ADEQ
Arizona Department of Environmental Quality

FACT SHEET

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Ambient Groundwater Quality of the Gila Bend Basin: A 2012-2015 Baseline Study – June 2015

Introduction

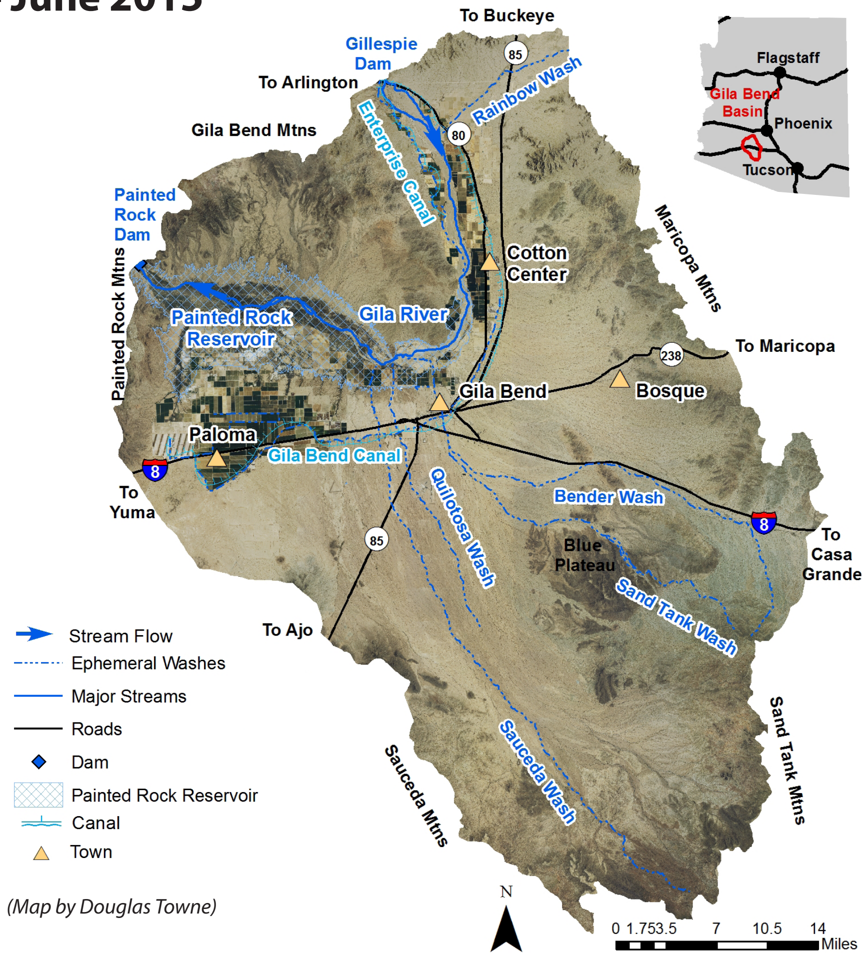
The Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring Program conducted a baseline study to characterize the groundwater quality of the Gila Bend basin from 2012 to 2015. ADEQ carried out this task pursuant to Arizona Revised Statutes §49-225 that mandates monitoring of waters of the state including its aquifers. The fact sheet is a synopsis of the ADEQ Open File Report 15-07.[1]

The Gila Bend basin is located in west-central Arizona about 50 miles southwest of Phoenix (Map 1). The basin comprises 1,284 square miles within Maricopa County and consists of a wide, gently sloping alluvial plain surrounded by rugged desert mountains. Land ownership consists of federal lands (75 percent) managed by the Bureau of Land Management (42 percent) and the U.S. Military (33 percent), private lands (16 percent), State Trust lands (six percent), and tribal lands (three percent). The basin had a population of 4,256 people in 2000, about half of whom resided in the Town of Gila Bend.[2]

Irrigated agriculture is historically the basin's most important economic activity. Alfalfa, cotton, and small grain crops have recently been augmented by new agricultural operations such as dairies and a fish farm. Other important economic contributors in the basin include military facilities, power plants, a prison, and Gila Bend's historic role as a service center for travelers. [3]

Hydrology

There are no perennial streams in the basin. All washes are ephemeral and flow only after heavy precipitation. The basin is drained by the Gila River that enters



(Map by Douglas Towne)

Figure 1 – ADEQ's Elizabeth Boettcher collects a groundwater sample from a high production irrigation well in the Cotton Center hydrologic area near the Gila Bend Mountains.

