet is in storage to a depth of 1,200 feet.⁶

Four sub-basins comprise the Salt River basin. From east to west in a downgradient progression, they are the Black River White River, Salt River Canyon, and Salt River Lakes.

Methods of Investigation

ADEQ personnel collected samples from 75 sites, 45 wells and 30 springs (Figure 4) to characterize regional groundwater quality. These sites were located in the following sub-basins: Black River (19), White River (0), Salt River Canyon (17), and Salt River Lakes (39). All 75 sites were sampled for inorganic constituents. Other samples collected include radio-nuclides at 52 sites, isotopes (oxygen, deuterium, and nitrogen) at 36 sites, VOCs at 20 sites, and radon at 11 sites.

Sampling protocol followed the ADEQ Quality Assurance Project Plan (see www.azdeq.gov/function/programs/lab/).⁷ The effects of sampling equipment and procedures were not significant based on quality assurance/quality control evaluations.

Water Quality Sampling Results

Public drinking water systems are mandated by the Federal Safe Drinking Water Act (SDWA) to meet health-based, water quality standards, called Primary Maximum Contaminant Levels (MCLs), when supplying water to their customers. These enforceable standards are based on a lifetime (70 years) consumption of two liters of water per day.⁸

Public drinking water systems are encouraged by the SDWA to meet unenforceable, aesthetics-based water quality guidelines, called Secondary MCLs, when supplying water to their customers. Water exceeding Secondary MCLs may be unpleasant to drink and create unwanted cosmetic or laundry effects but is not a health concern.

Public drinking water quality standards and guidelines are summarized in Table 1. Groundwater sample results were compared with the SDWA health and aesthetics-based water quality standards.⁹

Of the 75 wells sampled, 43 (57 percent) met all drinking water quality standards. Health-based, Primary MCLs were exceeded at 13 sites (17 percent), while

aesthetics-based Secondary MCL water quality guidelines were exceeded at 27 sites (36 percent) (Figure 5).

Groundwater Composition

Oxygen and deuterium isotope values at most sites in the Salt River basin appear to reflect recharge occurring at various elevations within the basin. This pattern suggests that much of the groundwater was recharged from recent precipitation.

Nitrogen-15 ($\delta^{15}\text{N}$) results indicate that the nitrogen source is predominantly organic soil matter. The sites with the five highest nitrate concentrations, however, are all associated with $\delta^{15}\text{N}$ values that would indicate the nitrogen source is animal waste. At all five sites, there were either livestock on the property and/or the onsite septic system likely receives a high volume of use.

Groundwater characteristics are summarized in Table 2.

Table 1. Public drinking water quality standards and guidelines

Primary Maximum Contaminant Levels (Health-based Standards)		
Constituent	Number of Wells Exceeding Standards	Percentage of Wells Exceeding Standards
Arsenic	8	11%
Gross Alpha	4	5%
Fluoride	1	1%
Uranium	3	4%
Secondary Maximum Contaminant Levels (Health-based Standards)		
Constituent	Number of Wells Exceeding Standards	Percentage of Wells Exceeding Standards
TDS	14	19%
Iron	6	8%
Manganese	5	7%
pH-field	4	5%
Aluminum	4	5%
Chloride	3	4%
Sulfate	2	3%
Fluoride	2	3%
Zinc	1	1%

Table 2. Groundwater characteristics of Salt River basin samples

pH-field	
Slightly Acidic (< 7 su)	9
Slightly Alkaline (7 – 8 su)	52
Moderately Alkaline (> 8 su)	7
TDS	
Fresh (< 1,000 mg/L)	72
Slightly Saline (1,000 – 3,000 mg/L)	3
Hardness	
Soft (<75 mg/L)	23
Moderately Hard (75 – 150 mg/L)	7
Hard (151 - 300 mg/L)	28
Very Hard (301 - 600 mg/L)	16
Extremely Hard (> 600 mg/L)	1
Water Chemistry	
Calcium-Bicarbonate	36
Mixed-Bicarbonate	24
Sodium-Bicarbonate	5
Other Types	10
Nitrate	
Natural Background (<0.2 mg/L)	33
May or May Not be from Human Influence (0.2-3.0 mg/L)	39
May Result from Human Influence (3.0 - 10 mg/L)	3
Trace Elements	
Detected at less than 50 percent of sites	aluminum, antimony, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc
Detected at more than 50 percent of sites	arsenic, barium, fluoride, strontium, and zinc

