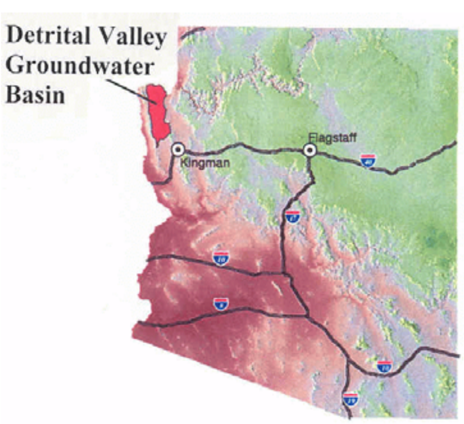
Ambient Groundwater Quality of the Detrital Valley Basin: An ADEQ 2002 Baseline Study

Figure 1. In a bit of hydrologic serendipity, during the course of ADEQ's study of the Detrital Valley basin, Lake Mead receeded to levels low enough to expose Monkey Cove Spring for the first time since July 1969. The spring flowed at an amazing 1,200 gallons per minute in 1964.

I. Introduction

The Detrital Valley Groundwater Basin (DET), traversed by U.S. Highway 93, is roughly located between the city of Kingman and Hoover Dam on the Colorado River in northwestern Arizona (**Map 1**). Although lightly populated with retirement and recreation-oriented communities, the recent decision to construct a Hoover Dam bypass route for U.S. Highway 93 will likely bring new residents to the area who commute to Las Vegas for employment. From a hydrology perspective, the basin is most noteworthy as having Lake Mead along its northern boundary (**Figure 1**). This factsheet reports upon the results of groundwater quality investigations in the DET and is a summary of the more extensive report produced by the Arizona Department of Environmental Quality (ADEQ).[1]



Map 1. Although the name "Detrital Valley" may be unfamiliar to most Arizona residents, many people will have actually driven through the basin while en route to Las Vegas, Nevada.

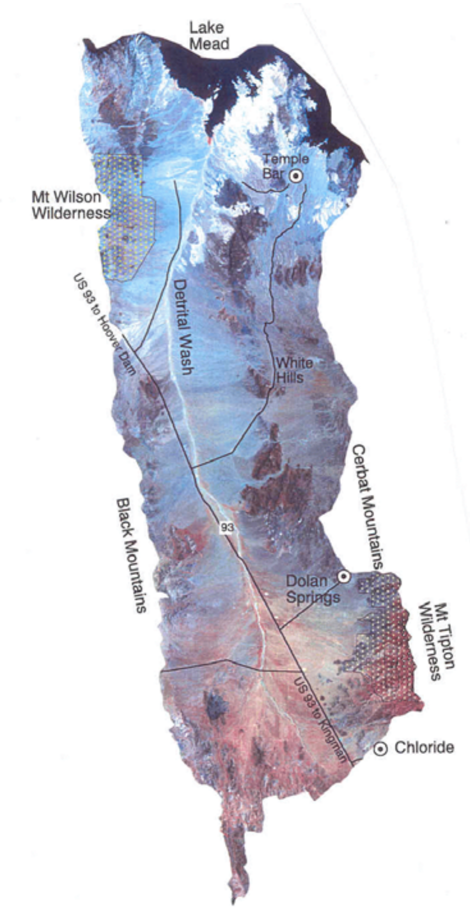
II. Background

The DET is approximately 50 miles long (north to south) and 15 miles wide (east to west), covering 875 square miles in Mohave County.[2] The basin is bounded by the Black Mountains to the west, Lake Mead to the north, the White Hills and Cerbat Mountains to the east, and a low topographic rise to the south near Grasshopper Junction, a historic roadside enterprise (**Map 2**). Upland elevations in the DET rise to 6,900 feet at Mt. Tipton in the Cerbat Mountains and to 5,456 feet at Mt. Perkins in the Black Mountains. In the center of the basin is Detrital Valley, whose floor slopes downward from 3,400 feet at the southern boundary to around 1,225 feet where Detrital Wash drains into the normal pool elevation of Lake Mead. Dolan Springs is the largest community in the basin. In the DET, 27 percent of land is managed by the National Park Service as part of the Lake Mead National Recreational Area. The remainder is managed by the Bureau of Land Management (42 percent) and State Trust land (9 percent) or consists of private lands (22 percent).