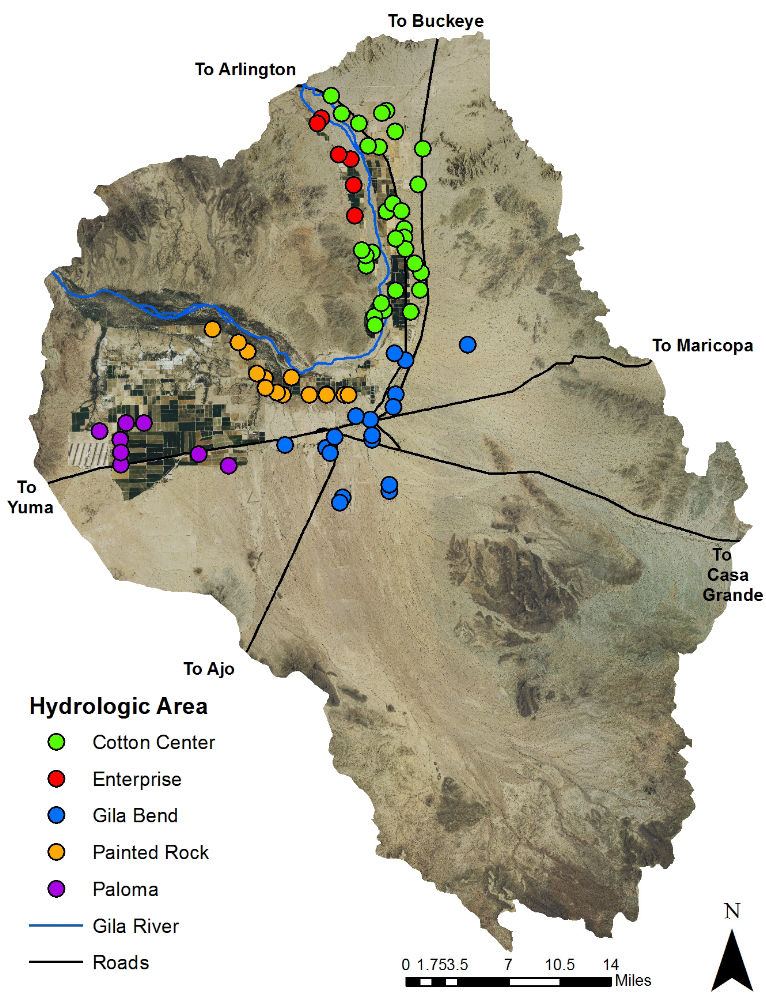
from the north at Gillespie Dam. After a 36-mile stretch, the Gila River exits the basin at Painted Rock Reservoir, a flood control structure built in 1960, which can hold 4.8 million acre-feet at maximum storage.[4]

The Gila River above Gillespie Dam is perennial, which is the result of regulated discharges by Phoenix-area wastewater treatment facilities, upstream drainage wells, and irrigation returns. All surface water from the Gila River is normally diverted for irrigation use into the eight-mile Enterprise Canal on the west side, and the 35-mile Gila Bend Canal on the east side.

Gillespie Dam diverted water from 1921 until it was breached during record flooding in 1993. Since then, pumps are used to lift water trapped by a diversion dike just below the remnants of Gillespie Dam into the canals, both of which have their flows supplemented by groundwater pumped by large-capacity wells (Figure 1).[5] Downstream leakage from the diversion dike creates a short stretch of intermittent flow in the uppermost reach of the Gila River within the basin.

Groundwater in the basin is contained in alluvial deposits that can be divided into younger alluvial (or upper basin fill) and older alluvial (or lower basin fill) units. These are considered to be a single aquifer because the units are hydrologically connected and both contribute water to wells. The basin fill north of Gila Bend is relatively thin; to the west of town it's much thicker and contains greater amounts of groundwater. Groundwater is predominantly pumped for irrigation purposes with minor amounts used for public water, domestic, industrial, and stock uses.[6]

Figure 2 – ADEQ's Elizabeth Boettcher samples a well that supplies irrigation water in the Paloma area.



