Using Geochemical Data to Identify Sources of Salinity to the Freshwater Navajo Aquifer in Southeastern Utah

Aneth Technical Committee[1] Fact Sheet

Navajo Aquifer, a Source of Freshwater

Ground water is an important freshwater source for domestic and livestock uses in southeastern Utah because of the arid climate and unavailability of surface water from the San Juan River. The study area includes about 1,200 square miles in the southeastern corner of Utah (fig. 1). Precipitation on mountainous areas north, south, and east of the study area (fig. 2) seeps into the Navajo and overlying aquifers where the sandstones that contain the aquifers are exposed at the surface along mountain flanks. The ground water then moves slowly away from the mountainous areas toward the area of lowest elevation in the region, the San Juan River. The ground water reappears at land surface where it discharges as seepage to the San Juan River or is consumed by vegetation on the flood plain. Generally, wells finished in the Navajo aquifer near the San Juan River do not require pumping because water flows freely from the well casing when it is not sealed.

Salinity increases in water in some parts of the Navajo aquifer in southeastern Utah (fig. 1) have been documented in recent years by the U.S. Geological Survey (Avery, 1986; Kimball, 1992; Spangler, 1992). Oil is produced in this part of Utah, and saline ground water, which is produced with the oil (referred to as "oil-field brine") and later injected into the subsurface to enhance oil recovery, was considered to be a potential source for the increasing salinity of water in the Navajo aquifer (fig. 3). Additional sources of salinity considered during the study included water from the upper Paleozoic aquifer and brines not associated with oil deposits (referred to as "non-oil-field brine") (fig. 3). Beginning in 1989, the U.S. Geological Survey began collecting and interpreting geochemical data from ground-water samples in the study area to determine the possible origin(s) of saline water that could be mixing with the fresh ground water in the Navajo aquifer.

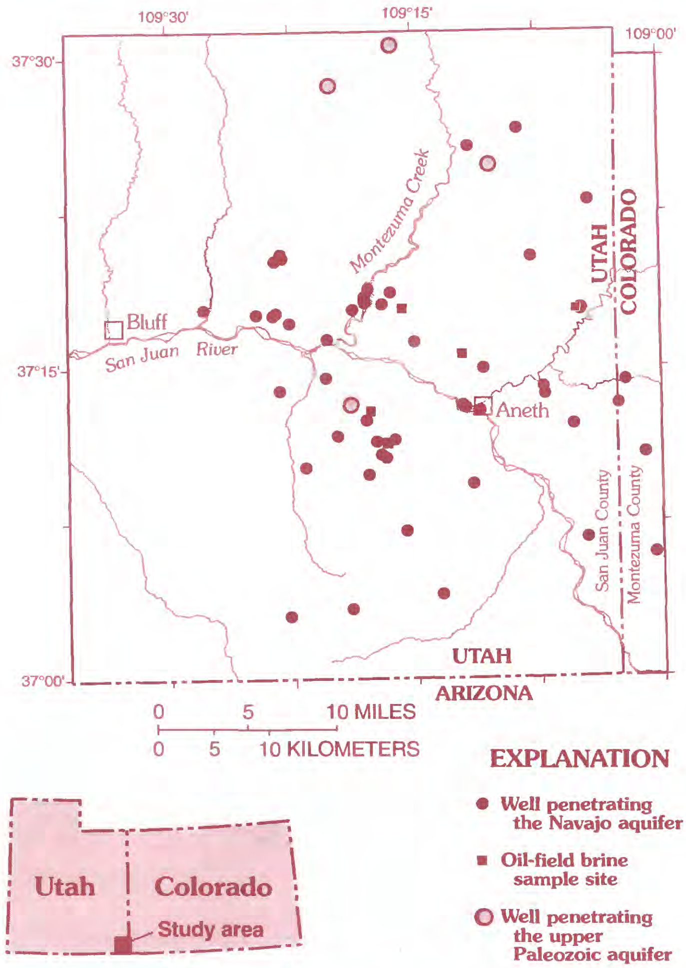

Figure 1. Location of selected wells where geochemical data were collected during the study.

Figure 2. The Abajo Mountains, a source of recharge water to the Navajo aquifer in the study area.

[1]The Aneth Technical Committee, which comprises State, Tribal, and Federal government agencies as well as private oil companies, is a liaison group formed to investigate the source(s) and process(es) that cause the observed salinity increases in the freshwater Navajo aquifer in the vicinity of the Greater Aneth Oil Field. Represented on the technical committee are the Bureau of Reclamation; the Bureau of Land Management; U.S. Environmental Protection Agency; the Bureau of Indian Affairs; Texaco Exploration and Production, Inc.; Mobil Exploration and Producing U.S., Inc.; the Utah Division of Oil, Gas, and Mining; the Navajo Environmental Protection Administration; Navajo Water Resources Management; and the U.S. Geological Survey.

