ADEQ
Arizona Department of Environmental Quality
Janet Napolitano, Governor
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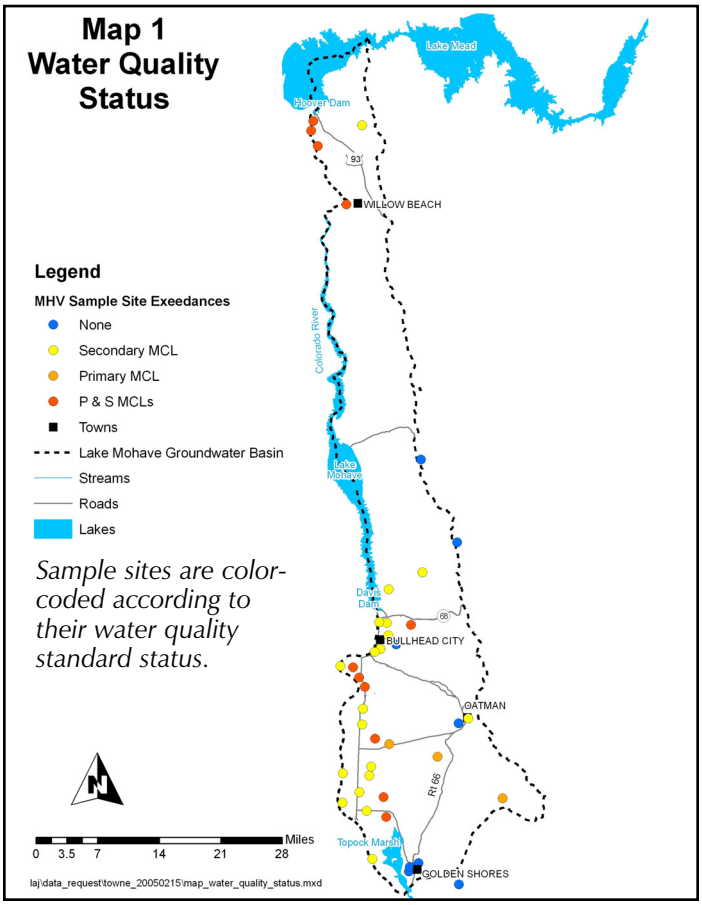
FACT SHEET

Ambient Groundwater Quality of the Lake Mohave Basin: A 2003 Baseline Study - October 2005

INTRODUCTION

Containing approximately 1,050 square miles, the Lake Mohave groundwater basin (MHV) stretches along the Colorado River from Hoover Dam south to the community of Topock in northwestern Arizona.[1] The Black Mountains form the eastern boundary of this long, thin basin (Map 1). Precipitation averages from 6 to 10 inches annually depending on elevation.[2]

Two major storage dams are located on the Colorado River along the MHV. To the north is Hoover Dam, completed in 1936, which forms Lake Mead. To the west is Davis Dam (Figure 1), completed in 1950, which forms the much smaller Lake Mohave.[1] Davis Dam was constructed along a granite outcrop that divides the MHV into North and South basins.[1] However, the South basin's southern boundary near Topock (Figure 2) is a surface water divide that does not impede groundwater flow with the neighboring Sacramento Valley groundwater basin.



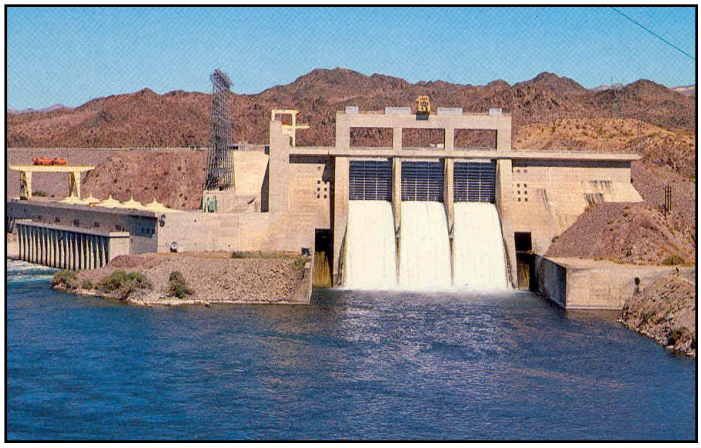


Figure 1- *Located 67 miles downstream from Hoover Dam, Davis Dam is an earthfill impoundment finished in 1950 that forms Lake Mohave, a long, narrow reservoir with a 1.8 million acre-feet capacity.*