III. Hydrology

Groundwater from the *alluvial aquifer* underneath Detrital Valley is the principle water source in the basin and has the ability to supply up to 150 gallons per minute (gpm).[3] However, depths to groundwater, approaching 800 feet below land surface (bls) in the valley, make tapping this aquifer for domestic use an expensive proposition.[2]

"Groundwater in the Detrital Wash Basin is often suitable for domestic use though health-based water quality exceedances do occur throughout the basin."



Map 2. The aridity and small population of the Detrital Valley basin is shown in this June 1983 infrared satellite image. Lake Mead, formed by Hoover Dam on the Colorado River, forms the northern boundary of the basin.

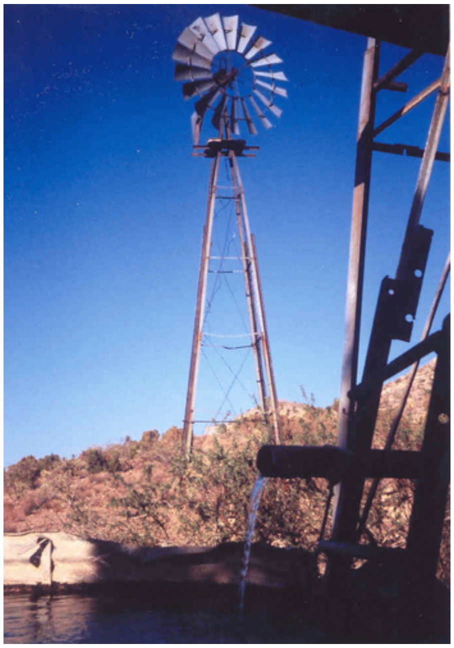


Figure 2. Windmills, such as "Twin Mills"in the Black Mountains are used by ranchers for stock water. Groundwater is found at shallow levels near the mountains and historically these have been important sources of water in the Detrital Valley basin.

Limited amounts of groundwater are also found in mountain *hardrock* areas where the bedrock is sufficiently faulted and fractured and/or where thin deposits of alluvium occur. Although usually yielding less than 50 gpm in springs and shallow wells (**Figure 2**), historically this has been an important water source because of its greater accessibility.[2]

Groundwater is also found in the *Lake Mead aquifer* located in northern areas adjacent to the reservoir created with the completion of Hoover Dam in 1935 which impounded the Colorado River. This aquifer consists largely of recharged water from Lake Mead, which has saturated the previously dry alluvium and sedimentary rocks above the level of the Colorado River.

Groundwater movement in the DET is from the surrounding mountains toward the Detrital Wash and north toward Lake Mead.[2] A potential groundwater drainage divide has been reported in the northern part of the basin, which may be related to the effects of a salt body in the area which tends to impede groundwater flow to the north.[3]

"Groundwater in the alluvial aquifer appears to be very old, judging from isotopes and a sodium-mixed chemistry that contains trace elements such as arsenic and chromium."

Essentially all streamflow in the DET is ephemeral, generated by precipitation in the surrounding mountains. Surface flow rarely reaches the central parts of the valley because of evapotranspiration and infiltration on alluvial fans, areas which provide most of the groundwater recharge.[3] The majority of the basin is drained by Detrital Wash, an ephemeral watercourse that debouches into Lake Mead at Bonelli Bay west of the resort community of Temple Bar (**Figure 3**).

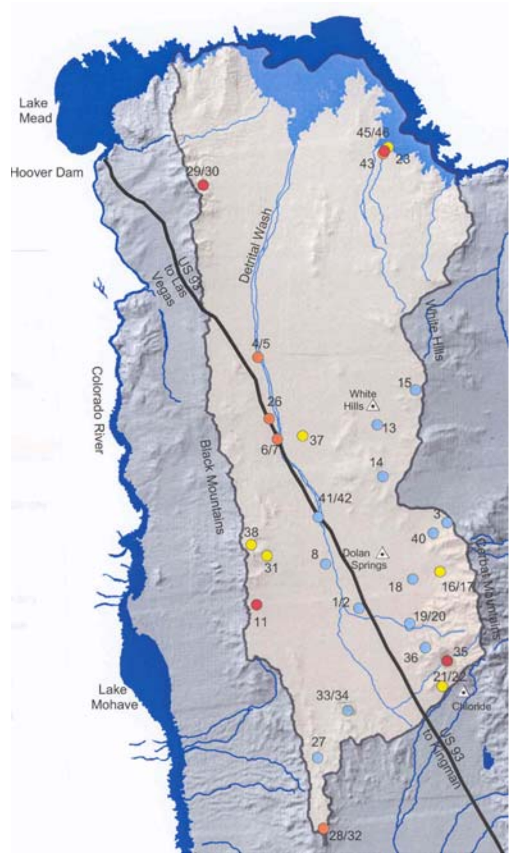
IV. Methods of Investigation

This study was conducted by the ADEQ Ambient Groundwater Monitoring Program, as authorized by the legislative mandate in Arizona Revised Statutes §49-225. To characterize regional groundwater quality, 28 sites (21 wells and 7 springs) were sampled. Most sample sites were located in the southern part of the basin as few sites were available for sampling in the northern portion of the DET.

