Brackish Groundwater

and its Potential as a Resource in the Southwestern United States

Secure, reliable, and sustainable water resources are fundamental to food production, energy independence, and the health of humans and ecosystems. But the large-scale development of fresh groundwater resources has stressed aquifers in some areas, causing declines in the amount of groundwater in storage and decreases in discharge to surface-water bodies like rivers and springs (Reilly and others, 2008). In some parts of the southwestern United States, the water supply is not adequate to meet demand without substantial effects on groundwater storage or surface discharge, and severe drought intensifies the stresses affecting water resources.

In support of the national census of water resources, the U.S. Geological Survey (USGS) completed the national brackish groundwater assessment to provide information about brackish groundwater as a potential resource to augment or replace freshwater supplies (Stanton and others, 2017). The objectives of the brackish groundwater assessment were to consolidate available data into a comprehensive database of brackish groundwater resources in the United States and to produce a summary report about the distribution, physical and chemical characteristics, and use of brackish groundwater. This fact sheet summarizes the occurrence of brackish groundwater and factors affecting its usability in the southwestern United States (specifically the Southwest Basins region) reported for the national study. The map below (fig. 1) summarizes the brackish zones for the five largest principal aquifers within the southwestern United States, along with groundwater resources in the remaining part of the region (Reilly and others, 2008).

