# GROUNDWATER QUALITY IN THE BULLHEAD CITY AREA, MOHAVE COUNTY, ARIZONA

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## Introduction

Bullhead City is located along the Colorado River in Mohave County in the northwestern section of the state (figure 1). The Bullhead City study area encompasses a thirty square mile area including old Bullhead City, Riveria and a part of Fort Mohave. The Bullhead City area is the fastest growing area in the state at this time.

In September 1987, the Arizona Department of Environmental Quality (ADEQ) conducted a field reconnaissance of groundwater quality in the Bullhead City area. Additional information was collected in August 1988 for a nitrogen isotope study and in May of 1989 as part of a state-wide virus study. Hydrologists measured water table depth and sampled groundwater quality in an attempt to better understand the regional hydrogeology. Our objectives in this investigation were to assess the impact of current wastewater disposal practices on groundwater quality and to obtain background information to be used in reviewing permit applications for discharging facilities.

The majority of the wastewater disposal in the study area has predominantly been through septic systems. Although there are three sanitary districts in the area they serve only a small percentage of the area. A map showing the distribution of sewered areas is included in figure 2. Due to the rapid growth of Bullhead City and surrounding areas and the increased use of septic systems the potential for groundwater contamination exists. The constituents of concern from these systems are nitrates, phosphates, salts, microbiological organisms, and total dissolved solids.

## Hydrology

The Colorado River is the dominant surface hydrologic feature and bounds the western part of the study area. Davis Dam impounds the River five miles to the north forming Lake Mohave. The fairly narrow river bed incises the alluvial flood plain and is enclosed by mountain ranges to the east and west. Lithology is divisible into three broad categories: riverbed alluvium, fanglomerates, and crystalline rocks. The primary aquifer is the riverbed alluvium of Quaternary (?) age

(Metzger and Loeltz, 1973). The depositional environment is a meandering river bed, with a typical stratigraphy of gravel, sand, silt and mud. The mountain-forming units are mid to late Tertiary volcanic and igneous rocks, but it is unlikely that these units are water bearing in the study area. Along the mountain fronts are the fanglomerates formed by the erosion of the mountain-forming units. The fanglomerates are composed of angular poorly sorted pebbles cemented in a sandy matrix (figure 3). A few wells located further east from the river and away from the riverbed alluvium probably withdraw water from the fanglomerate unit.

Depth to groundwater in wells measured in this study ranges from 30 feet near the river to 183 feet one and a quarter miles away from the river. The water elevation data was inconsistent and could not be contoured. Therefore, a groundwater flow direction for the area could not be determined. Inconsistent water elevation data could result from changing river stages, differences in total depth and perforated interval of the wells measured, and local pumping of wells.

However, the most likely groundwater flow direction is to the south-southwest along the axis of the Colorado River with a localized component of flow to the east-southeast away from the axis of the river. The data supports the premise that the aquifer is being recharged by the Colorado River because in most cases the elevation of the river is higher than groundwater elevation.

**Results of Groundwater Quality Investigation**

Groundwater samples were collected during three separate sampling events. In 1987 a field reconnaissance of groundwater quality was conducted, samples including two duplicates and one field blank were collected from twenty-two wells. An additional five samples were collected for a nitrogen isotope study in 1988. Recently in May of 1989, as part of a state wide virus study, 15 samples including one duplicate were collected. In all 36 wells were sampled. Three of these wells were sampled more than once. The Super 8 monitor well (B-20-22)01da was sampled four times once during each sampling event including one duplicate. The Riviera well (B-20-22)09dcd was sampled three times one sample and one duplicate were collected in 1987 and one sample was collected in 1988. A duplicate sample of the Tierra Verde well (AV40, AV41) was collected in 1989. A total of 42 samples were collected during the three sampling periods. All samples were analyzed for primary and secondary drinking water parameters. Bacteria samples were collected from 22 wells.