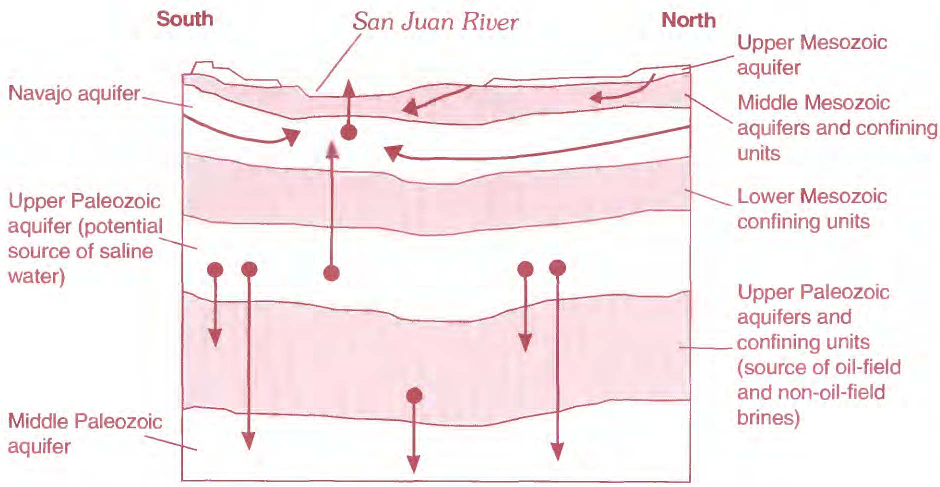

Figure 3. Aquifers and confining units within the Greater Aneth Oil Field, Utah. Arrows indicate potential for vertical ground-water movement due to hydraulic-head differences.

Bromide and Chloride Data Indicate Oil-Field Brines Not the Salinity Source

Bromide and chloride concentrations in ground-water samples are sometimes useful for differentiating salinity sources because neither element generally participates in chemical reactions except in very saline systems and because bromide is enriched in organic materials, which provide considerable enrichment in bromide concentrations in oil-field brine samples. Results from the Aneth study indicate that bromide-to-chloride ratio values are greater in oil-field brine samples than in saline water samples from the upper Paleozoic aquifer and in non-oil-field brine (fig. 4). The bromide-to-chloride ratio in water samples from the Navajo aquifer generally decreases as the chloride concentration increases (fig. 4).

Two mixing lines were constructed by using the mean bromide and chloride concentrations from water samples of the oil-field brine and upper Paleozoic aquifer saline end members. A mixing line is the estimated chemical composition of a water derived from mixing two waters of different chemical composition in various proportions. The mean chloride and bromide concentration of water samples from the Navajo aquifer (chloride concentration less than 60 milligrams per liter) was used as the chemical composition of the non-saline water in the mixing model. The trend of decreasing bromide-to-chloride ratio values with increasing salinity in Navajo aquifer water samples generally does not follow the oil-field brine mix line (fig. 4), which indicates that oil-field brines are not the source of salinity to the Navajo aquifer. The mix line that represents the chemical composition of water from the upper Paleozoic aquifer presents a more realistic fit to the Navajo aquifer data, which indicates that this aquifer is a geochemically feasible source of saline water.

Strontium Isotopic Data Indicate Oil-Field Brines Not the Salinity Source

In addition to the chemical elements of bromide and chloride, natural variations in the isotopes of the chemical element strontium (Sr) can be used to verify or eliminate sources of saline ground water in the Aneth area. An isotope of any element, such as Sr, has the same number of protons (a positively charged particle with a mass equal to one atomic mass unit) in the atomic nucleus, but a different number of neutrons (a non-charged particle with a mass equal to one atomic mass unit). Relative ratios between two different isotopes of Sr (Sr-87 and Sr-86) in water samples from the study area were measured with a very sensitive analytical instrument called a mass spectrometer. Each atom of Sr-87 has one more neutron than an atom of Sr-86, and the relative mass difference between the two isotopes can be used as a natural hydrologic tracer.

Small differences in the Sr-87 to Sr-86 values can be emphasized by comparing the sample ratio with the ratio in modern seawater by using the following formula:

$\delta^{87}Sr = (((^{87}Sr/^{86}Sr)_m/(^{87}Sr/^{86}Sr)_{sw})-1)1{,}000$,

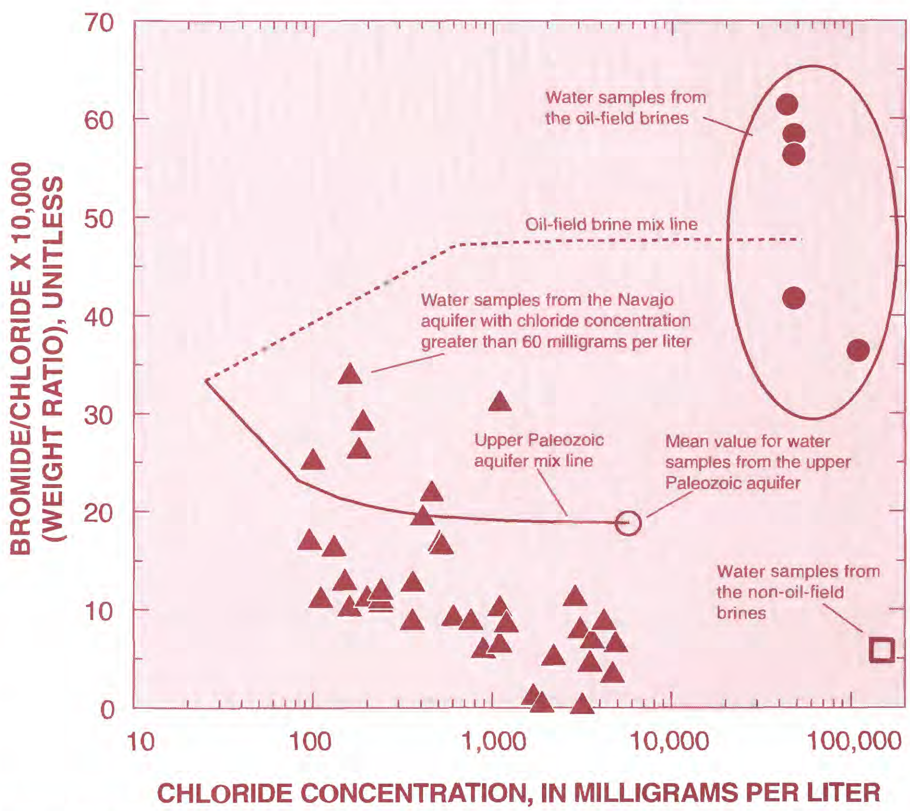

Figure 4. Mixing lines constructed between potential saline end-member water samples compared with bromide-to-chloride weight ratios of water samples from the Navajo aquifer.