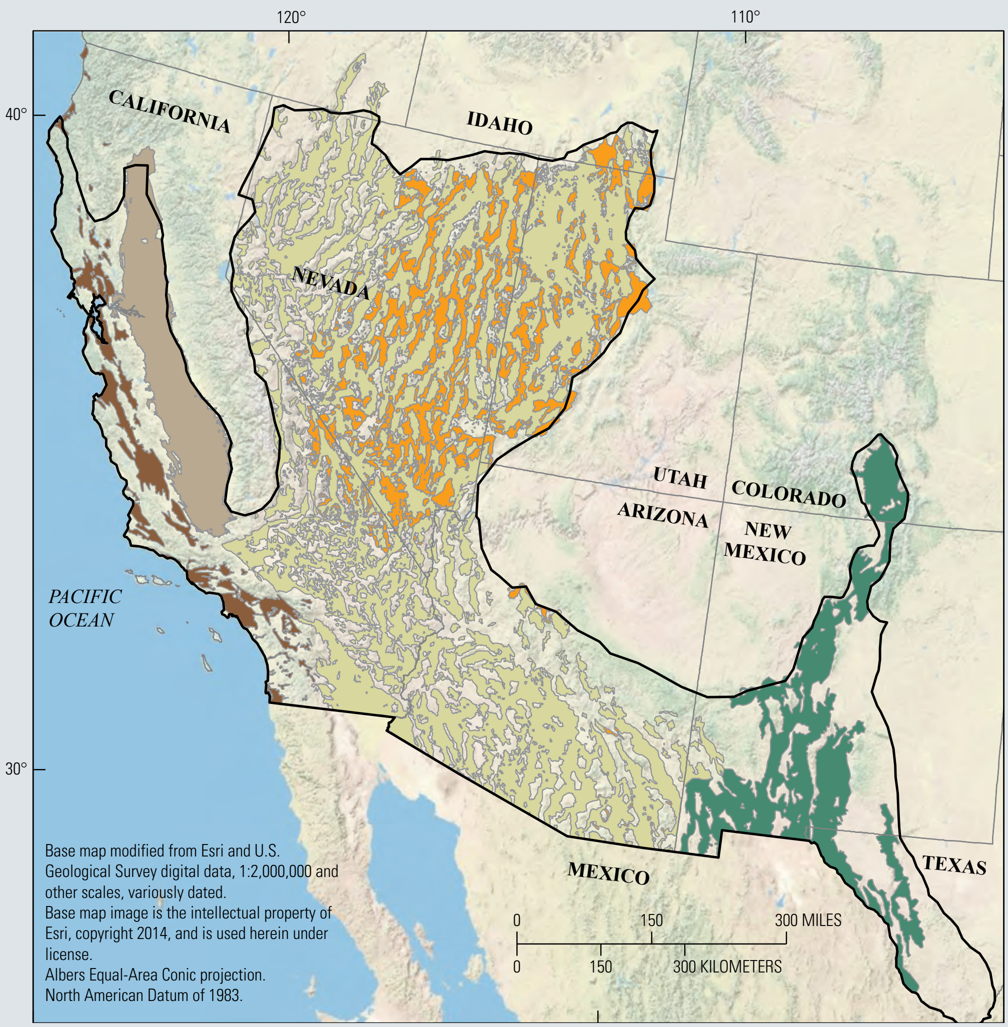

Figure 1. Map of the five principal aquifers in the southwestern United States and description of the settings where the brackish zones of each aquifer occur.

EXPLANATION

Principal aquifers and description of brackish zones

- **Central Valley aquifer system.** Brackish groundwater occurs in upper parts of unconfined system; saline water occurs in marine sediments at depth.
- **Rio Grande aquifer system.** Shallow brackish groundwater occurs in closed basins, and areas with upward-flowing deep basin groundwater that is brackish as a result of long flow paths.
- **Basin and Range basin-fill aquifers.** Shallow brackish groundwater occurs in closed basins near playas, above confining units, and areas with upward flowing deep basin groundwater that is brackish as a result of long flow paths. Water at depths greater than a few thousand feet yield saline water that is confined and has poor hydraulic connection with shallower systems.
- **Basin and Range carbonate-rock aquifers.** Brackish groundwater occurs in areas with geothermal activity and with groundwater discharge.
- **California Coastal Basin aquifers.** Shallow brackish groundwater results from concentration by evapotranspiration, application of saline waters (oil-field brines and irrigation waters) at land surface, and seawater intrusion. Deeper brackish groundwater occurs in unconsolidated to semi-consolidated marinesediments containing saline water.
- **Brackish groundwater assessment boundary for the Southwestern United States**

What is Brackish Groundwater?

Water containing moderate to high concentrations of dissolved solids such as minerals, metals, and salts is considered brackish. Important chemical constituents contributing to dissolved-solids concentrations are typically cations (positively charged molecules) such as calcium, magnesium, sodium, and potassium; anions (negatively charged molecules) such as sulfate, chloride, and bicarbonate; as well as charge-neutral silica. The U.S. Environmental Protection Agency advises, but does not require, that public drinking-water systems provide water with less than 500 milligrams per liter (mg/L) in total dissolved solids concentrations. Numerous water supplies, however, exceed this concentration. Water exceeding 1,000 mg/L in dissolved solids is generally considered undesirable for human consumption and may smell unpleasant or taste bitter, salty, or metallic. Water with higher dissolved-solids concentrations can be used for a variety of purposes other than drinking water. For comparison, the dissolved solids concentration of seawater is about 35,000 mg/L. For this assessment, brackish groundwater was defined as having a dissolved-solids concentration between 1,000 and 10,000 mg/L, and highly saline groundwater was defined as having dissolved-solids concentrations greater than 10,000 mg/L.

Brackish Groundwater Occurrence

Previous regional studies have found that groundwater quality for most of the aquifers in the southwestern United States varies horizontally and vertically and is related to regional geology, mineralogy, structure, drainage patterns, and development (Thiros and others, 2014). The Basin and Range basin-fill aquifers, California Coastal Basin aquifers, Central Valley aquifer system, and Rio Grande aquifer system consist of unconsolidated to semi-consolidated stream and lake sediments that in places are interspersed with volcanic rocks. The Basin and Range carbonate-rock aquifers are of marine origin and consist of interbedded limestone, dolomite, sandstone, shale, and volcanic rocks. Within these principal aquifers, brackish groundwater occurs in different settings and at different depths. Brackish groundwater conditions also occur outside of these principal aquifers.