A number of sample results in the study area are above the Primary (MCL) or Secondary (SMCL) drinking water maximum contaminant level. The two parameters detected above primary

MCLs are nitrate and arsenic. Below is a summary of constituents detected at levels of concern:

- o Nitrate is above background (typically 3 mg/l as N) in nine wells and exceeded the MCL (10 mg/l as N) in one well.
- o Chloride exceeds the SMCL(250 mg/l) in fifteen wells,
- o Total Dissolved Solids exceeds the SMCL (500 mg/l) in thirty six wells.
- o Arsenic exceeds the MCL (0.05 mg/l) in three wells.
- o Iron exceeds the SMCL (0.33 mg/l) in five wells.
- o Manganese exceeds the SMCL (0.05 mg/l) in ten wells.
- o Sulfate exceeds the SMCL (250 mg/l) in twenty four wells .

As indicated above, every well exceeded the SMCL (500 mg/l) for total dissolved solids. Many of the wells, also exceeded other SMCL's. However, only four wells sampled exceeded an MCL. One well exceeded the MCL for nitrate (10 mg/l) and three other wells exceeded the MCL for arsenic (.05 mg/l). All other results were below primary drinking water maximum contaminant levels. Coliform bacteria were not found in any of the samples from the 22 wells for which bacteria was tested. A map showing the wells which exceeded MCL's presented in Figure 4 for nitrate.

As part of a state wide virus study, 14 virus samples were taken in the study area. Although there are no water quality standards for viruses in groundwater, samples were taken to determine the prevalence of microbiological organisms in Arizona's groundwater. Laboratory analysis included waterborne enteroviruses which are harmful to humans. Virus samples taken from the study area indicated that no viral contamination was present.

A survey of 87,000 wells (Madison and Brunett, 1984) with nitrate analyses using the United States Geological Survey's National Water-Data Storage and Retrieval System (WATSTORE) of nitrate concentrations in groundwater indicates the following:

- o Less than 0.2 mg/l - assumed to represent natural background concentrations.
- o 0.21 to 3.0 mg/l - Transitional; concentrations that may or may not represent human influence.
- o 3.1 to 10.0 mg/l - May indicate elevated concentrations resulting from human activities.
- o Greater than 10 mg/l - Exceeds maximum contaminant limit.

Arsenic exceeded the MCL in three wells, all located within the same area. Although the source of the arsenic is unknown, there is no evidence of an anthropogenic source such as pesticides. Therefore, it is believed the source of arsenic is naturally occurring. There are several different natural environments with which arsenic is typically associated (Welch, Lico, Hughes, 1988). Two of these environments may be present in the study area. These environments are: 1) Sediments partially derived from volcanic rocks of intermediate acidic composition and 2) Evaporite deposits. No specific evaporite deposits have been documented in the area. However, they are known to occur in the Bouse Formation south of the study area and can be expected to occur in Quaternary meandering river deposits.

## Interpretation of Results

We have identified three potential major influences on groundwater quality in the Bullhead City area: recharge from surface water, discharge from septic systems, and local hydrogeology. How these three important factors affect groundwater quality depends on many factors such as the location of the well, total depth of the well and the stratigraphic units penetrated, and proximity to discharging septic systems.

**Surface/groundwater Interplay.** Figure 5 shows the stiff diagrams representative of water quality for the wells sampled. A surface water sample of the Colorado River (B-33) was included on figure 5 for comparative purposes. Stiff diagrams of similar shapes have ratios of concentrations of major ions though not necessarily the same chemical concentrations. Thus, these diagrams allow a qualitative assessment of groundwater geochemistry. Comparison of the stiff diagram for surface water with those of groundwater samples shows that samples B-6 and B-9 are similar to the surface water sample B-33, indicating that groundwater obtained from these wells is primarily derived from the river. This similarity indicates that wells which are strongly influenced by surface water are located closest to the river. Other groundwater samples show varying degrees of deviation from surface water quality indicating that other factors, either natural (lithologic changes) or anthropogenic (domestic sewage), are influencing groundwater quality.

**Wastewater Impact.** Recharge from domestic sewage contains nitrates, salts, phosphates, metals, bacteria, viruses and a variety of household contaminants. The major constituent of concern is nitrate which ranges from 40 to 70 mg/l (as N) in domestic sewage or 4 to 7 times the maximum contaminant level of 10 mg/l. Nitrate is not appreciably attenuated in the vadose zone. Consequently, most nitrate from septic tank discharge will reach the aquifer. Impacts of septic effluent are generally first observed in the upper portion of the aquifer. Therefore, shallow wells will most likely exhibit high nitrates before other wells in a region. Increase of total dissolved solids (TDS) is another signature of the influence of septage. A rule of thumb is that water which passes through a septic tank experiences a TDS increase of about 100 to 300 mg/l. (Kaplan, 1987).

