ADEQ
Arizona Department of Environmental Quality

FACT SHEET

Publication Number: FS 14-11

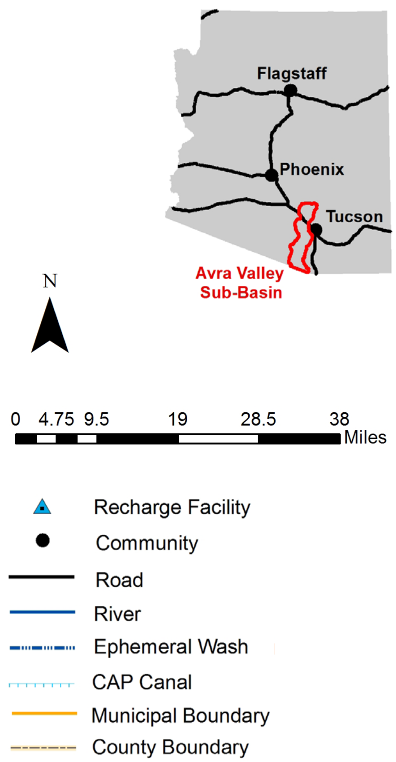
Ambient Groundwater Quality of the Avra Valley Sub-Basin of the Tucson Active Management Area: A 1998-2001 Baseline Study – September 2014

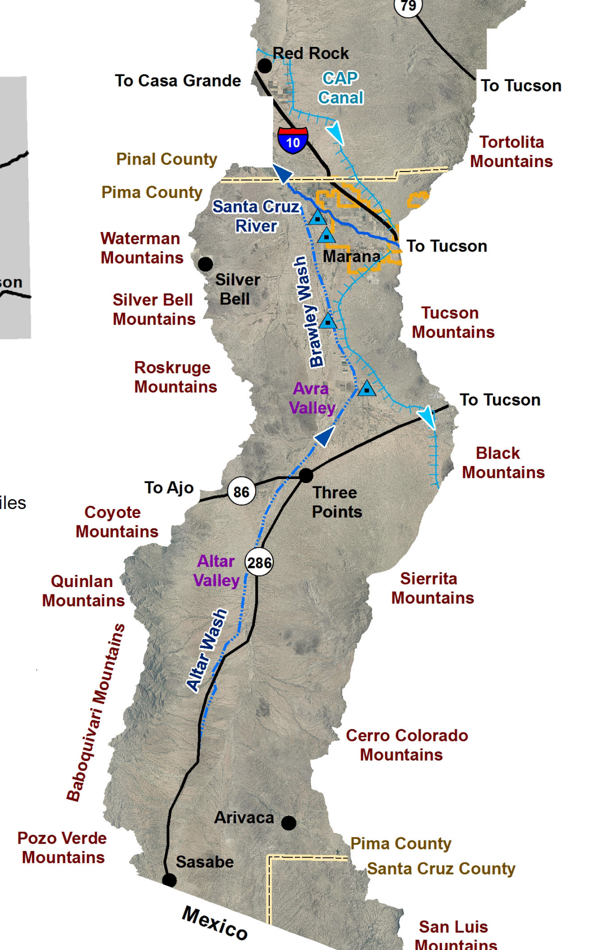
Introduction

A baseline groundwater quality study of the Avra Valley sub-basin of the Tucson Active Management Area (AMA) was conducted from 1998-2001 by the Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring Program. ADEQ carried out this task pursuant to Arizona Revised Statutes §49-225 that mandates monitoring waters of the state including aquifers. This fact sheet is a synopsis of ADEQ Open File Report 14-06.[1]

The Tucson AMA consists of two parallel sub-basins: Upper Santa Cruz Valley in the east and Avra Valley in the west. The Upper Santa Cruz Valley sub-basin and the adjacent Santa Cruz AMA were the subject of a joint ADEQ-U.S. Geological Survey groundwater quality study in 1998.[2] ADEQ subsequently sampled the Avra Valley sub-basin to complete the groundwater quality characterization of the Tucson AMA.

