

# Ambient Groundwater Quality of the Western Mexican Drainage Basin: A 2016-2017 Baseline Study – May 2017

## Introduction

The Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring Program conducted a baseline study to characterize the groundwater quality of the Western Mexican Drainage Basin from 2016-2017. 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 17-02.<sup>1</sup>

The basin contains 610 square miles within Yuma and Pima counties in southwestern Arizona. The basin comprises a thin strip of land, no more than 15 miles wide, along the international boundary with Mexico (Figure 1). The majority of the Western Mexican Drainage basin lies within Mexico.

The desert basin consists of valleys divided by low elevation mountains. The population of the basin was estimated in 2000 to be 33 residents, who live at Organ Pipe Cactus National Monument and in Lukeville, which is located along the international border with Mexico.<sup>2</sup> Lukeville is the port of entry to the much larger Mexican city of Sonoyta, which had almost 16,000 residents in 2010.

Along the Rio Sonoyta, which goes through Sonoyta, are agricultural fields that are supplied by shallow irrigation wells. The headwaters of the Rio Sonoyta are in the Sierra de El Cobre in Sonora, Mexico and the Baboquivari Mountains in the eastern part of the Tohono O'odham Nation in the U.S. The latter range is the source of two major washes, which both are located within the Tohono O'odham Nation: Vamori Wash and San Simon Wash. The river's course continues west through Sonoyta along the international border.

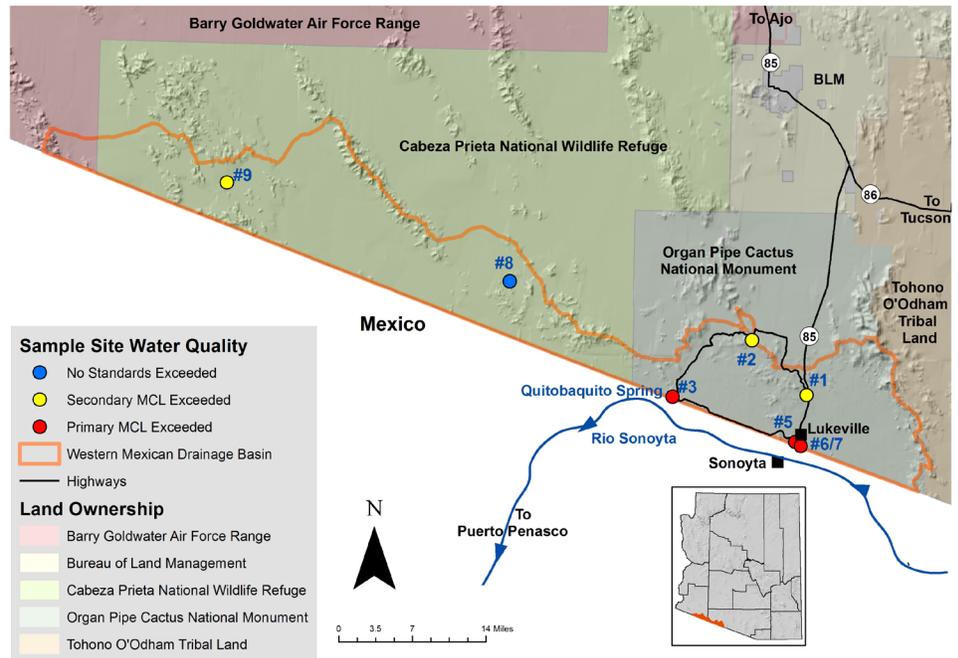


Figure 1 - Western Mexican Drainage Basin

\*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.



Figure 2 - The Cabeza Prieta National Wildlife Refuge comprises 61 percent of the basin.

Near Quitobaquito Spring, the Rio Sonoyta dips south and ends at the Sea of Cortez, east of the beach town of Puerto Penasco.

Land ownership in the Western Mexican Drainage basin consists of federal lands (99 percent). These are managed by the U.S. Fish and Wildlife Service as the Cabeza Prieta National Wildlife Refuge (61 percent) (Figure 2) the National Park Service as the Organ Pipe Cactus National Monument (36 percent) (Figure 3), and the U.S. Military as the Barry Goldwater Air Force Range (2 percent). The national monument is located in the eastern part of the basin, the national wildlife refuge in the center and the military range is in the western portion.

Less than one percent of the basin is Tohono O'odham tribal land, State Trust land and private land; the majority of these lands are located near Lukeville.<sup>3</sup>

Elevation ranges from 4,024 feet above mean sea level (AMSL) in the Ajo Mountains to 680 feet at Las Playas along the international boundary near the center of the basin. Located within the basin are portions of numerous mountain ranges, including the Ague Dulce, Ajo, Bates, Cabeza Prieta, Puerto Blanco, Sierra Pina and Tule mountains, along with the Cipriano and Quitobaquito Hills. Other notable geographic features include the Lechuguilla and Tule deserts, La Abra Plain and Sonoyta Valley.