To assess the potential impacts of domestic sewage on groundwater quality a map of nitrate concentrations and stiff diagrams representing groundwater quality (figure 5) were prepared. The impact of domestic sewage on groundwater quality is shown by increases in nitrate, chloride and TDS concentrations, and by a distinct shape of the stiff diagram. To determine where the impact of domestic sewage would most likely occur, a map illustrating the distribution of sewered areas and population density was produced and is included as figure 2. This figure shows that development in the study area are predominantly on septic systems except along the northern reach of the river bend where both Riverside Sanitary District and Citizens Utilities service areas are located. Examination of figure 2 suggests that domestic sewage recharge would probably be greatest in the Old Bullhead City and Riviera areas, since these areas have the highest density of development dependent on septic tank systems for wastewater disposal.

To characterize the shape of the stiff diagram representing groundwater affected by municipal sewage, the three monitor wells at the Sierra Wastewater Treatment Plant were examined. Monitor wells B 21-1 and B 21-3 are upgradient of the percolation ponds and show identical stiff diagram. However, the downgradient well B 21-2 illustrates an increase of nitrate, chloride, sulfate and total dissolved solids, all of which are indications of wastewater impact. The characteristic Stiff diagram shape in the downgradient monitor well is an excellent example of groundwater contamination by wastewater. A comparable signature might be expected for septic effluent. Wells exhibiting this stiff configuration were found in the old Bullhead City area (B-28, B-30, B-18, A-36) and in Riviera (A-34, B-15, B-17, B-22). All these wells contain nitrate concentrations above 3 mg/l, chloride above 180 mg/l, sulfate above 250 mg/l and TDS above 1000 mg/l. An increase of all these parameters is indicative of wastewater impact. In addition, preliminary results from the Nitrogen Isotope Study currently being conducted by ADEQ indicate that the nitrogen stable isotope ratio ($N^{15}/N^{14}$) at B 21-2 (Sierra Wastewater Treatment Plant) and B 28 (Super 8 Motel) represents a nitrate source from septic or wastewater effluent. The ratio was too high to indicate a synthetic source. The final results will be presented in a report entitled "The Application of Nitrogen Isotopes in Groundwater as an identifier of Nitrate Sources in Arizona" by Melanie Redding and Dave Totman.

There are three reasons why old Bullhead City is the most likely area to exhibit impacts from discharging septic systems: 1) this area has been inhabited the longest; 2) shallow groundwater (depth to water is approximately 30 feet) and 3) this area has the highest density of discharging facilities in the study area, over 5 houses per acre. Indeed, high nitrate values are found in the old Bullhead City area (B-18, B-28, B-30, A-36). Since there are a number of discharging facilities in the area, it is difficult to pinpoint specific facilities as sources of nitrate. In addition it appears that the elevated nitrate levels may extend across a large area because all wells sampled in the area contain above 7 mg/l total nitrogen. However, to determine the extent of nitrate contamination, additional sampling in this area will be required.

**Lithology and Water Quality.** The local geology in the study area has not been studied in any great detail. At this time, it is difficult to assess the total impact of lithology on water quality. However, the presence of some elevated constituents, such as chlorides in the southern end of the study area and arsenic (B-3, B-4, B-5) in the Riviera area might be related to geology since there is no other identifiable source. Mountain-front recharge and recharge along individual surface streams may impact individual wells.

## Conclusions

Our study identified three influences on groundwater quality in the study area: recharge from the Colorado river, recharge from septic systems, and possibly local geology.

Groundwater due to recharge from the Colorado River is characterized by lower sodium and chloride levels. Groundwater quality has been affected by discharging septic systems in the old Bullhead City area and other parts of the Riviera area, as evidenced by high nitrate, elevated chlorides, sulfates and total dissolved solids. Individual wells in the southern end of the study area exhibit unique chemical signatures indicative of the influence of the local hydrogeology. It is possible that nitrate concentrations measured in groundwater as a result of septage discharges will increase due to a lag between the first appearance of high nitrates in groundwater and the equilibrium (full impact) condition.