The Avra Valley sub-basin comprises 2,167 square miles within Pima, Pinal, and Santa Cruz counties. The long, thin basin is located west of Tucson and includes the Altar and Avra valleys, which are divided by State Route 86 (Map 1). Population centers are exurban areas of the Tucson metropolitan area, most of Town of Marana, and unincorporated communities including Arivaca, Three Points, Red Rock, and Sasabe. Much of the sub-basin, especially Altar Valley, is public land and sparsely populated (Figure 1). Land ownership consists of State Trust land (45 percent) and federal lands (26 percent) managed by the Bureau of Land Management, the U.S. Fish and Wildlife Service, the U.S. Forest Service, private land (22 percent), and tribal lands (7 percent) belonging the Tohono O'odham Nation and the Pascua Yaqui Tribe.





Map 1 – The Avra Valley sub-basin of the Tucson AMA.

(Map by Douglas Towne)

Hydrology

The sub-basin is drained by Altar Wash, which becomes Brawley Wash north of State Route 86, and eventually empties into the Santa Cruz River. All washes in the sub-basin are ephemeral.[3] Nine miles of perennial flow in the Santa Cruz River is the result of effluent discharge from wastewater treatment plants.[4] Groundwater was the only source of irrigation, public water, domestic, industrial, and stock uses. But since 1992, Colorado River water, delivered through the Central Arizona Project canal, has supplemented the water supply of the Tucson AMA.[5]

Figure 1 – Most groundwater development in Altar Valley is for livestock use such as at the Santa Margarita Ranch, owned for many years by the famed Ronstadt family. Baboquivari Mountain is framed by the gateway to the ranch.

Geologic sediments in the sub-basin have been divided into upper and lower alluvial units, and form the regional aquifer.[4] The upper unit is the primary water producer and is composed of streambed deposits of silt, sand, and gravel along Altar and Brawley washes and their major tributaries. The upper alluvial unit ranges in thickness from less than 100 feet to more than 1,000 feet.[3] The lower alluvial unit is thousands of feet thick and consists of gravel and conglomerates near the mountains. These deposits transition into clayey silts and mudstones along the sub-basin's central axis. Lower alluvial unit deposits reach an estimated thickness of 9,600 feet in Avra Valley and thin southward, with sediments in the Altar Valley decreasing from 4,800 feet near Three Points to 400 feet thick near Mexico.[4] There are limited amounts of groundwater in the surrounding mountains in thin alluvial deposits and in fractured or faulted bedrock.

Groundwater flow follows surface-water drainage, moving north and northwest from Mexico. Groundwater generally is found in unconfined conditions. There has been minimal groundwater development in Altar Valley, where depth-to-water ranges from 14 to 720 feet below land surface (bls). Most groundwater development has occurred within Avra Valley, where water levels range from 140 to 600 feet bls.[4]

Methods of Investigation

To characterize regional groundwater quality, samples were collected from 42 wells used for domestic, stock, irrigation, and public water supply purposes. Sampled wells generally did not have driller's logs but most were thought to tap the upper alluvial unit (Figure 2).[6] Inorganic samples were collected at each site while radionuclide (24), volatile organic compounds or VOCs (22), and radon (19) samples were collected at selected sites. Sampling protocol followed the ADEQ Quality Assurance Project Plan (see www.azdeq.gov/function/programs/lab/). 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.[7] Of the 42 sites sampled, 36 sites met all water quality standards, excluding the proposed radon standard (Map 2). Based on these results, groundwater in the sub-basin is generally suitable for drinking water use.

Figure 2 – The sample at the Avra Valley Air Park well was collected before any treatment. The well was one of the few in the study with an available driller's log that indicated the source of groundwater was the upper alluvial unit of the regional aquifer.

Public drinking water systems must meet health-based, water quality standards, called Primary Maximum Contaminant Levels (MCLs). These enforceable standards are based on a lifetime (70 years) consumption of two liters per day.[7] Primary MCLs were exceeded at 6 of the 42 wells (14 percent). Constituents exceeding Primary MCLs include arsenic (two sites), gross alpha (five sites), uranium (two sites), and one site each for nitrate and radium-226+228.