Figure 3 - Organ Pipe Cactus National Monument comprises 36 percent of the basin.



Figure 4 - ADEQ's Elizabeth Boettcher at Quitobaquito Spring, which is critical habitat for the endangered desert pupfish.

## Hydrology

The basin is composed of elongated fault-block mountain ranges composed of igneous, metamorphic and sedimentary rocks with intervening alluvial valleys. All natural waterways are ephemeral, and there are only a few perennial springs, including Quitobaquito Spring (Figure 4) within the Organ Pipe Cactus National Monument.

Groundwater occurs primarily in the basin fill, but there is little detailed information about the aquifer. The basin fill is composed of the erosional remnants of the nearby mountains and consists of unconsolidated gravel, sand, silt and clay deposits. The mountains may contain, in some areas, enough groundwater for low-yield wells and springs.<sup>4</sup>

Groundwater flow is from north to south into Mexico, with an estimated 2,400 acre-feet crossing the border annually.

Well yields are less than 100 gallons per minute (GPM), with a median well yield of approximately 50 GPM. Recharge is estimated to average 1,000 acre-feet per year. There are an estimated 3.0 to 4.1 million acre-feet in storage in the basin.<sup>5</sup>

## Investigation Methods

ADEQ personnel collected samples from seven sites, five wells and two springs, to characterize regional groundwater quality. The seven sites included Organ Pipe Cactus National Monument South Well (#1) (Figure 5), Dripping Spring (#2), Quitobaquito Spring (#3), Lukeville Port of Entry Well (#5/6), Gringo Pass Motel Well (#7), Papago Well (#8), and Tule Well (#9) (Figure 1). Inorganic constituents and stable isotopes of oxygen, hydrogen, and nitrogen were collected at all sites. Other samples collected include radon at five sites and radionuclides at four sites.

Sampling protocol followed the ADEQ Quality Assurance Project Plan (see [www.azdeq.gov/function/programs/lab/](http://www.azdeq.gov/function/programs/lab/)).<sup>6</sup> 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 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 per day.<sup>7</sup>



Figure 5 - ADEQ's Elizabeth Boettcher samples South Well #4, which supplies Organ Pipe Cactus National Monument.

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 considered a health concern.<sup>8</sup>

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.

Of the seven sites sampled, one (14 percent) met all drinking water quality standards. Health-based, Primary MCLs were exceeded at three sites (43 percent). Aesthetics-based Secondary MCL water quality guidelines were exceeded at eight sites (86 percent) (Figure 6).

**Table 1.**

Primary Maximum Contaminant Levels (Health-based Standards)		
Constituent	Number of Wells Exceeding Standards	Percentage of Wells Exceeding Standards
Arsenic	3	43%
Fluoride	3	43%
Uranium	1	14%
Secondary Maximum Contaminant Levels (Aesthetics-based Guidelines)		
Constituent	Number of Wells Exceeding Standards	Percentage of Wells Exceeding Standards
Fluoride	4	57%
TDS	3	43%
Aluminum	1	14%
Chloride	1	14%
Iron	1	14%
Manganese	1	14%
Sulfate	1	14%

Radon is a naturally occurring, intermediate breakdown product from the radioactive decay of uranium-238 to lead-206. Of the five sites sampled for radon, none exceeded the proposed 4,000 picocuries per liter (pCi/L) standard, while three sites (60 percent) exceeded the proposed 300 pCi/L standard.<sup>9</sup>

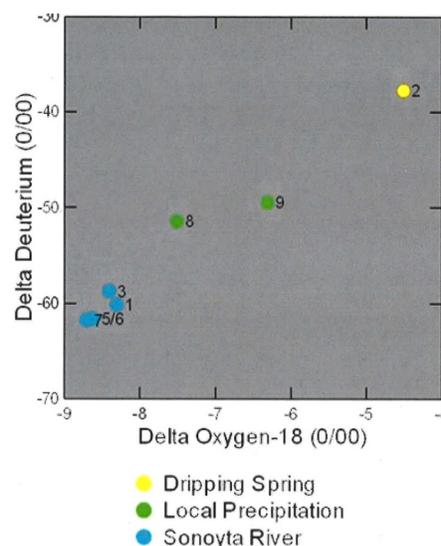


Figure 6 - Stable isotopes values of oxygen and hydrogen reflect precipitation occurring at different elevations and providing groundwater recharge to the sample sites.

## Groundwater Composition

Groundwater characteristics are summarized in Table 2.