Water quality is determined, in part, by dissolved-solids concentrations, which vary across a basin. Concentrations are typically lower in groundwater recharge areas, such as along mountain fronts, and higher in groundwater discharge areas, which often occur in the middle of the basins. In many parts of the southwest, brackish groundwater occurs primarily in two zones: a shallow zone affected by the concentration of minerals from evaporative processes, particularly at the terminus of closed basins; and a deep zone affected by long flow paths, the presence of soluble salts (such as gypsum, anhydrite, and halite), inflow from adjacent geologic units, or saline water contained within marine sediments. Other processes that are associated with elevated dissolved-solids concentrations are stream leakage, thermal springs, oil-field brines, and seawater intrusion along the California coast.

The national brackish groundwater assessment reported dissolved-solids concentration data for groundwater samples from about 34,000 wells sampled by Federal, state, and local agencies in the southwestern United States (see table; Qi and Harris, 2017). These data were then added to a three-dimensional model that provided a framework to analyze the spatial distribution of brackish groundwater conditions. The model grid consists of 4 layers of cells with 6.2 mile (mi) by 6.2 mi horizontal extents, and each layer extends through different depth intervals below the land surface (bls): 0–50 feet (ft), 50–500 ft, 500–1,500 ft, and 1,500–3,000 ft. Although the model grid in its entirety represents about 216,000 mi^3 of the subsurface, only about 14 percent of that volume (30,300 mi^3) is represented by sampled wells, and the remaining 86 percent has unknown brackish conditions.

Brackish groundwater occurs in many parts of the southwestern United States (fig. 2). The model grid used for the brackish groundwater assessment maps both the extent of brackish conditions above 3,000 feet bls—about 9,300 mi^3—and the percent volume indicated by well data—about 31 percent. Most of the observed brackish groundwater occurred between 50 and 1,500 ft bls (fig. 3).

Brackish Groundwater as a Potential Resource

Brackish groundwater potentially represents a substantial water resource for the southwestern United States that could be used to augment or replace freshwater supplies in some areas. In the southwest, about 22.5 million acre-feet of groundwater are withdrawn annually from the five principal aquifers for irrigation, public supply, and industrial purposes (Maupin and Barber, 2005). An acre-foot of water is about 326,000 gallons, or almost enough to fill a football field one foot deep. Only about 0.6 million acre-feet (or about 3 percent) of the annual withdrawals are brackish or highly saline (Stanton and others, 2017), but, for example, if the amount of brackish groundwater that could be withdrawn and used from the subsurface is 1 percent of the total volume represented by wells observed to contain brackish groundwater in the southwestern United States, then there is about 93 mi3, or 310 million acre-feet, of brackish groundwater resources potentially available for use. There is likely even more brackish groundwater potentially available than this estimate, because the unobserved area (86 percent of the region) may also yield usable brackish water supplies. A predictive model from the national study indicates a high probability of brackish groundwater occurrence across much of the southwest region (Stanton and others, 2017).

Areas underlain by the principal aquifers of the southwestern United States could benefit from the development of brackish water as a resource to complement fresh water supplies. Occurrence near the surface makes the brackish groundwater potentially less expensive and more feasible to extract through wells. Brackish groundwater resources can be found within the 50 feet of the land surface in extensive areas of the Central Valley aquifer system in California and in the Rio Grande aquifer system of south-central New Mexico (figs. 1 and 2). Brackish groundwater can be found within 50 to 500 ft bls in extensive areas in the California Coastal aquifers, the Basin and Range basin-fill aquifers of southwestern Arizona and western Utah, and the Rio Grande aquifer system of central New Mexico and west Texas (figs. 1 and 2). Between 20 and 33 percent of the wells completed in each southwest principal aquifer produced brackish groundwater, and 1 to 2 percent produced highly saline groundwater (see table). Of the wells that could not be assigned to or were not completed within one of the principal aquifers evaluated, 20 percent of them yielded brackish groundwater. The observed volume of brackish groundwater occurring between 0 and 3,000 ft bls within grid cells from each of the five principal aquifers evaluated in the Southwestern Basin region ranged from 31 to 38 percent of the total volume of the region with wells (see table).