Public drinking water systems are encouraged by the SDWA to meet unenforceable, aesthetics-based water quality guidelines, called Secondary MCLs. Water exceeding Secondary MCLs may be unpleasant to drink and/or create unwanted cosmetic or laundry effects but is not considered a health concern.[7] Secondary MCLs were exceeded at 11 of the 42 wells (26 percent). Constituents above Secondary MCLs include total dissolved solids or TDS (seven sites), fluoride (five sites), manganese (two sites), iron and sulfate (one site).

Figure 3 – The sample collected by former ADEQ employee Wang Yu from a 740-foot-deep domestic well located north of Interstate 10 had the study's highest field-pH value and exceeded standards for arsenic, fluoride, and gross alpha.

Radon is a naturally occurring, intermediate breakdown product from the radioactive decay of uranium-238 to lead-206. Of the 19 sites sampled for radon, one exceeded the proposed 4,000 picocuries per liter (pCi/L) standard that would apply if Arizona establishes a multimedia program to address the health risks from radon in indoor air.[8] This sample had the highest radon concentration, 83,620 pCi/L ever collected by ADEQ's ambient groundwater monitoring program. Sixteen of the 19 sites (84 percent) exceeded the proposed 300 pCi/L standard that would apply if Arizona does not develop a multimedia program.[8]

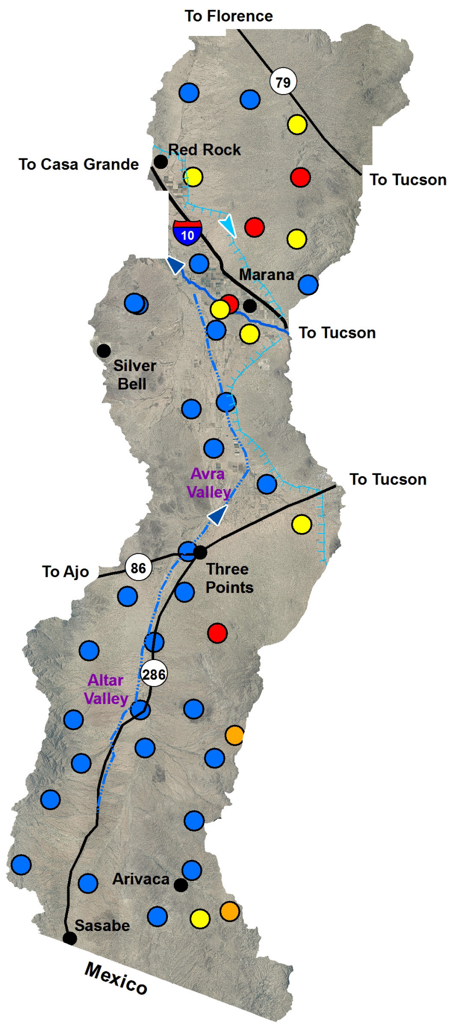
Of the 22 sites sampled for VOCs, there were no detections of any of the 32 compounds.

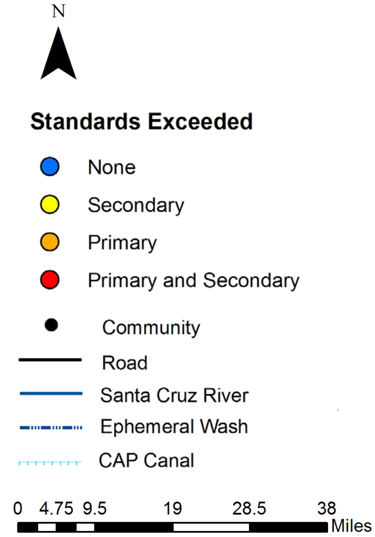
Groundwater Composition

Groundwater chemistry in the basin is predominantly calcium or mixed-bicarbonate chemistry (Figure 5). Other groundwater characteristics are summarized in Table 1.

Groundwater Patterns

Groundwater constituent concentrations significantly differed between valley areas and geology. Constituents such as temperature, specific conductivity (SC), TDS (Figure 6), sodium, potassium, chloride, sulfate, nitrate, and fluoride had significantly higher concentrations at sites in Avra Valley than at sites in Altar Valley (Kruskal-Wallis test, $p \leq 0.05$). Constituents such as hardness, turbidity, magnesium, bicarbonate (Figure 7), and radon had significantly greater concentrations in sites located in consolidated rock than in unconsolidated sediment; temperature and nitrate exhibited the opposite pattern (Kruskal-Wallis test, $p \leq 0.05$). Constituents including temperature, SC, TDS, turbidity, sodium, chloride, sulfate, nitrate (Figure 8) and radon had significantly different concentrations when grouped by valley/geologic areas (Kruskal-Wallis with Tukey test, $p \leq 0.05$).