Finally, the impact of the tremendous population growth both within and outside the 208 plan area which are dependant on septic systems represents the most significant threat to groundwater quality in the study area.

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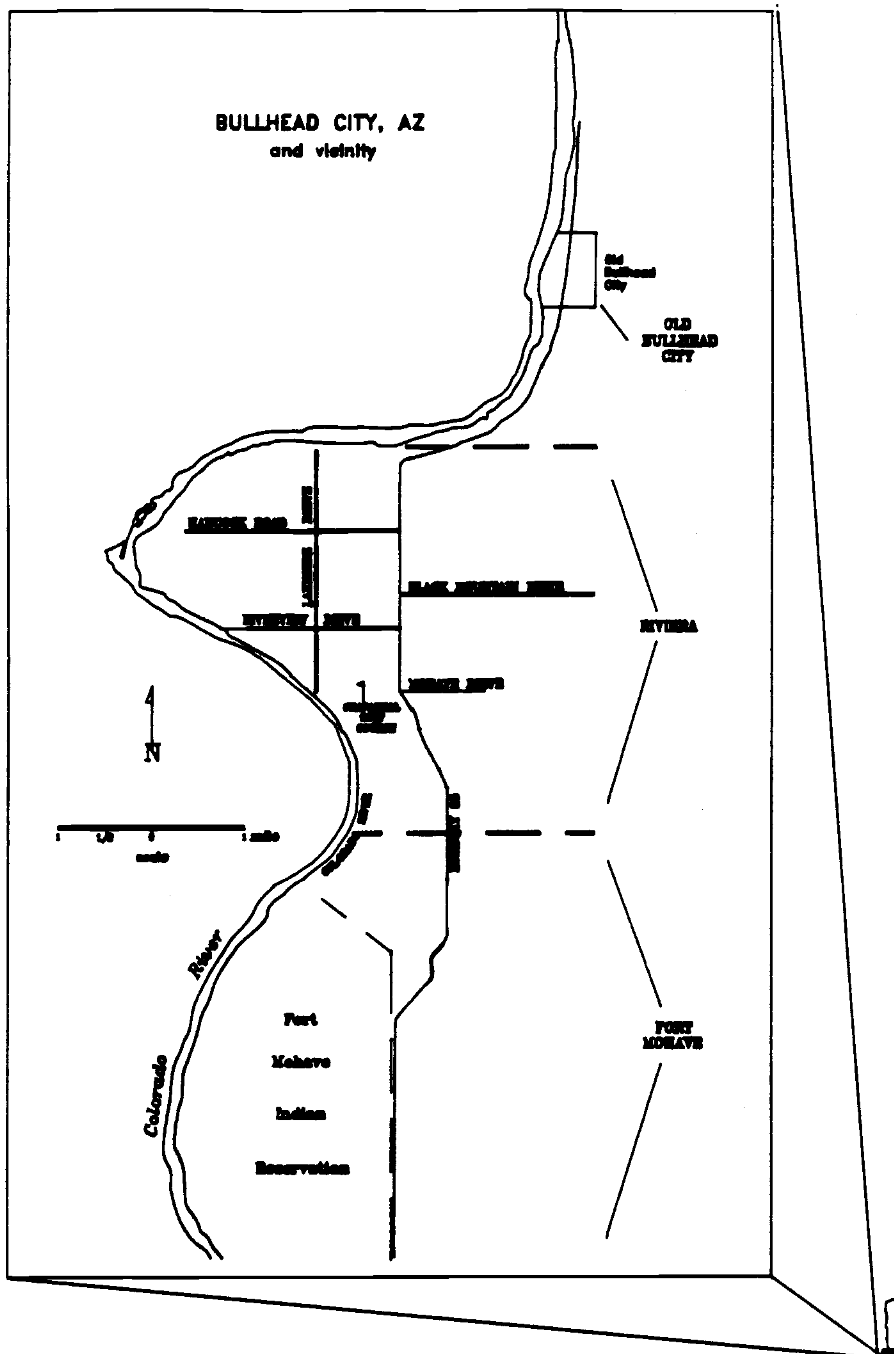


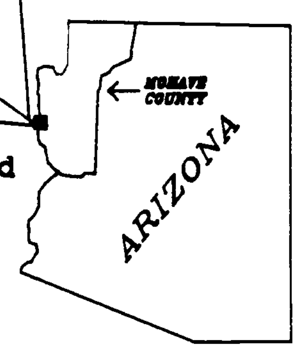




Figure 1. Located across the river from Old Bullhead City is Laughlin Nevada.