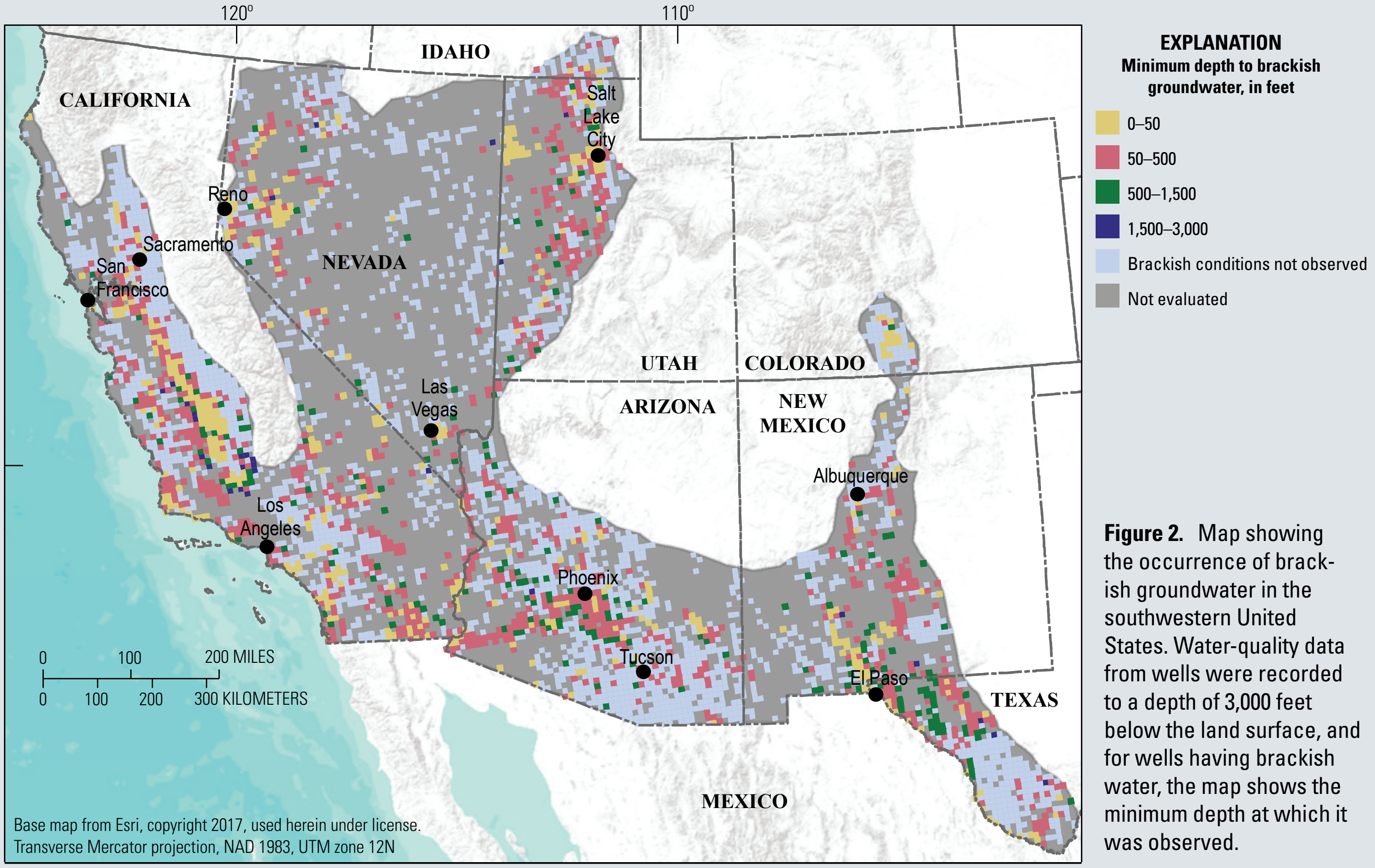

Figure 2. Map showing the occurrence of brackish groundwater in the southwestern United States. Water-quality data from wells were recorded to a depth of 3,000 feet below the land surface, and for wells having brackish water, the map shows the minimum depth at which it was observed.