Samples were collected at all sites for inorganic constituents and isotopes of hydrogen and oxygen. At selected sites, samples were also collected for radiochemistry (11 sites) and radon gas (11 sites) analyses. In addition, isotope samples were collected from Lake Mead and Detrital Wash.

Sampling protocol followed the *ADEQ Quality Assurance Project Plan*. Based on quality control data, the effects of sampling equipment and procedures were not considered significant.

Figure 3. The basin is largely drained by Detrital Wash, a wide, shallow, typically dry watercourse. Those unfamiliar with the intensity of desert thunderstorms find it difficult to believe that this dusty wash can quickly become a full-blown river.



Map 3. The 28 Detrital Valley basin sample sites are color-coded according to water quality standard status. Health-based water quality exceedances are in red and orange, aesthetics-based water quality guidelines are in red and yellow, and blue sites have no exceedances.

V. Water Quality Sampling Results

The collected groundwater quality data were compared with Environmental Protection Agency (EPA) Safe Drinking Water (SDW) water quality standards.

Primary Maximum Contaminant Levels (MCLs) are enforceable, health-based water quality standards that public systems must meet when supplying water to their customers. Primary MCLs are not acute standards but based on a lifetime daily consumption of two liters of water. Of the 28 sites sampled, 9 had constituent concentrations exceeding a Primary MCL (**Map 3**). At three sites each, arsenic (under standards effective in 2006), gross alpha, and nitrate concentrations each exceeded Primary MCLs.

EPA SDW Secondary MCLs are unenforceable, aesthetics-based water quality guidelines for public water systems. Water with Secondary MCL exceedances may be unpleasant to drink and/or create unwanted cosmetic or laundry effects but is not considered a health concern. Of the 28 sites sampled, 11 had constituent concentrations exceeding a Secondary MCL (**Map 3**). Constituents above Secondary MCLs

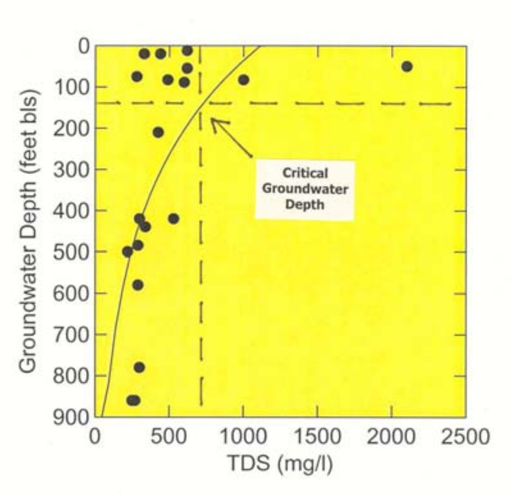


Figure 4. Most groundwater quality constituents, including TDS, decreased significantly with increasing groundwater depth bls (regression analysis, p # 0.05). Well location strongly influences this relationship since concentrations are relatively constant in deep alluvial wells but may greatly vary in hardrock wells with shallow depths.

included total dissolved solids or TDS (11 sites), sulfate (7 sites), manganese (3 sites), fluoride and iron (2 sites apiece), and chloride (1 site).

VI. Water Quality Exceedances

The nine sites having constituents exceeding health-based water quality standards appear to be the result of by both natural and humans sources.

The elevated gross alpha concentrations at two sites appear to be naturally occurring because of the surrounding granitic geology. Granite is commonly associated with elevated radiochemistry concentrations in groundwater. These constituents may be further elevated by nearby hardrock mining which exposes more rock surface.

Of the three sites with elevated arsenic concentrations (all of which barely exceed the standard effective in 2006), two are deep alluvial wells which often have elevated concentrations of trace elements such as arsenic.[4]

The nitrate exceedances at two shallow windmills may be the result of livestock impacts at nearby corrals. No other nitrate sources were evident at these remote sites. The other nitrate exceedance occurred at a deep well in the *alluvial aquifer* and may be the result of natural soil organic matter.