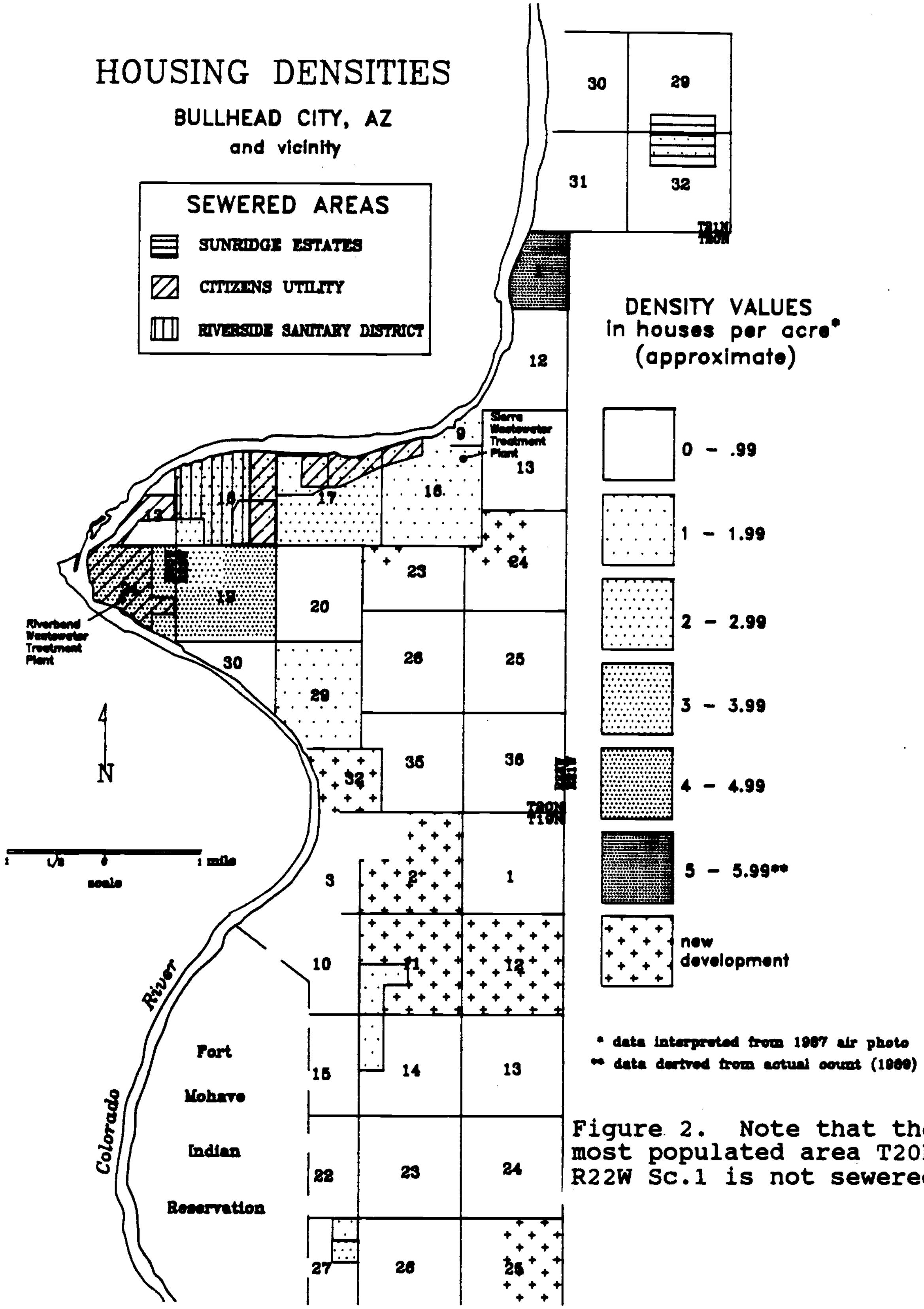