**Table 2. Groundwater characteristics of sampled sites.**

pH-field	
Slightly Acidic (< 7 su)	0
Slightly Alkaline (7 – 8 su)	5
Moderately Alkaline (> 8 su)	2
TDS	
Fresh (< 1,000 mg/L)	6
Slightly Saline (1,000 – 3,000 mg/L)	1
Hardness	
Soft (<75 mg/L)	2
Moderately Hard (75 – 150 mg/L)	4
Hard (151 - 300 mg/L)	1
Water Chemistry	
Sodium-Chloride	5
Sodium-Mixed	1
Sodium-Sulfate	1
Nitrate	
Natural Background (<0.2 mg/L)	1
May or May Not be from Human Influence (0.2-3.0 mg/L)	3
May Result from Human Influence (3.0 - 10 mg/L)	3
Probably Result from Human Influence (> 10 mg/L)	0
Trace Elements	
Detected at less than 50 percent of sites	aluminum, antimony, beryllium, cadmium, copper, iron, lead, manganese, mercury, nickel, silver, and thallium.
Detected at more than 50 percent of sites	arsenic, barium, boron, chromium, fluoride, selenium, strontium, and zinc.

$\delta^{18}\text{O}$  and  $\delta^2\text{H}$  values at wells and springs in the Western Mexican Drainage basin reflect recharge from local precipitation. However, five samples appear to also have inputs from other recharge sources.

Four of the samples collected in Organ Pipe Cactus National Monument and Lukeville form a tight cluster that are less evaporated than the other samples. An additional recharge source is likely underflow from precipitation that occurred in the headwaters of the Rio Sonoyta, either in the Sierra de El Cobre in Sonora, Mexico or from the Baboquivari Range in the eastern part of the Tohono O'odham Nation. Local precipitation is also a likely

component of the recharge for these sites.

The samples collected from two wells located on the Cabeza Prieta National Wildlife Refuge, Papago well (WMD-8) and Tule well (WMD-9), have higher values than the previous samples. These sites match the average values of local precipitation in the area.

Dripping Springs (WMD-2), located within the national monument, is the most evaporated. Evaporation may have occurred before infiltration or after discharge at the spring. The spring is open to the surface, so it might also receive direct recharge from precipitation. If the precipitation occurs during the summer monsoon season, it would also result in higher  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  values as summer rainfall has higher values and evaporation is more intense during the summer months.<sup>10</sup>

No significant water quality differences were found when analyzing constituent concentrations from these recharge sources. The lack of differences may be the result of the limited groundwater sites available for sampling for the study, and the corresponding low number of samples available for statistical analysis.

Nitrogen-15 ( $\delta^{15}\text{N}$ ) results indicate that the nitrogen source varies by location. Sample sites in the Cabeza Prieta National Wildlife Refuge are likely from animal waste, which may be due to people and animals congregating around these water sources for many years. In contrast, samples from other areas of the basin appear to have an indeterminate or organic soil matter as their nitrate source.

Six of the seven sites that ADEQ sampled were previously sampled by the U.S. Geological Survey between 1974 and 2003. When comparing the two groups of water quality data, constituent concentrations were remarkably similar, which is expected in this remote basin that has little groundwater development.

## Discussion

The Western Mexican Drainage basin comprises a thin strip of land south of



*Figure 7 - Papago Well in the Cabeza Prieta National Wildlife Refuge was the only sample site without any water quality exceedances.*

Ajo along the international border with Mexico. Groundwater quality is unknown in many areas of the remote basin, which consists almost entirely of federal land used for wildlife, recreation and military purposes. There has been little groundwater development, with the basin's few wells located near Organ Pipe Cactus National Monument and the community of Lukeville.

Limited sampling near the Organ Pipe Cactus National Monument headquarters suggests groundwater quality meets health-based water quality standards in the vicinity. However, about five miles downgradient at the community of Lukeville, samples collected from two wells had arsenic and fluoride concentrations that exceeded health-based water quality standards.

Quitobaquito Springs, located about a dozen miles to the northwest from Lukeville along the border with Mexico, also had exceedances of arsenic and fluoride water quality standards, along with uranium.

The results of this ADEQ study support the findings of previous groundwater quality studies in Arizona by the agency. Arsenic, fluoride and uranium concentrations commonly exceeded Primary MCLs, and are three of the four most prevalent groundwater contaminants in the state.<sup>11</sup>

Elevated concentrations of arsenic, fluoride and uranium naturally occur in groundwater. Arsenic concentrations are affected by reactions with hydroxyl ions and are influenced by factors such as an oxidizing environment, lithology and aquifer residence time.<sup>12</sup> Calcium often controls fluoride concentrations in groundwater through precipitation or dissolution of the mineral fluorite. Dissolved fluoride concentrations exceeding 5 mg/L may occur in groundwater depleted in calcium if a source of fluoride ions is available for dissolution.<sup>13</sup> Uranium exceedances may be caused by weathering of rocks or sediments, especially granite which composes the Quitobaquito Hills from which issues Quitobaquito Spring.<sup>14</sup>