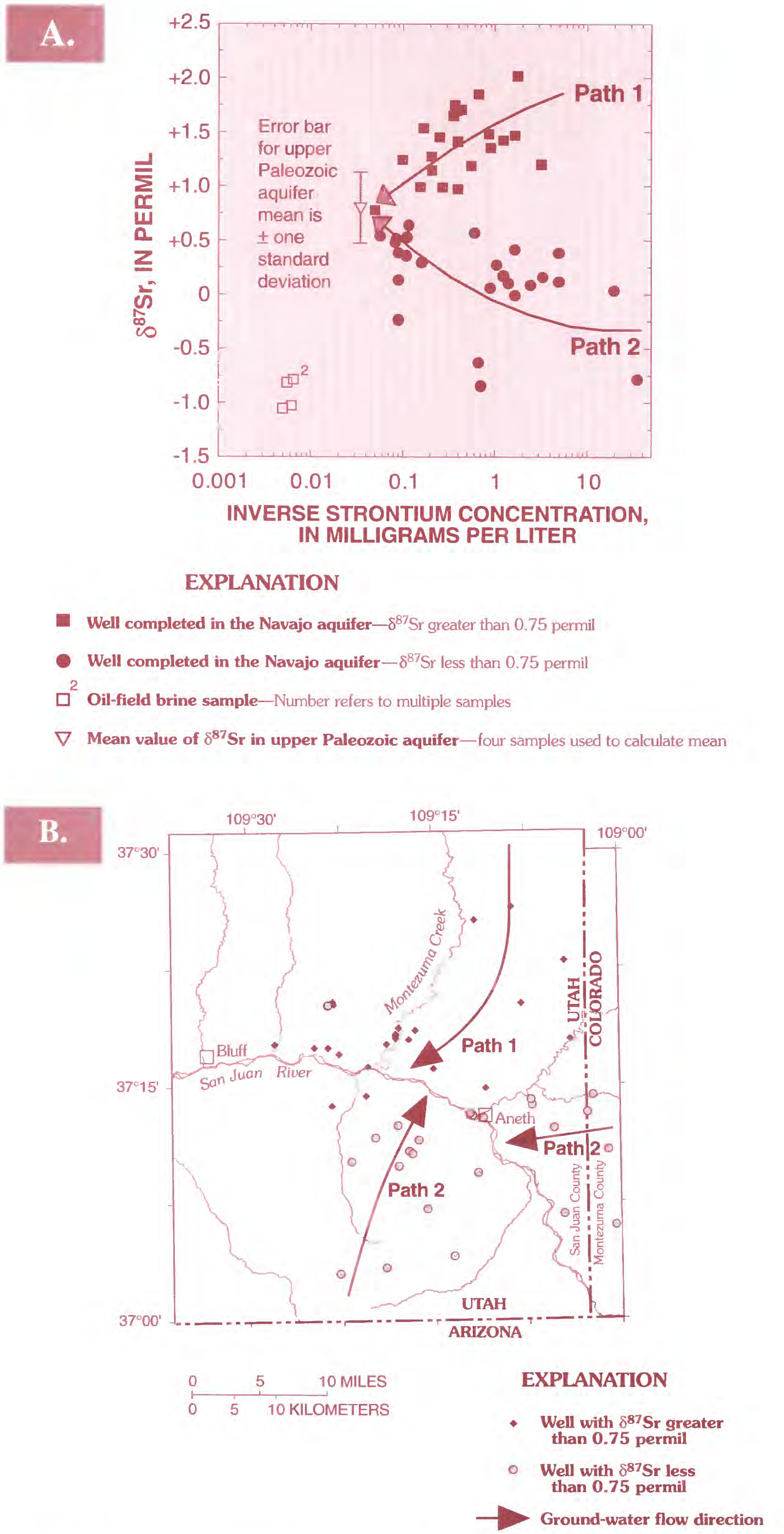

Figure 5. (**A**) Variation of $\delta^{87}Sr$ values and strontium concentrations in water samples from the study area and (**B**) Location of wells completed in the Navajo aquifer with large (greater than 0.75 permil) and small (less than 0.75 permil) $\delta^{87}Sr$ values.

where $(^{87}Sr/^{86}Sr)_m$ is the isotope ratio of the sample; $(^{87}Sr/^{86}Sr)_{sw}$ is the isotope ratio of seawater (0.70920); and $\delta^{87}Sr$ is the sample deviation from seawater expressed in units of permil.

The $\delta^{87}Sr$ values were determined for 56 ground-water samples from throughout the Aneth area (fig. 5). The $\delta^{87}Sr$ values of the oil-field brine samples are considerably more negative relative to values of water samples from the Navajo aquifer (fig. 5A), which indicates that oil-field brines are not the source of salinity to the Navajo aquifer.

Wells in the Navajo aquifer that have water with $\delta^{87}Sr$ values greater than 0.75 permil generally are located in the northern half of the study area, and wells that have water with $\delta^{87}Sr$ values less than 0.75 permil are located in the southern half of the study area (figs. 5A, B). This geographic segregation of the data reflects the different hydrologic flow paths in the Navajo aquifer. A north-to-south ground-water flow direction (path 1) is associated with the $\delta^{87}Sr$ values that are greater than 0.75 permil and east-to-west and south-to-north flow directions (path 2) are associated with $\delta^{87}Sr$ values that are less than 0.75 permil (fig. 5A).

As the strontium concentration increases, flow paths 1 and 2 appear to converge to the mean $\delta^{87}Sr$ value of four water samples from the upper Paleozoic aquifer (fig. 5A). This convergence indicates that water from the upper Paleozoic aquifer may be a plausible source of salinity to the Navajo aquifer and is in agreement with the bromide and chloride mixing model. Additional geochemical and hydrological data are being collected to investigate this source of salinity further. The study is scheduled for conclusion during September 1995.

Sources of Additional Information

The following publications contain additional information on the hydrology and sources of salinity within the study area:

Avery, Charles, 1986, Bedrock aquifers of eastern San Juan County, Utah: State of Utah Department of Natural Resources Technical Publication No. 86, 124 p.

Howells, Lewis, 1990, Base of moderately saline ground water in San Juan County, Utah: State of Utah Department of Natural Resources Technical Publication No. 94, 35 p.

Kimball, B.A., 1992, Geochemical indicators used to determine source of saline water in Mesozoic aquifers, Montezuma Canyon area, Utah, *in* Seymour Subitzky, ed., Selected Papers in the Hydrological Sciences: U.S. Geological Survey Water-Supply Paper 2340, p. 89-106.

Naftz, D.L., and Spangler, L.E., 1993, Using geochemical techniques to identify salinity sources in the freshwater Navajo aquifer, Aneth Oil Field, Utah [abs.]: American Association of Petroleum Geologists Conference, Salt Lake City, Utah, September 12-15, 1993, Proceedings, p. 58.

Naftz, D.L., and Spangler, L.E., 1994, Salinity increases in the Navajo aquifer in southeastern Utah: Water Resources Bulletin, v. 30, no. 6, p. 1,119-1,135.

Spangler, L.E., 1992, Records of wells in sandstone and alluvial aquifers and chemical data for water from selected wells in the Navajo aquifer in the vicinity of the Greater Aneth Oil Field, San Juan County, Utah: U.S. Geological Survey Open-File Report 92-124, 44 p.

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Information on technical reports and hydrologic data related to the ongoing study in the vicinity of the Aneth Oil Field can be obtained from:

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