Map 2 – Sample sites in the Avra Valley sub-basin are color-coded according to their water quality status. Based on these water quality results, groundwater is generally suitable for drinking water use.

(Map by Douglas Towne)

Discussion

ADEQ sampled 42 wells to characterize water quality in the Avra Valley sub-basin of the Tucson AMA. Constituents above health-based, water quality standards in the ADEQ study include arsenic, nitrate, and radionuclides (gross alpha, uranium, and radium-226+228). These are three of the four constituents that most commonly exceed health-based water quality standards in Arizona, and appear to be naturally occurring with the possible exception of nitrate.[9]

The most common health-based exceedance was for radionuclides, despite these samples being collected at only 24 of 42 sample sites. Of the five wells exceeding Primary MCLs, only two were located in granitic geology, which is often associated with elevated

Table 1. Groundwater characteristics of Avra Valley sub-basin samples

pH-field	
Slightly Alkaline (> 7 su)	42
Moderately Alkaline (>8 su)	3
TDS	
Fresh (below 999 mg/L)	42
Slightly Saline (1,000 - 3,000 mg/L)	0
Hardness	
Soft (< 75 mg/L)	2
Moderately Hard (76-150 mg/L)	21
Hard (151-300 mg/L)	13
Very Hard (301-600 mg/L)	5
Extremely Hard (> 600 mg/L)	1
Nitrate[7]	
Natural Background (< 0.2 mg/L)	4
May or May Not be from Human Influence (0.2 – 3.0 mg/L)	23
May Result from Human Influence (3.0 – 10 mg/L)	14
Probably Results from Human Influence (> 10 mg/L)	1
Trace Elements	
Detected at less than 25 percent of sites	aluminum, antimony, arsenic, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and thallium
Detected at more than 25 percent of sites	barium, boron, fluoride, and zinc

radionuclide concentrations in groundwater.[10] None of the five wells were located in proximity to active or inactive mines, which can elevate concentrations because of increased rock surface exposure.[10] The only commonality with radionuclide exceedances was that all the wells were located on the east side of the sub-basin.

Arsenic was exceeded in two wells, one near Marana (Figure 3) and the other in the Sierrita Mountains in Altar Valley. The former sample also exceeded aesthetics-based standards for fluoride, and had the highest pH value and the softest water in the study. These four constituents are frequently significantly correlated in Arizona.[9] Arsenic concentrations are affected by reactions with hydroxyl ions and are influenced by factors such as aquifer residence time, an oxidizing environment, and lithology.[11]

Figure 4 – An irrigated field of corn is almost ready for harvest in the late spring near the Town of Marana. Most irrigated agriculture in the Avra Valley sub-basin is located in this area, which is becoming a bedroom community of Tucson. Saguaro National Monument West and the Tucson Mountains are in the distance.