The North basin consists largely of rugged topography and undeveloped public lands that are part of the Lake Mead National Recreation area. The South basin consists of public uplands managed by the Bureau of Land Management and a piedmont descending to Mohave Valley, which is a combination of private, State Trust, and Fort Mohave Indian Reservation lands. This basin includes scattered subdivisions, the Mohave Valley Irrigation and Drainage District, and the recreation, retirement, and service communities of Bullhead City, Golden Shores, Oatman, and Topock. Across the Colorado River from Bullhead City is the resort community of Laughlin, Nevada.

This 2003 Arizona Department of Environmental Quality (ADEQ) baseline groundwater quality study of the MHV was conducted to more comprehensively examine the basin than was possible during four previous ADEQ groundwater studies in 1987-89, 1994, 1996, and 1997. For these studies, over 150 wells were sampled to investigate links between septic systems and nitrate concentrations.

HYDROLOGY

The MHV is characterized by three distinct geologic features: consolidated bedrock, piedmont alluvial deposits, and floodplain deposits.[3] The rugged Black Mountains rise abruptly from the piedmont slopes (or

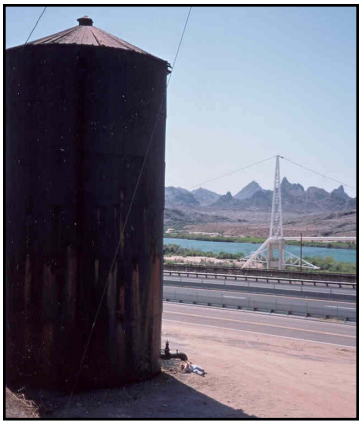


Figure 2 - *The Santa Fe Railroad's historic water tank marks the MHV's southern extent. To the south is Interstate 40, a natural gas pipeline utilizing the "Old Trails Arch Bridge" which carried Route 66 motorists from 1916 until 1947, the Colorado River, and sharp peaks called "The Needles of the Colorado River" after which Needles, California was named in 1883.*

the Colorado River in the bedrock narrows) and consist mainly of volcanic rocks interspersed with granite and sedimentary rocks and, less frequently, metamorphic and basaltic rocks. Alluvial areas occur only along the river immediately north and south of Davis Dam in Cottonwood Valley and Mohave Valley, respectively. Overlying tilted bedrock is the fanglomerate that represents deposited alluvial fans, the Bouse Formation which is a marine-brackish water unit, and alluvium deposited by the Colorado River.[3] Bounded by a terrace, the floodplain consists of younger alluvium and older alluvium.[3]

Until 1936, the Colorado River annually inundated much of the floodplain each spring. In the North basin, since the filling of Lake Mohave, water has moved outward saturating the adjacent unconsolidated rock units.[1] In the South basin, the Colorado River loses water throughout the Mohave Valley except near Topock where tributary inflow associated with the Sacramento Wash creates groundwater discharge.[3]

Locally, groundwater flows away from the Colorado River in an east-southeast direction while regionally following the axis of the river in a south-southwest direction. Water levels average 10 feet below land surface in the floodplain and, on the alluvial slopes, are largely governed by the height of the land surface.[3]

METHODS OF INVESTIGATION

This study was conducted by the ADEQ's Ambient Groundwater Monitoring Program, as authorized by legislative mandate in Arizona Revised Statutes §49-225. To characterize regional groundwater quality, 43 groundwater sites (36 wells and 7 springs) were sampled for inorganic constituents and isotopes of oxygen and hydrogen. At selected sites, samples were also collected for radon (31 sites), perchlorate (18 sites), and radiochemistry (15 sites) analyses.

Sampling protocol followed the ADEQ Quality Assurance Project Plan. Based on quality control data, the effects of sampling equipment and procedures were not found to be significant based on seven quality assurance/quality control tests.