"Limited groundwater is normally available in hardrock mountain areas but historically it has been an important water source in the basin because of its accessibility as spring flow or from windmills pumping at shallow depths."

"The Lake Mead aquifer was largely created by recharge from impounded Colorado River water. The aquifer's TDS, sulfate, and arsenic concentrations are similar to the lake water and historical data indicates it's still evolving."

VII. Groundwater Composition

Groundwater in the DET is generally *slightly alkaline* (pH > 7 standard units), *fresh* (TDS < 1000 milligrams per liter or mg/L), and *moderately* to *very hard*. The groundwater is most commonly of a *mixed-mixed* chemistry, though it varies widely in the basin.

Boron, chromium, fluoride, and zinc were the only trace elements detected at more than 25 percent of sample sites. Others such as antimony, arsenic, barium, beryllium, cadmium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and thallium were rarely, if ever, detected.

Many significant correlations were found among concentrations of water quality constituents. TDS was positively correlated with major ions (calcium, magnesium, sodium, potassium, chloride, and sulfate), hardness, turbidity, and boron (Pearson Correlation Coefficient test, p # 0.05). TDS concentrations were best predicted among major ions by calcium concentrations (multiple regression analysis, p # 0.01).

Many groundwater quality constituent concentrations varied significantly with groundwater depth. Most constituents, including TDS (**Figure 4**), bicarbonate, calcium, magnesium, hardness, chloride, and sulfate decreased with groundwater depth. In contrast, temperature, pH-field, nitrate, and chromium increased with groundwater depth (regression analysis, p # 0.05).

VIII. Groundwater Quality Patterns

Constituent concentrations were compared statistically among aquifers. Bicarbonate (**Figure 6**), calcium and hardness were higher in *hardrock* than in the *alluvial aquifer* (ANOVA test in conjunction with Tukey test, p # 0.05).

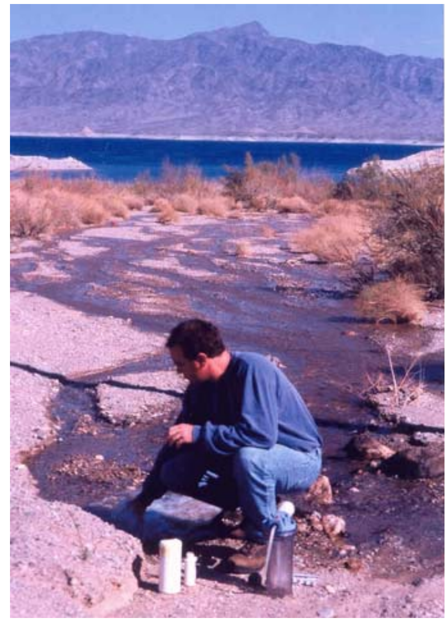


Figure 5. Wells near the community of Temple Bar are recharged by Colorado River water impounded in Lake Mead. ADEQ's Doug McCarty is sampling one such well with Nevada's Bonelli Peak rising in the distance.

Elevated concentrations of these constituents are commonly found in groundwater recharge areas.[4] In contrast, temperature, nitrate, and chromium were higher in the *alluvial aquifer* than in *hardrock*. Temperature differences may be attributed to greater groundwater depths in the alluvium since temperature typically increases 3 degrees Celsius with every 100 meters in depth. Chromium typically occurs in Arizona in old groundwater that receives little recharge, conditions that characterize the *alluvial aquifer*.[4] Higher nitrate levels in deep alluvial wells are probably result from natural soil organic matter.

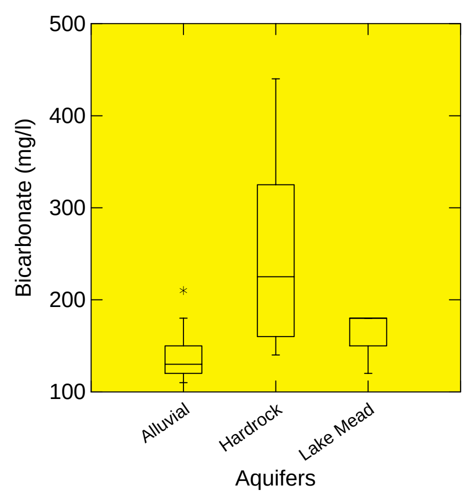


Figure 6. Bicarbonate concentrations are greater in hardrock than the alluvial aquifer with Lake Mead aquifer concentrations not significantly different from either (ANOVA test in conjuction with Tukey test, p # 0.05).