Significant groundwater development started in 1935 and, subsequently, numerous high-capacity irrigation wells have been drilled. Well yields in the alluvium vary widely depending on the substrate, ranging from 200 gallons to more than 2,000 gallons per minute.[7]

Groundwater typically moves from the mountain fronts toward the Gila River, then south and later west following the river's course. Groundwater levels vary from 15 feet below land surface (bls) near the Gila River to more than 600 feet bls near the mountain fronts, and have been declining over time due to heavy irrigation pumping. Though groundwater pumping is slowly depleting the aquifer, the amount of groundwater in storage, to a depth of 1,200 feet bls, is estimated to be 27.6 million acre-feet.[8]

The basin can be divided into distinct hydrologic areas based on land uses:

- **Cotton Center** - an area between Gillespie Dam and Gila Bend irrigated solely with groundwater,
- **Enterprise** - an area on the west side of the Gila River just below Gillespie Dam irrigated with both surface water from the Enterprise Canal and groundwater,

- **Gila Bend** – an area south and west of irrigated agriculture centered on the Town of Gila Bend,
- **Painted Rock** - an area on the south side of the Gila River and northwest of Gila Bend irrigated solely with groundwater, and
- **Paloma** - an area that encompasses the Paloma Irrigation and Drainage District, located west of Gila Bend, which is irrigated with both surface water from the Gila Bend Canal and groundwater.

Methods of Investigation

To characterize regional groundwater quality, samples were collected from 77 wells. The wells were predominantly used for irrigation (61 wells) (Figure 2), domestic (nine wells), public supply (six wells), and stock (one well). Samples for inorganic constituents and isotopes (oxygen, deuterium, and nitrogen) were collected from all 77 wells. Other samples collected include radon (51 wells) and radionuclides (19 wells).

Sampling protocol followed the ADEQ Quality Assurance Project Plan (*see www.azdeq.gov/function/programs/lab/*).[9] The effects of sampling equipment and procedures were not significant based on quality assurance/quality control evaluations.

Water Quality Sampling Results

Groundwater sample results were compared with the Safe Drinking Water Act (SDWA) health and aesthetics-based water quality standards.[10] Of the 77 wells sampled, none met all drinking water quality standards (Table 1).

Public drinking water systems must 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.[11]

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/or create unwanted cosmetic or laundry effects but is not considered a health concern.[12]

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
Nitrate	21	27%
Arsenic	18	23%
Fluoride	17	22%
Uranium	3	4%
Secondary Maximum Contaminant Levels (Health-based Standards)		
Constituent	Number of Wells Exceeding Standards	Percentage of Wells Exceeding Standards
TDS	77	100%
Chloride	77	100%
Fluoride	44	57%
Sulfate	41	53%
pH-field	2	3%
Aluminum	2	3%

Radon is a naturally occurring, intermediate breakdown product from the radioactive decay of uranium-238 to lead-206. Of the 51 sites at which a water sample was collected for radon, none exceeded the proposed 4,000 picocuries per liter (pCi/L) standard that would apply if Arizona were to establish an air and water multimedia program to address the health risks from radon in indoor air.[13] Forty-eight sites (94 percent) exceeded the proposed 300 pCi/L standard that would apply if Arizona were not to develop a multimedia program.

Groundwater Composition

Oxygen and deuterium isotope values in most samples are lighter than would be expected from recharge occurring at elevations within the basin. This suggests that much of the groundwater was recharged long ago (8,000 to 12,000 years) during cooler climatic conditions rather than more recent recharge.[14]