The collection of  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  values at sample sites in the Western Mexican Drainage Basin assisted in determining the sources of recharge to the basin. Particularly important was the improved understanding of the groundwater sources that supply Quitobaquito Spring, perhaps the most ecologically important spring in southwestern Arizona

Previous studies indicated that Quitobaquito Spring was a fissure spring, with its source located below the local water table. The spring was thought to be supplied by a groundwater flow system along Agaujita Wash, located to the north. The spring was also speculated to be hydraulically connected to the regional aquifer system in Mexico.<sup>15</sup>

The stable isotopes of oxygen-18 and hydrogen collected at Quitobaquito Spring confirm the influence of the regional aquifer supplied by underflow from the Rio Sonoyta.<sup>16</sup> This determination is based on the higher values that indicate a contribution from less-evaporated precipitation from the higher-elevation headwaters of the Rio Sonoyta. The additional certainty about the source of Quitobaquito Spring indicates that Organ Pipe Cactus National Monument should monitor how groundwater withdrawals in Mexico impact the flow to assure the vital water source's continued viability.

## References Cited

- <sup>1</sup> Towne, D.C., 2017, *Ambient groundwater quality of the Western Mexican Drainage Basin: a 2016-2017 baseline study*: Arizona Department of Environmental Quality Open File Report 17-02, 41 p.
- <sup>2</sup> ADWR Statewide Planning Water Atlas website, [http://www.azwater.gov/azdwr/StatewidePlanning/WaterAtlas/CentralHighlands/documents/volume\\_5\\_SRB\\_final.pdf](http://www.azwater.gov/azdwr/StatewidePlanning/WaterAtlas/CentralHighlands/documents/volume_5_SRB_final.pdf), accessed 5/8/2017.
- <sup>3</sup> ADWR, 1994.
- <sup>4</sup> ADWR Statewide Planning Rural Programs website, [http://www.azwater.gov/azdwr/StatewidePlanning/RuralPrograms/OutsideAMAs\\_PDFs\\_for\\_web/Lower\\_Colorado\\_River\\_Planning\\_Area/Western\\_Mexican\\_Drainage\\_Basin.pdf](http://www.azwater.gov/azdwr/StatewidePlanning/RuralPrograms/OutsideAMAs_PDFs_for_web/Lower_Colorado_River_Planning_Area/Western_Mexican_Drainage_Basin.pdf), accessed 5/9/2017.
- <sup>5</sup> *ibid.*
- <sup>6</sup> Arizona Department of Environmental Quality, 1991, *Quality Assurance Project Plan: Arizona Department of Environmental Quality Standards Unit*, 209 p.
- <sup>7</sup> U.S. Environmental Protection Agency website, [www.epa.gov/waterscience/criteria/humanhealth/](http://www.epa.gov/waterscience/criteria/humanhealth/), accessed 5/8/17
- <sup>8</sup> *ibid.*
- <sup>9</sup> U.S. Environmental Protection Agency website, <https://archive.epa.gov/water/archive/web/html/regulations.html>, accessed 4/19/17.
- <sup>10</sup> Email communication from Hector Alejandro Zamora, 05/08/2017.
- <sup>11</sup> Towne, Douglas, and Jones, Jason, 2011, *Groundwater quality in Arizona: a 15-year overview of the ADEQ ambient groundwater monitoring program (1995-2009)*: Arizona Department of Environmental Quality Open File Report 11-04, 44 p.
- <sup>12</sup> Robertson, F.N., 1991, *Geochemistry of ground water in alluvial basins of Arizona and adjacent parts of Nevada, New Mexico, and California*: U.S. Geological Survey Professional Paper 1406-C, 90 p.
- <sup>13</sup> *ibid.*
- <sup>14</sup> Lowry, Jerry D. and Lowry, Sylvia B, 1988, "Radionuclides in Drinking Waters," in *American Water Works Association Journal*, July 1988. 15-year overview of the ADEQ ambient groundwater monitoring program (1995-2009): Arizona Department of Environmental Quality Open File Report 11-04, 44 p.
- <sup>15</sup> Carruth, R.L., 1996, *Hydrogeology of the Quitobaquito Springs and La Abra Plain area, Organ Pipe Cactus National Monument, Arizona, and Sonora, Mexico*: U.S. Geological Survey Water-Resources Investigations Report 95-4295, 23 p.
- <sup>16</sup> Email communication from Hector Alejandro Zamora, 05/09/2017.

### For More Information Contact:

Michael J. Chang  
 Hydrologist, ADEQ Monitoring Unit  
 1110 W. Washington St. #5560-B  
 Phoenix, AZ 85007  
 email: [mc12@azdeq.gov](mailto:mc12@azdeq.gov)  
[www.azdeq.gov/node/882](http://www.azdeq.gov/node/882)