Groundwater Patterns

Most groundwater constituent concentrations significantly differed by sub-basins and increased downgradient in elevation (Kruskal-Wallis with Tukey test, $p \leq 0.05$). Depending on the parameter, the middle Salt River Canyon sub-basin had concentrations that were similar to either the upgradient Black River sub-basin or the downgradient Salt River Lakes sub-basin.

Fifteen constituents had significant concentration differences: oxygen-18,

deuterium, temperature, pH-field, pH-lab, SC-field, SC-lab, TDS (Figure 6), hardness, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and fluoride (Kruskal-Wallis and Tukey tests, $p \leq 0.05$). No significant differences were found with six constituents: pH-field, turbidity, chloride, nitrate, nitrogen-15, and strontium.

Discussion

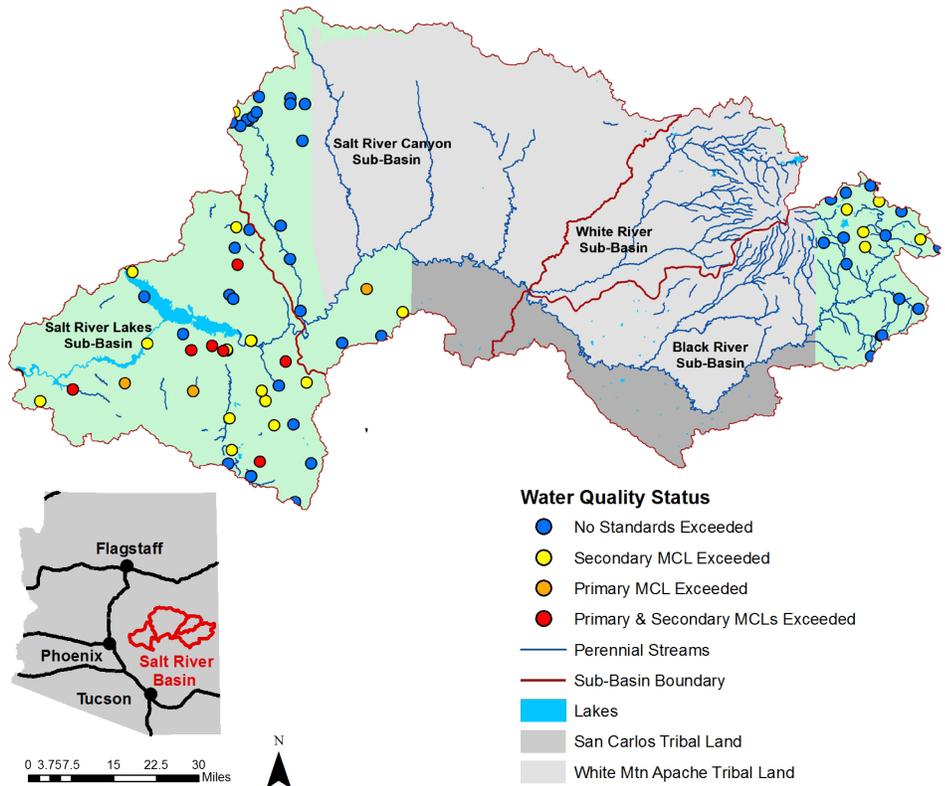
The Salt River basin, through which the Salt River Project’s series of four dams on the Salt River provides much of the Phoenix metropolitan area’s water supply, contains some of the best groundwater in Arizona, as judged by water quality standards and salinity levels.

The large basin, which stretches almost from the New Mexican border east to the Phoenix AMA, contains four sub-basins. Water quality varies among the sub-basins, as constituent concentrations typically increase as the water moves from up-gradient to downgradient areas.