WATER QUALITY SAMPLING RESULTS

The groundwater sample results were compared with Environmental Protection Agency (EPA) Safe Drinking Water (SDW) water quality standards. Of the 43 sites sampled, only 9 (21 percent) met all federal water quality standards and guidelines (Map 1). Perchlorate was not detected at any sample site.

EPA SDW Primary Maximum Contaminant Levels (MCLs) are enforceable, health-based water quality standards that public water systems must meet when supplying water to their customers. Primary MCLs are based on a daily lifetime consumption of two liters of water. Of the 43 sites sampled, 15 (35 percent) had constituent concentrations exceeding a health-based standard. Constituents exceeding Primary MCLs were arsenic (2 sites under the current standard, 14 sites under the standard effective in 2006), fluoride (1 site) and nitrate (3 sites).

EPA SDW Secondary MCLs are unenforceable, aesthetics-based water quality guidelines for public water systems. Water with Secondary MCLs may be unpleasant to drink and/or create unwanted cosmetic or laundry effects but is not considered a health concern. Of the 43 sites sampled, 31 (72 percent) had constituent concentrations exceeding an aesthetic-based standard. Constituents exceeding Secondary MCLs were chloride (19 sites), fluoride (8 sites), iron (7 sites), manganese (13 sites), sulfate (24 sites), and total dissolved solids (TDS) (30 sites).

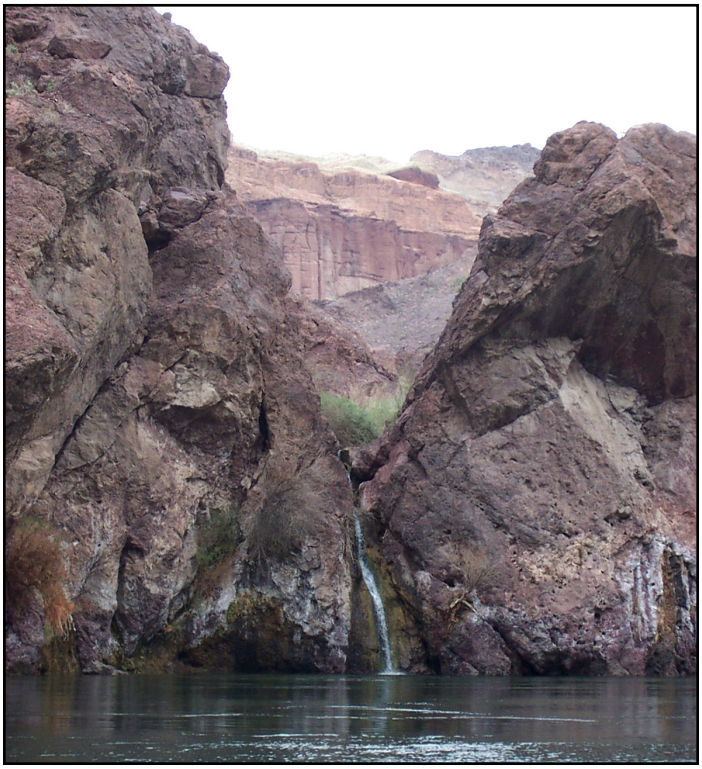


Figure 3 - *Probably the only perennial waterfall in the basin, Sugarloaf Spring pours into the Colorado River about a mile south of Hoover Dam. The spring existed previous to the dam.*

NORTH BASIN

Only 10 sites were able to be sampled in this basin, 4 of which were thermal springs along the Colorado River just downgradient from Hoover Dam (Figure 3). Based on hydrogen and oxygen isotope values, four sites were recharged by local precipitation and the remaining six sites were of an indeterminate recharge source.[2] Sites other than the thermal springs generally met health-based water quality standards.