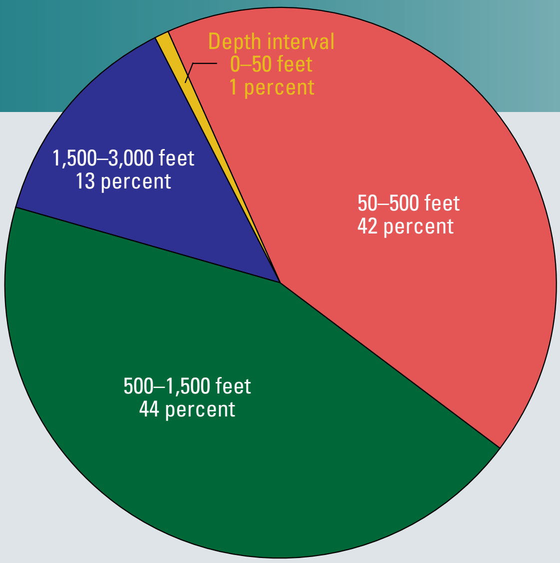

Figure 3. This pie chart plots the percent of total subsurface volume observed to contain brackish groundwater in each depth interval. Of a mapped total 9,300 cubic miles, most of the observed brackish water in the Southwestern Basins region occurs between 50 and 1,000 feet below land surface.

Summary of observed brackish and highly saline groundwater in principal aquifers of the southwestern United States.

[Grid cells are categorized as “fresh,” “brackish,” or “highly saline” on the basis of the maximum observed dissolved-solids concentration found in groundwater samples collected from wells within the designated grid cell being less than 1,000 milligrams per liter (mg/L), between 1,000 mg/L and 10,000 mg/L, or greater than 10,000 mg/L, respectively. In this categorization, “fresh” cells could also contain unobserved brackish or highly saline groundwater, “brackish” cells could also contain observed or unobserved fresh groundwater and unobserved highly saline groundwater, and “highly saline” cells could also contain observed or unobserved fresh and/or brackish groundwater]

Principal aquifer	Basin and Range basin-fill aquifers	Basin and Range carbonate-rock aquifers	California Coastal Basin aquifers	Central Valley aquifer system	Rio Grande aquifer system	Other[1]
Statistics for wells and samples						
Number of sampled wells	13,874	335	3,403	6,276	2,813	7,516
Median sample dissolved-solids concentration, milligrams per liter	490	630	590	400	660	440
Sampled wells with brackish groundwater, in percent	24	25	26	20	33	20
Sampled wells with highly saline groundwater, in percent	2	2	1	2	1	1
Estimated grid-cell volume represented by samples [2]						
Fresh, brackish, and highly saline groundwater, in cubic miles	11,130	590	1,960	4,220	1,870	10,530
Brackish groundwater, in cubic miles (percent of represented volume)	3,510 (32)	200 (33)	600 (31)	1,550 (37)	720 (38)	2,680 (25)
Highly saline groundwater, in cubic miles (percent of represented volume)	300 (3)	35 (6)	85 (4)	145 (3)	60 (3)	130 (1)
Well yields for shallow brackish wells, less than 500 feet depth interval						
Number of sampled wells	803	Included in deeper brackish wells	26	38	42	Not compiled
Median well yield, gallons/minute	1,570		425	600	10	
Interquartile range of well yield, gallons/minute	449 to 2,780		40 to 800	175 to 1,500	3 to 150	
Well yields for deeper brackish wells, 500 to 3,000 feet depth interval						
Number of sampled wells	336	18	10	46	5	Not compiled
Median well yield, gallons/minute	1,970	300	900	1,510	315	
Interquartile range of well yield, gallons/minute	1,140 to 2,650	30 to 800	800 to 2,000	1,130 to 2,180	200 to 1,150	

[1]Includes 6 wells from the Southern Nevada volcanic-rock aquifers and 31 wells in sand and gravel of alluvial or glacial origin. The remainder of wells are either outside the horizontal and vertical extent of the listed principal aquifers, or could not definitively be assigned to one of the listed principal aquifers.