The most pristine groundwater is in the uppermost Black River sub-basin, where all the sample sites met health-based water quality exceedances. Samples collected in the Black River sub-basin had a significantly lower temperature, pH, SC, TDS, hardness, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and fluoride concentrations than was found in the most downgradient sub-basin, the Salt River Lakes.

Fort Apache and San Carlos tribal lands encompass significant portions of both the Black River and Salt River Canyon sub-basins and all of the White River sub-basin. No sampling was conducted on tribal land. Based on data from other sub-basins, it is likely that water quality in the White River sub-basin has few standard exceedances and is low in salinity.

The Salt River Canyon sub-basin is the next downgradient sub-basin. Depending on the constituent, it has concentrations similar to the up-gradient Black



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Figure 5 - Water quality status of sampled sites.

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River sub-basin or the downgradient Salt River Canyon sub-basin.

The downgradient Salt River Lakes sub-basin has significantly higher concentrations of most constituents, the greatest water chemistry variability, and the most Primary and Secondary MCL exceedances.

The results of this ADEQ study substantiate previous water quality research in Arizona. Arsenic, gross alpha, uranium, and fluoride concentrations exceeded Primary MCLs and are the four of the five most common groundwater contaminants throughout the state.¹⁰ All these exceedances appear to be naturally occurring, though gross alpha and uranium exceedances may be influenced by human activities.

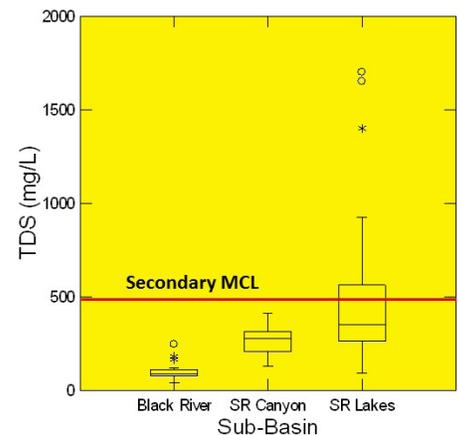


Figure 6 - TDS concentrations in the Salt River Lakes sub-basin are significantly higher than both the Salt River Canyon and Black River sub-basins (Kruskal-Wallis and Tukey tests, $p \leq 0.01$).

Arsenic concentrations are affected by reactions with hydroxyl ions and are influenced by factors such as an oxidizing environment, lithology, and aquifer residence time.¹¹

How groundwater chemistry can impact arsenic concentrations is highlighted by the chloride-sodium relationship (Figure 7). Sample sites with high levels of the two constituents that are on or above the regression line (shown with a blue circle) have no arsenic Primary MCL exceedances. Samples below the regression line that are only high in sodium concentrations (designated with a red star) without the accompanying elevated chloride all have arsenic Primary MCL exceedances.

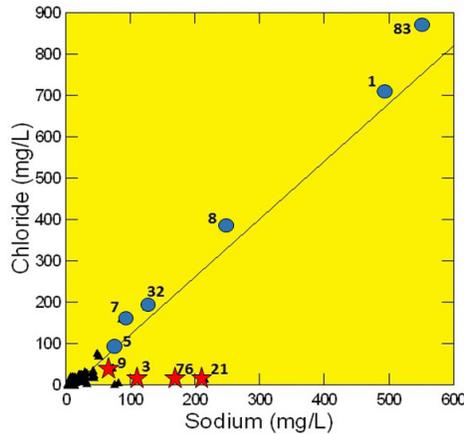


Figure 7 - Sodium-Chloride Relationship with Arsenic Exceedances.

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Fluoride concentrations in groundwater are controlled by two reactions:

- By calcium through precipitation and dissolution of the mineral fluorite, or
- By hydroxyl ion exchange or sorption-desorption reactions.¹²

Elevated gross alpha and uranium concentrations are linked to two factors:

- Granitic geology that is associated with elevated radionuclide concentrations,¹³ or
- The recharge of high alkalinity water, which liberates naturally occurring uranium that is absorbed to aquifer sediments.¹⁴

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