Figure 6. The productivity of the alluvial aquifer is apparent in this photo. The White Hills Well was later deepened beneath a gypsum bed about 1,040 feet below land surface that intersected a deeper aquifer that dramatically increased its TDS, sulfate, and calcium concentrations.

Groundwater Isotope Investigation

Stable isotopes of oxygen (^{18}O) and hydrogen (deuterium or D) were collected at each DET sample site as well as from Lake Mead and Detrital Wash. This data was compared to the standard reference water or Global Meteoric Water Line, which is based upon world-wide precipitation not exposed to evaporation. The DET data form a *Local Meteoric Water Line* whose slope of 5.15 is within the range of slopes (3 to 6) normally found in arid environments.[4]

The most *depleted*, or isotopically lightest, waters were collected from Lake Mead and nearby groundwater sites and consists of recent recharge from the Colorado River.[4] Further up the evaporation line is a tight cluster of 16 *depleted* waters consisting mainly of deep alluvial wells and springs. This cluster may represent the oldest water in the basin that was recharged during a cooler time period than the present. Stretching from this cluster to the most *enriched* water (runoff collected after a storm in Detrital Wash) is an evaporation line of waters from 10 typically shallow wells that may be a combination of older water and recharge from recent precipitation. Most of these wells are located in or near *hardrock* areas of the basin.

The *Lake Mead aquifer* (**Figure 5**) had higher levels of oxygen and hydrogen isotopes, sodium, sulfate, and boron.. These patterns are influenced by the constituent levels in the Colorado River water that recharges the aquifer.

IX. Study Conclusions

Limited groundwater is available in mountain *hardrock* but historically it has been an important water source in the DET because of its accessibility as spring flow (**Figure 7**) or from windmills pumping from shallow depths. Many hardrock sites have a *calcium-bicarbonate* chemistry, which is indicative of recharge areas. This conclusion is supported by isotope analyses. Hardrock sites also tend to be higher in salinity which may be due to recharge water traveling considerable distances through fractured bedrock, picking up dissolved salts and minerals in these weathered zones.[3]

In contrast, the *alluvial aquifer* located beneath Detrital Valley is capable of producing abundant amounts of water. Often located at great depths, however, it is expensive to tap. Groundwater in this aquifer appears to be older, based upon isotope analysis, a largely *mixed-mixed* water chemistry, and the levels of trace elements such as arsenic and chromium.[4] Only a few wells in this aquifer appear to receive recent recharge. This recharge originates from percolating flow in the coarse alluvium beneath stream beds in the upper portions of alluvial fans, a pathway with less opportunity to dissolve and transport salts and minerals.[3]

Finally, the *Lake Mead aquifer* was created in the northern part of the basin by recharge from impounded Colorado River water. Limited historical data suggest its water quality is still evolving and its elevated TDS, sulfate, and arsenic concentrations are similar to those found in Lake Mead.

Most groundwater in the DET meets drinking water standards. The health-based water quality exceedances that did occur were widely scattered. Therefore, ADEQ suggests that well owners in the basin periodically have their groundwater analyzed by certified laboratories. A list of such laboratories may be obtained from the state's Environmental Laboratory Licensure Section at (602) 255-3454.

---Douglas Towne
Maps by Larry W. Stephenson
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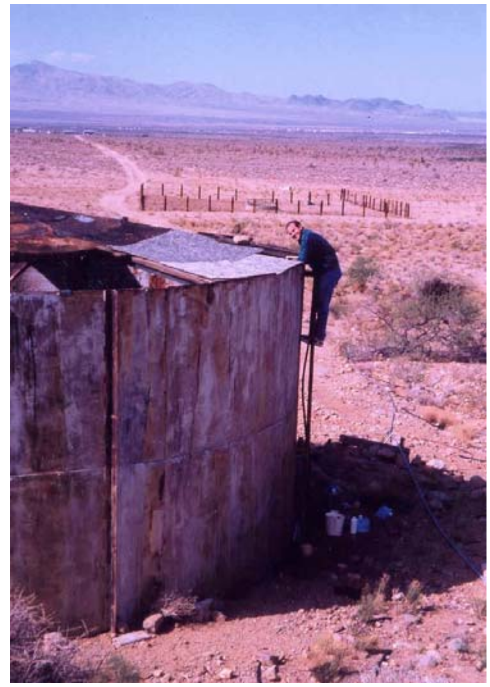

Figure 7. Doug McCarty of ADEQ demonstrates the agility occasionally required to collect a groundwater sample. Quail Spring is piped a short distance before discharging into the top of this water tank.

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