[2]Grid-cell volumes include air, water, and rock occupied in the subsurface to 3,000 feet below land surface. Volumes are computed based on grid-cell dimensions and on well construction and sample information associated with each grid cell. Estimates reported here reflect grid-cell volumes for areas where well observations are available. Entire principal aquifer subsurface volumes could be greater than those reported here because of the lack of observations in many grid cells.


Photograph by Jeff Vanuga, USDA National Resources Conservation Service


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Photograph by David Anning, U.S. Geological Survey


Photograph courtesy of the U.S. Nuclear Regulatory Commission

Potential uses of brackish groundwater include (from top to bottom) crop irrigation, in drilling and hydraulic fracturing for recovery of oil and gas resources, livestock watering, and cooling during power generation.

Using Brackish Groundwater

The feasibility of using brackish groundwater may be limited by factors such as the concentration of individual ions or the ability of subsurface materials to yield groundwater in sufficient volume, but these factors do not necessarily preclude brackish groundwater as viable supply. For example, water high in dissolved solids may initially be unusable for drinking water, but concentrations can sometimes be reduced using processes like reverse osmosis, or by blending brackish water with freshwater supplies. Brackish groundwater supplies may also be used for a variety of purposes other than drinking water, such as for cooling during power generation, irrigation, livestock watering, aquaculture, and in the oil and gas industry for drilling, enhanced recovery, and hydraulic fracturing.

Some chemical constituents may be found in brackish groundwater at concentrations high enough to be of concern for certain uses. Of the many constituents analyzed in brackish groundwater samples during the national assessment, arsenic, nitrate, and uranium were most likely to be present in southwest aquifers in concentrations greater than drinking-water standards allow. This finding corroborates results from other groundwater-quality studies of the southwestern United States (Thiros and others, 2014).

The Basin and Range basin-fill aquifers contained the largest percentage of brackish groundwater samples that exceeded livestock consumption standards for constituents such as arsenic, boron, and fluoride. In other principal aquifers, however, untreated brackish groundwater was found to generally be within criteria for livestock. Arsenic, boron, or fluoride are also potential concerns where untreated brackish groundwater is used for irrigation.

Other chemical characteristics can also limit brackish water use; for example, mineral scaling can impede conveyance, storage, and treatment of brackish groundwater.

The feasibility of using brackish groundwater as a resource is limited in some parts of the Nation, where groundwater yields are low. In the southwestern United States, however, well yields of brackish groundwater appear to be sufficiently high (see table 1). About 80 percent of the wells evaluated in the assessment had yields greater than 100 gallons per minute, and almost 60 percent of the brackish wells reported yields greater than 1,000 gallons per minute. Although compaction and cementation of deep deposits could limit development of brackish groundwater resources in some areas, reported yields indicated that both shallow and deep wells produce adequate amounts of brackish water for many uses.

Toward Resource Development

The USGS national brackish groundwater assessment has provided updated basic information about the occurrence and characteristics of brackish aquifers in the southwestern United States, and has indicated areas of interest for future research in the development of this resource. For more information about the national brackish groundwater assessment, visit https://water.usgs.gov/ogw/gwrp/brackishgw/, where data compiled from more than 30 national, regional, state, and local sources are available for download.

The next task toward development of brackish groundwater as a usable resource is to acquire detailed water chemistry and aquifer information for specific areas of interest. These data are needed to evaluate the sustainability of brackish groundwater development, including the potential effects of brackish groundwater withdrawals on adjacent water resources.

Interactions between groundwater and subsurface evaporite minerals, like the gypsum in the photo above, can increase the dissolved-solids content of groundwater, making it more brackish. Below, a U.S. Geological Survey scientist prepares to sample a municipal well near Phoenix, Arizona, as part of one of many ongoing groundwater-monitoring programs in the Southwest. Both photographs by David Anning, U.S. Geological Survey.

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