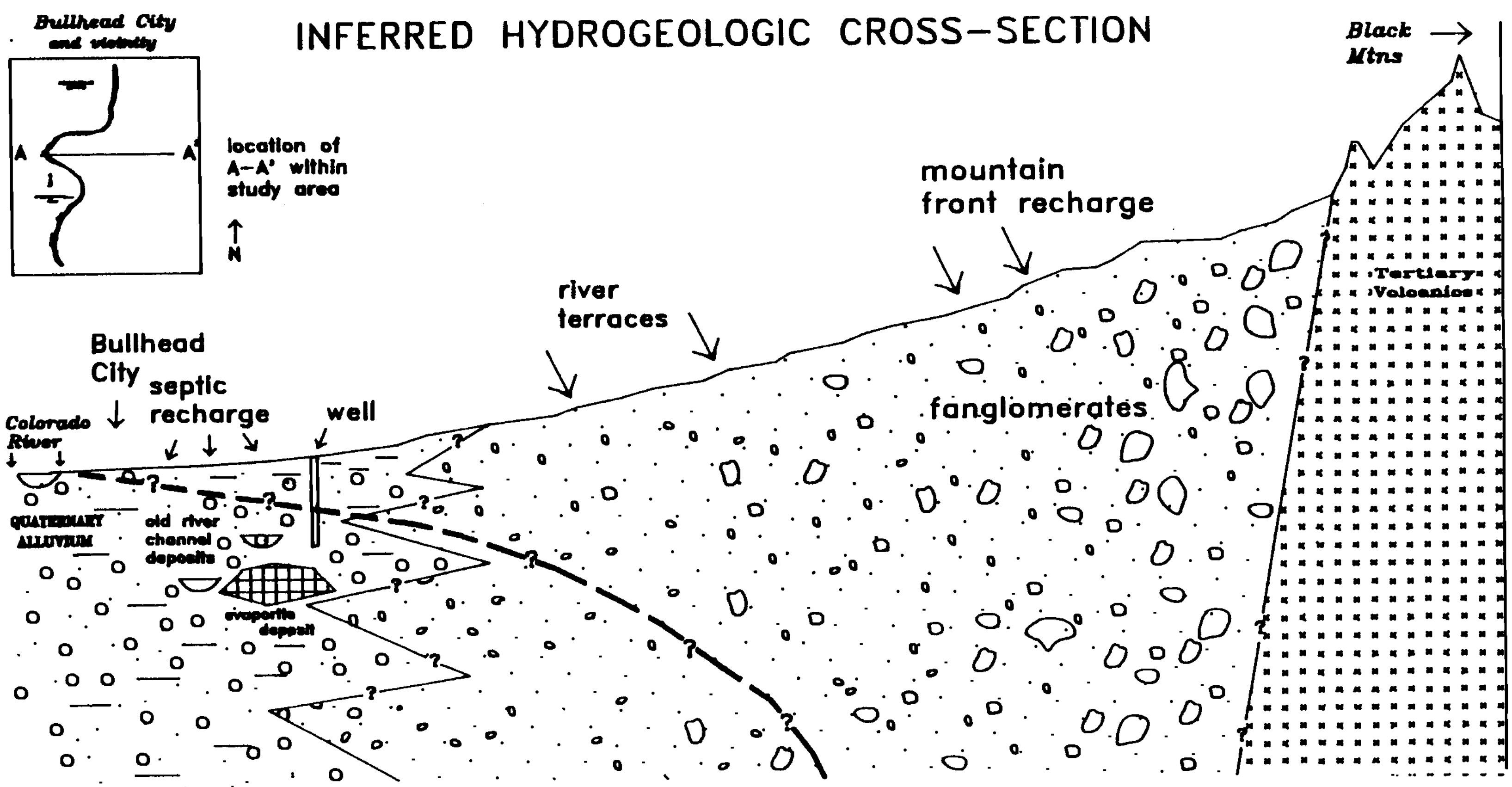