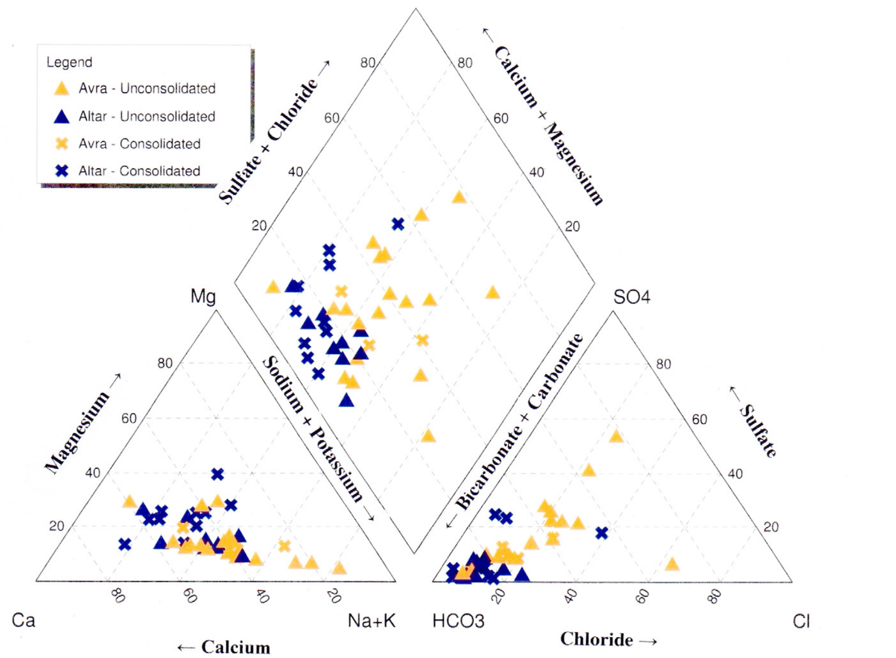


Figure 5 – Samples collected in the sub-basin predominantly have a calcium-bicarbonate or mixed-bicarbonate chemistry, which is reflective of younger groundwater.[11] The most variable chemistry was in samples collected from unconsolidated sediments in Avra Valley, probably as a result of having the most development, particularly irrigation, in that portion of the sub-basin.

Nitrate exceeded health-based, water quality standards in just one sample and only 17 percent of wells exceeded 5 mg/L or half the Primary MCL. Still, five wells sampled near Marana (Figure 4) had elevated nitrate concentrations. Likely sources of nitrate include irrigation recharge through the unsaturated vadose zone or from vertical leakage along well casings, and treated sewage effluent released into the Santa Cruz River by wastewater treatment plants since 1969.[12]

Other wells with elevated nitrate concentrations likely have different sources. The high density of residential septic systems probably contributes to the 6.6 mg/L nitrate concentration near the community of Three Points.[12] More research in the Sonoran desert is needed, however, to better understand the relative contributions of nitrate from various sources including naturally occurring soil organic matter and anthropomorphic activities.

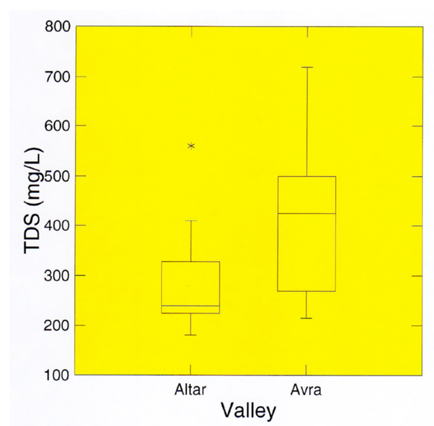


Figure 6 – Samples from sites in Avra Valley have significantly higher TDS concentrations than samples from sites in Altar Valley (Kruskal-Wallis, $p \leq 0.01$). TDS concentrations typically increase downgradient.[11] This characteristic, along with the undeveloped nature of Altar Valley, likely contribute to this pattern.

Many constituents including TDS, some major ions, nitrate, and fluoride significantly increase downgradient from Altar Valley to Avra Valley. These patterns are likely the result of natural increases along the groundwater flowpath. Anthropomorphic impacts, particularly irrigated agriculture in northern Avra Valley, also contribute to these patterns.[11,12]

Based on results from this ADEQ study, groundwater in the Avra Valley sub-basin is generally suitable for drinking water uses. This is a conclusion also reached by previous groundwater quality studies.[3] This ADEQ study, however, sampled for constituents such as radionuclides that had not been collected during previous baseline studies, and identified new water quality issues in the sub-basin. Future groundwater quality studies in the Avra Valley sub-basin should better characterize radionuclide concentrations.