Table 2. Groundwater characteristics of Gila Bend basin samples

pH-field	
Slightly Acidic (< 7 su)	5
Slightly Alkaline (7 – 8 su)	56
Moderately Alkaline (> 8 su)	16
TDS	
Fresh (< 1,000 mg/L)	2
Slightly Saline (1,000 – 3,000 mg/L)	56
Moderately Saline (3,001 – 10,000 mg/L)	19
Hardness	
Soft (<75 mg/L)	1
Moderately Hard (75 – 150 mg/L)	11
Hard (151 - 300 mg/L)	14
Very Hard (301 - 600 mg/L)	13
Extremely Hard (> 600 mg/L)	38
Water Chemistry	
Sodium-Chloride	59
Mixed-Chloride	8
Could not be determined because of lab error	10
Nitrate	
Natural Background (<0.2 mg/L)	1
May or May Not be from Human Influence (0.2-3.0 mg/L)	22
May Result from Human Influence (3.0 - 10 mg/L)	33
Probably Results from Human Influence (> 10 mg/L)	21
Trace Elements	
Detected at less than 50 percent of sites	aluminum, antimony, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, thallium, and zinc
Detected at more than 50 percent of sites	arsenic, barium, boron, fluoride, selenium, and strontium

Groundwater Patterns

Groundwater constituent concentrations were influenced by hydrologic area and recharge age.

Constituents such as oxygen-18, deuterium, temperature, pH, TDS, hardness, calcium, magnesium, sodium, potassium, bicarbonate, chloride, sulfate, nitrate, nitrogen-15, arsenic, boron, fluoride, and strontium, had significantly different concentrations among hydrologic areas (Kruskal-Wallis with Tukey test, $p \leq 0.05$). The Gila Bend and Paloma areas had the highest arsenic and fluoride concentrations and pH and temperature levels; the Enterprise area had the highest TDS and major ion concentrations.

Sample sites were divided into older and younger groundwater age using cluster analysis. Constituents such as oxygen-18, deuterium, TDS, hardness, calcium, magnesium, sodium, chloride, sulfate, nitrate, boron, copper, fluoride, selenium, and strontium had significantly higher constituent concentrations at sites with younger, enriched samples than at sites with older, depleted samples (Kruskal-Wallis test, $p \leq 0.05$).

Figure 5 – ADEQ's Patti Spindler samples a 1,785 foot-deep well located in the Paloma area. Analytical results revealed high pH levels, elevated arsenic and fluoride concentrations, and the basin's second-lowest TDS concentration (980 mg/L).

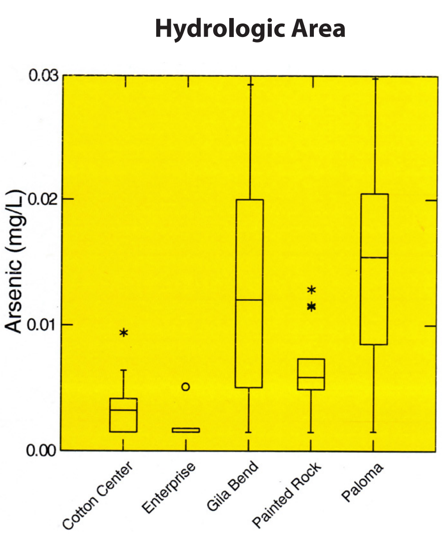


Figure 3 - Arsenic concentrations are significantly higher in the Gila Bend and Paloma areas (Kruskal Wallis and Tukey tests, $p \leq 0.05$).

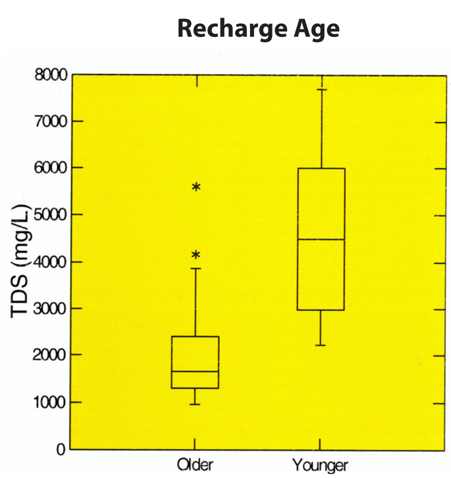


Figure 4 – More recent, high-salinity recharge is exhibited in TDS concentrations in a subset of wells mostly located in the Enterprise and Paloma areas, which are partially irrigated with water from the Gila River.

Discussion

Groundwater in the Gila Bend basin is generally unsuitable for use as drinking water without proper treatment based on the sampling results of this study. Groundwater quality is, however, generally suitable to irrigate many crops, which is the predominant water use in the basin.