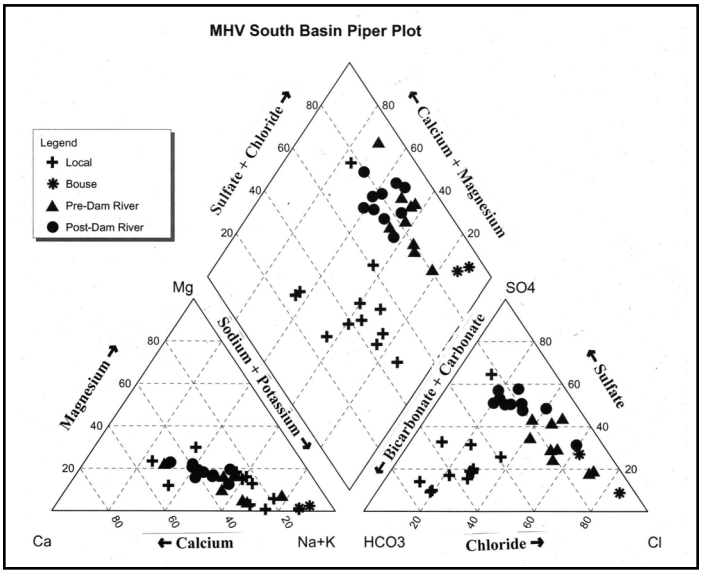


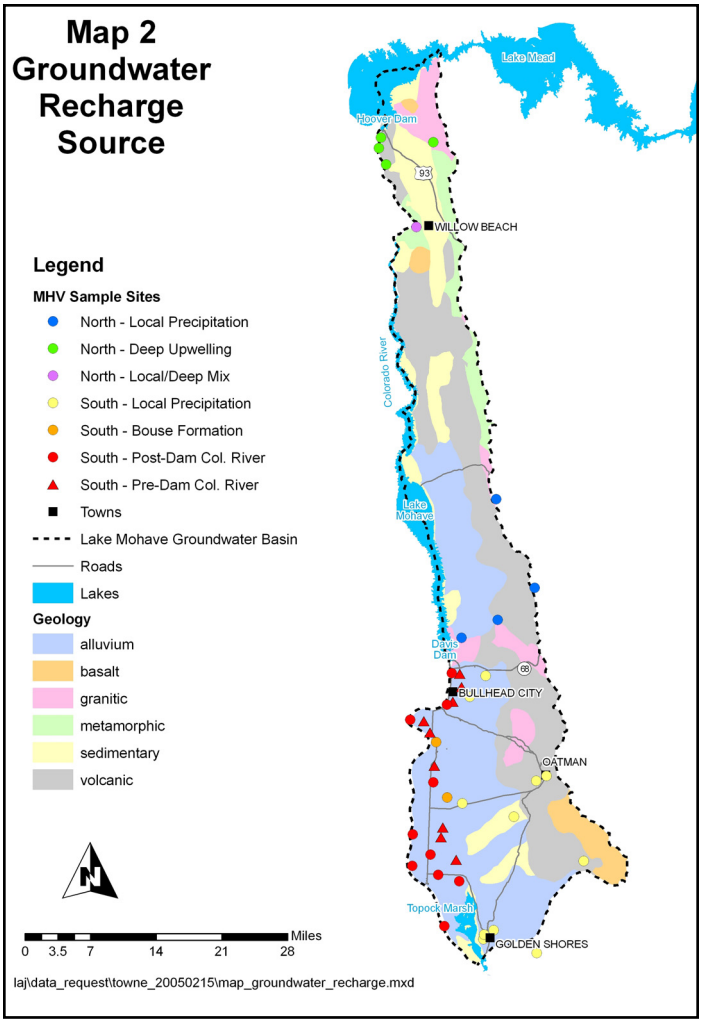
Figure 4 - *The South basin piper diagram shows sample sites are predominantly clustered by recharge source: Bouse Formation is strongly sodium-chloride; local recharge is sodium-bicarbonate and Colorado River recharge is calcium/sodium-sulfate.*

SOUTH BASIN

The 33 groundwater sites sampled in this basin, based on hydrogen and oxygen isotope values (Figure 4), appeared to consist of 9 sites recharged by pre-dam Colorado River water, 10 sites recharged by post-dam Colorado River water, 12 sites recharged by local precipitation (Figure 5), and 2 sites whose source is the marine-related Bouse Formation (Map 2).[2, 4] Water chemistry supports these source-water categorizations as Colorado River recharge is higher in chloride and sulfate, local recharge is higher in bicarbonate, and the Bouse Formation is strongly sodium-chloride (Figure 6).[3]

Five general groundwater quality patterns were found between recharge sources (ANOVA with Tukey test, $p \leq 0.05$). TDS, sodium, chloride, and sulfate were higher at sites recharged by pre/post-dam Colorado River water or tapping the Bouse Formation than at sites recharged by local precipitation. Similarly, calcium, magnesium, and hardness (Figure 7) were higher at sites recharged by pre/post-dam Colorado River water than at sites recharged by local precipitation.