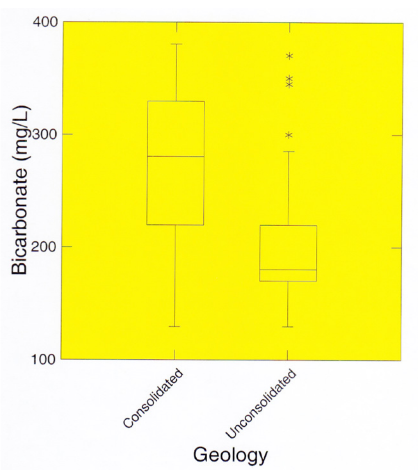


Figure 7 – Samples collected from sites in consolidated rock have significantly higher bicarbonate concentrations than sample sites collected from unconsolidated sediments (Kruskal-Wallis, $p \leq 0.01$). Elevated bicarbonate in ground water is often associated with recently recharged water that has dissolved carbon dioxide gas. The carbon dioxide combines with water to form carbonic acid, which then dissociates to hydrogen and bicarbonate ions.[12]

For More Information Contact:
Douglas C. Towne
Hydrologist, ADEQ Monitoring Unit
1110 W. Washington St. #5330D
Phoenix, AZ 85007
email: dct@azdeq.gov
www.azdeq.gov/environ/water/assessment/ambient.html#studies
Publication Number: FS-14-11

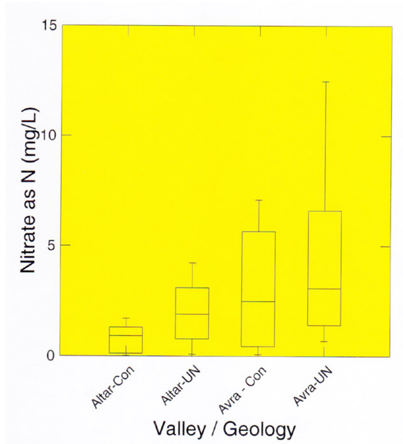


Figure 8 – Samples collected from sites in unconsolidated sediment in Avra Valley have significantly higher nitrate concentrations than samples collected from sites in consolidated rock in Altar Valley (Kruskal-Wallis, $p \leq 0.05$). There are no significant differences with nitrate concentrations in consolidated rock in Avra Valley or unconsolidated sediments in Altar Valley. The elevated nitrate concentrations in the Avra Valley basin fill are likely linked to irrigation recharge, treated sewage effluent released into the Santa Cruz River, and improperly operating and/or high densities of septic systems.[12]

References Cited

[1] *Towne, D.C., 2014, Ambient groundwater quality of the Avra Valley sub-basin: A 1998 - 2001 baseline study: Arizona Department of Environmental Quality Open File Report 14-06, 65 p.*

[2] *Coes, A.L., Gellenbeck, D.J., Towne, D.C., and Frreark, M.C., 1998, Ground-Water quality in the Upper Santa Cruz basin, Arizona, 1998: U.S. Geological Survey Water Resources Investigations Report 00-4117, 55 p.*

[3] *Reeter, R.W. and Cady, C.V., 1982, Maps showing ground-water conditions in the Avra/Altar Valley area, Pima and Santa Cruz counties, Arizona—1981; Arizona Department of Water Resources Hydrologic Map Series Report Number 7, 2 sheets, scale, 1:250,000.*

[4] *Arizona Department of Water Resources, 1994, Arizona Water Resources Assessment – Volume II, Hydrologic Summary, Hydrology Division, pp. 174-187.*

[5] *Bloomquest, William, Schlager, Edella, and Heikkila, Tanya, 2004,* Common Waters, Diverging Streams: Linking Institutions and Water Management in Arizona, California, and Colorado: *Washington D.C, Resources for the Future, 210 p.*

[6] *Arizona Department of Water Resources Water Atlas website, 2014, http://www.azwater.gov/AzDWR/GeneralServices/Imaging/ accessed 6/26/14.*

[7] *U.S. Environmental Protection Agency website, www.epa.gov/waterscience/criteria/humanhealth/, accessed 3/05/10.*

[8] *U.S. Environmental Protection Agency website, http://water.epa.gov/lawsregs/rulesregs/sdwa/radon/regulations.cfm, accessed 6/18/14.*

[9] *Towne, D.C. and Jones, J., 2011, Groundwater quality in Arizona: A 15-year overview of the ADEQ ambient groundwater quality program (1995-2009): Arizona Department of Environmental Quality Open File Report 11-04, 44 p.*

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

[11] *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, 94 p.*

[12] *Conner, L.L., 1986, Geochemistry of ground water in Avra Valley, Pima County, Arizona: Master's thesis, University of Arizona, 81 p.*