The results of this ADEQ study generally substantiate previous water quality research in Arizona. Arsenic, fluoride, nitrate, and uranium concentrations exceeded Primary MCLs, and are the four most common groundwater contaminants throughout the state.[15] Arsenic and fluoride exceedances appear to be naturally occurring, while nitrate and uranium exceedances are a combination of natural sources and human influences.

Arsenic concentrations are affected by reactions with hydroxyl ions and are influenced by factors such as an oxidizing environment, lithology, and aquifer residence time.[16]

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.[17]

Both arsenic and fluoride concentrations tend to be highest in the Gila Bend and Paloma areas (Map 3). This pattern is influenced by their high pH levels, which is the result of a long aquifer residence time in the Gila Bend area, and of wells producing groundwater from great depths in the Paloma area.

Nitrogen isotopes suggest the predominant source of nitrate is animal waste, which is used as a fertilizer and supplied by the many dairy operations. Some sites, however, appear to be the result of naturally occurring soil organic matter.[18] Nitrate concentrations tend to be lowest in the Gila Bend area, which has limited agricultural activities and highest in the Painted Rock area.

Elevated uranium concentrations are linked to two factors:

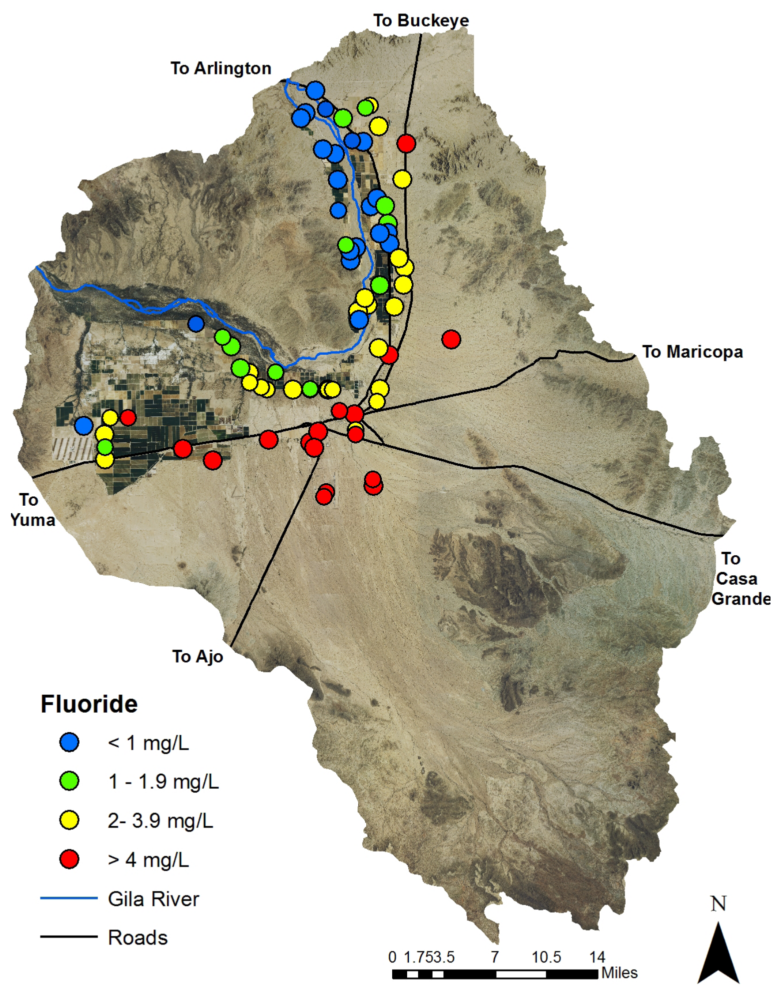
- Granitic geology that is associated with elevated radionuclide concentrations[19], or
- The recharge of high alkalinity water, which liberates naturally occurring uranium that is adsorbed to aquifer sediments.[20]

The basin's essential groundwater quality characteristics of elevated TDS concentrations, sodium-chloride chemistry, and lower fluoride concentrations north of Gila Bend were first documented in 1946.[21] Only limited previous sampling for arsenic, nitrate, and uranium has been conducted in the basin.