Arsenic, boron and fluoride were higher at sites



Map 2 - *On a geology map, sample sites are color and shape-coded according to their recharge source.*

tapping the Bouse Formation than at sites recharged by pre/post-dam Colorado River water or local precipitation. Temperature, pH, nitrate and chromium were higher at sites recharged by local precipitation than from pre/post-dam Colorado River water. Total kjeldahl nitrogen, ammonia, total phosphorus, iron, and manganese were higher at sites recharged by post-dam Colorado River water than at sites recharged by local precipitation.

Figure 5 - *With Laughlin, Nevada in the distance, Doug Wall of North Mohave Water Company assists ADEQ's Elizabeth Boettcher in sampling Well #2. The water source for this 1,300 foot well is recharged local precipitation.*

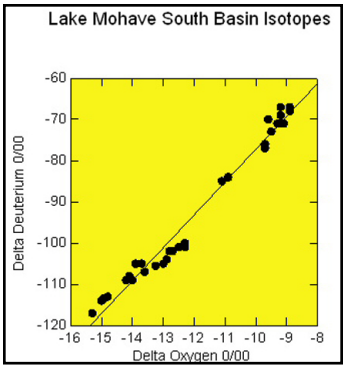


Figure 6 - *Four clusters of isotope values representing different water sources in the South basin were found to be significantly different (ANOVA with Tukey test, $p \leq 0.01$).*

Figure 7 - *A shallow well in Mohave Valley shows the effects of scale build-up. A nearby well had hardness concentrations of 2,200 milligrams per Liter (mg/L) and TDS concentrations of 4,900 mg/L.*

CONCLUSIONS

Based on ADEQ sampling results, groundwater in much of the MHV appears suitable for domestic use though there are drinking water concerns involving all basins and recharge sources. In the North basin, groundwater, especially at sites recharged by local precipitation, generally met water quality standards. However, health and aesthetic standards were exceeded at five sites along the Colorado River down-gradient of Hoover Dam.

In the South basin, groundwater quality varied significantly between recharge sources. Groundwater recharged by local precipitation is the preferred drinking or municipal source because of its much lower salinity and few aesthetic water quality exceedances. However, outside the Golden Shores area, sample sites often had arsenic concentrations above the 2006 health-based standard. The evolved sodium-bicarbonate chemistry at these sites suggest the elevated arsenic concentrations occur naturally because of a long groundwater residence under chemically closed conditions.[4]

In contrast, groundwater recharged by Colorado River water had fewer health-based exceedances. However, this water source had numerous aesthetics-based standards exceedances and salinity was elevated to the extent that often well owners didn't use groundwater for domestic purposes. TDS, sulfate and chloride concentration increases from fresher river water are probably not a function of evapotranspiration but the dissolution of halite and gypsum.[4] Manganese and iron concentrations likely indicate that, in contrast to Arizona's usual oxidizing groundwater environment, reducing conditions driven by the oxygen demand of decomposing soil organic carbon occur along the Colorado River in Mohave Valley.[4]

Samples collected from the Bouse Formation, a marine to brackish-water sequence deposited by an embayment of the Gulf of California, not unexpectedly had high salinity concentrations, a strong sodium-chloride chemistry, and both health and aesthetics-based standard exceedances.[3]

Many of the health-based exceedances, such as arsenic and fluoride, found in the MHV basin appear to be the result of naturally occurring geochemical processes. Nitrate however, typically results from human activities such as wastewater disposal practices. Limited time-trend analysis reveals constituent concentrations such as nitrate to be generally stable. This likely indicates that providing sewers to portions of the study area as recommended by ADEQ and local governments has decreased nitrogen loading to the groundwater. In addition, although not addressed specifically by this report, ADEQ continues to monitor the Golden Shores area for any chromium impacts from the Pacific Gas and Electric Topock compressor station located in San Bernadino County, California..

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Maps by Lisa Rowe

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