Figure 2. Note that the most populated area T20N R22W Sc.1 is not sewered.

Figure 3. Horizontal scale 1"= 2000', vertical scale 1"= 550'.



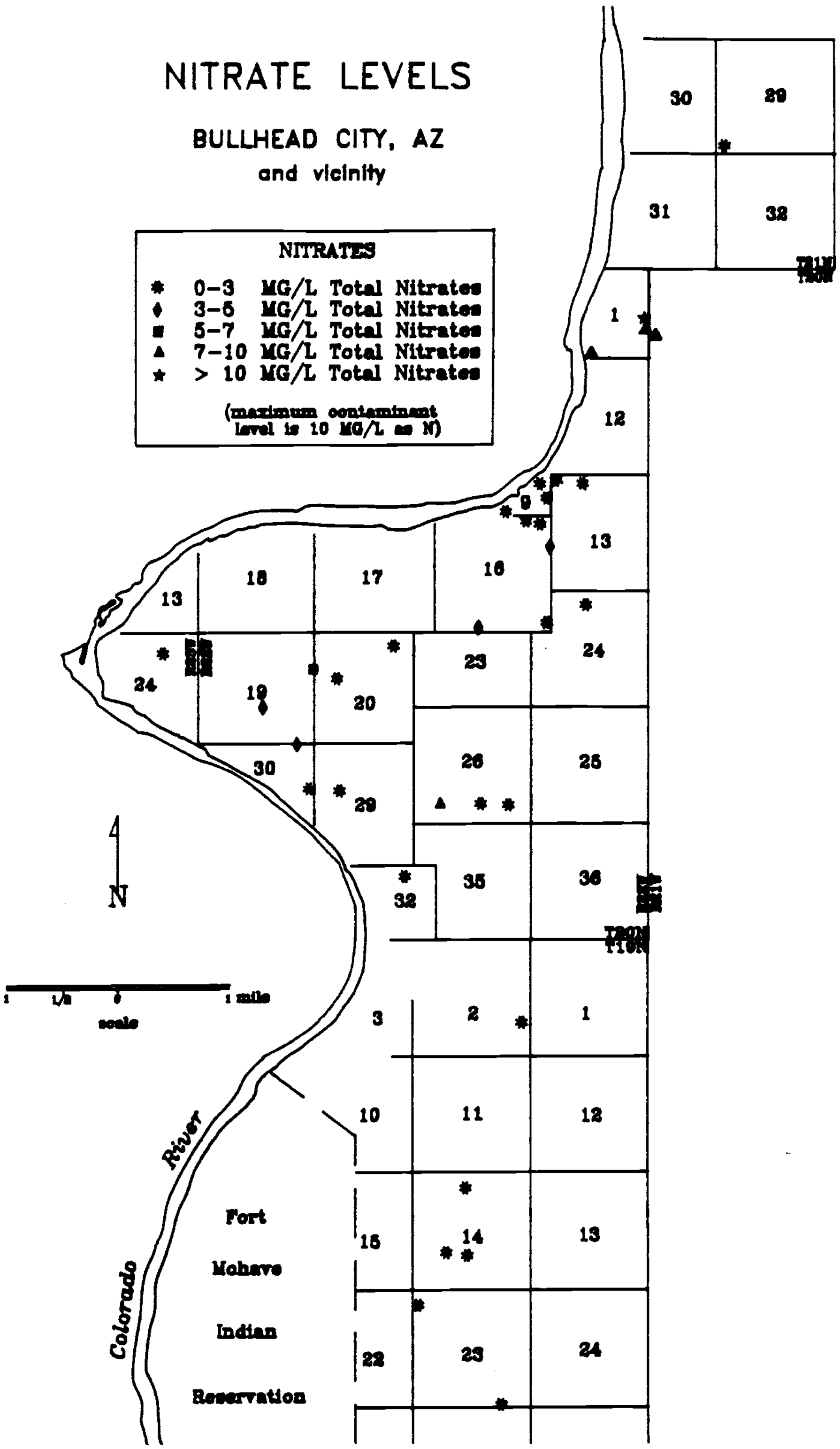



Figure 4. Note the elevated nitrate levels in old Bullhead City area.