The basin's elevated TDS concentrations will likely increase as a result of saline recharge from excess water applied to crops. This groundwater degradation process is especially pronounced in areas where surface water diverted from the Gila River is used for irrigation. The imported water source maintains relatively shallow groundwater levels, resulting in a short lag time before the saline recharge percolates to the aquifer, impacting groundwater quality. This process accounts for the significantly higher TDS concentrations found in the Enterprise area.

TDS increases in the basin have been considerably moderated, however, by fresh recharge from floods on the Gila River that dilute saline groundwater with low TDS surface water. Major flooding occurred 1973, 1978, 1979, 1993, and 2005. Mean annual flows in the Gila River have declined since 1921 because of increased upstream water use and storage facilities.[22] If this trend continues, it's likely that TDS concentrations in groundwater will increase in the basin. Future groundwater sampling should monitor for this trend.

Not all irrigation wells are equally impacted by saline irrigation recharge. Besides variability by hydrologic area, differences in well depth and perforation intervals are major influences on TDS concentrations. The seven deepest irrigation wells (all greater than 1,390 feet in depth) had low TDS concentrations ranging from 960 – 1,710 mg/L (Figure 5). These wells are likely only perforated at great depth, and do not draw shallow saline groundwater. In contrast, two shallow domestic wells (averaging 400 feet in depth) located in irrigated areas had an average TDS concentration of 6,775 mg/L.



References Cited

1. Towne, D.C., 2015, Ambient groundwater quality of the Gila Bend basin: a 2012-2015 baseline study: Arizona Department of Environmental Quality Open File Report 15-07, 75 p.

2. Arizona Department of Water Resources website, http://www.azwater.gov/AzDWR/StatewidePlanning/WaterAtlas/LowerColoradoRiver/documents/Volume_7_GIL_final.pdf, accessed 6/28/15.

3. Ibid

4. Rascona, S.J., 1996, Maps showing groundwater conditions in the Gila Bend basin, Maricopa County, Arizona—1993; Arizona Department of Water Resources Hydrologic Map Series Report Number 29, two sheets, scale, 1:250,000.

5. ibid

6. Arizona Department of Water Resources website, http://www.azwater.gov/azdwr/StatewidePlanning/RuralPrograms/OutsideAMAs_PDFs_for_web/Lower_Colorado_River_Planning_Area/Gila_Bend_Basin.pdf, accessed 6/28/15.

7. ibid

8. ibid

9. Arizona Department of Environmental Quality, 1991, Quality Assurance Project Plan: Arizona Department of Environmental Quality Standards Unit, 209 p.

10. U.S. Environmental Protection Agency website, www.epa.gov/waterscience/criteria/humanhealth/, accessed 6/28/15.

11. ibid

12. ibid

13. U.S. Environmental Protection Agency website, http://water.epa.gov/lawsregs/rulesregs/sdwa/radon/regulations.cfm, accessed 6/28/15.

14. Earman, Sam, et al, 2003, An investigation of the properties of the San Bernardino groundwater basin, Arizona and Sonora, Mexico: Hydrology program, New Mexico Institute of Mining and Technology, 283 p.

15. 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.

16. 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.

17. ibid

18. Sustainability of Semi-Arid Hydrology and Riparian Areas website, http://web.sahra.arizona.edu/programs/isotopes/nitrogen.html#2, accessed 6/28/15.

19. Lowry, J.D. and Lowry, S.B., 1988, "Radionuclides in Drinking Waters," in American Water Works Association Journal, 80 (July), pp. 50-64.

20. Jagucki, M.L., Jurgens, B.C., Burow, K.R. and Eberts, S.M., 2009, Assessing the vulnerability of public-supply wells to contamination: Central Valley aquifer system near Modesto, California: U.S. Geological Survey Water Fact Sheet 2009-3036, 6 p

21. Rascona, 1996.

22. Arizona Department of Water Resources website, http://www.azwater.gov/azdwr/StatewidePlanning/RuralPrograms/OutsideAMAs_PDFs_for_web/Lower_Colorado_River_Planning_Area/Gila_Bend_Basin.pdf, accessed 6/28/15.

Figure 6 – Groundwater produced by a high-capacity well supplements the flow of the Gila Bend Canal.

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