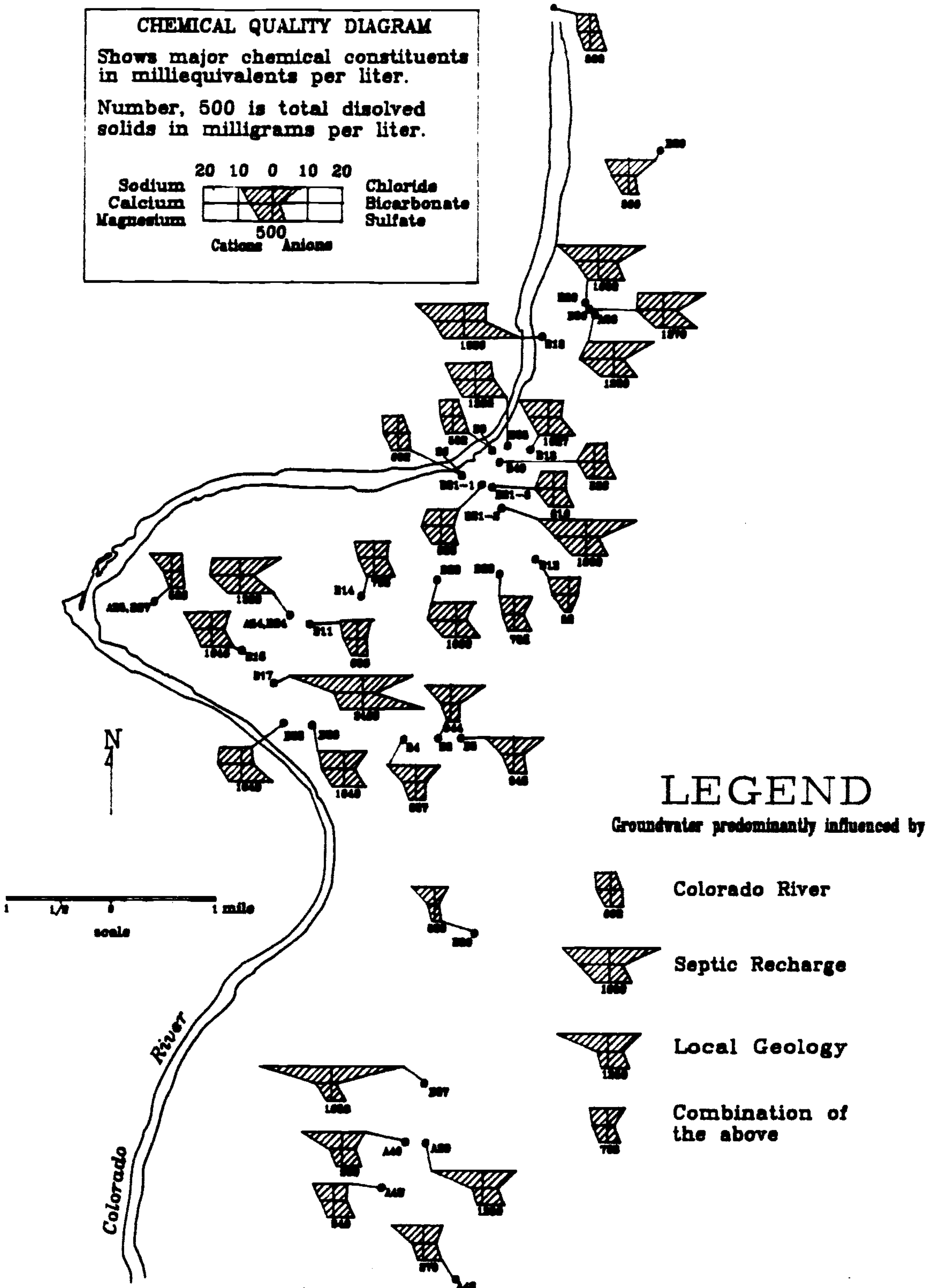



Figure 5. The stiff diagram illustrates that there are three influences on groundwater: Colorado River, septic recharge and local geology.