Section 6.—Conceptual Understanding and Groundwater Quality of the Basin-Fill Aquifer in Las Vegas Valley, Nevada

By Jena M. Huntington

in

Conceptual Understanding and Groundwater Quality of Selected Basin-Fill Aquifers in the Southwestern United States

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Contents

Figures

Tables

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Basin Overview

Las Vegas Valley in southern Nevada is characteristic of basin and range topography. The valley is bounded by high mountain peaks surrounding a valley floor underlain by thick unconsolidated sediments that contain a basin-fill aquifer. The valley is about 30 mi wide and 50 mi long (approximately 1,640 mi^2) (fig. 1). The Spring Mountains to the west and northwest of the valley rise to an altitude of about 11,900 ft at Mount Charleston. The altitude of the valley floor sits at about 1,600 ft and drains southeastward through Las Vegas Wash into Lake Mead on the Colorado River, at about 1,200 ft. Other mountain ranges bordering Las Vegas Valley include the Sheep Range to the north, the Las Vegas Range to the northeast, the McCullough Range to the south, the River Mountains to the southeast, and Frenchman Mountain and Sunrise Mountain to the east.

Plume (1989, p. A2) divided Las Vegas Valley into three physiographic units: mountains, piedmont surfaces, and valley lowlands. The mountain blocks are separated from the valley lowlands by long, gently sloping, laterally continuous piedmont surfaces. These sloped surfaces were interpreted as coalescing alluvial fans in early investigations (Longwell and others, 1965, p. 6; Malmberg, 1965, p. 11), but have since been interpreted as pediment surfaces of older basin-fill deposits (Bell, 1981, p. 10).

The climate of Las Vegas Valley is considered arid, with about 4.5 in/yr of precipitation on the valley floor (period of record 1971–2000; National Oceanic and Atmospheric Administration, 2002, p. 12). Higher altitudes in the Spring Mountains can receive more than 24 in/yr. Mean annual temperature is 68°F on the valley floor (period of record 1971–2000; National Oceanic and Atmospheric Administration, 2002, p. 8), although typically daily high temperatures are 90°F or warmer on more than 125 days each year (Houghton and others, 1975, fig. 22).

In the past, most of the valley's population has resided in the lowlands, although recent expansion to the west, northwest, and southwest has been onto the sloping pediments that formerly were rangeland. The city of Henderson is on a piedmont surface. Further expansion of the urban areas is towards the pediment/mountain contact in the western, southern, and eastern parts of Las Vegas Valley. The population in the Las Vegas area increased from about 795,000 in 1990 to about 1,367,000 in 2000. By 2005 the population had increased by an additional 28 percent, to about 1,752,000 (fig. 2) (Nevada State Demographer's Office, 2009). Corresponding gross water use in the valley, almost all of which was for public supply, was about 325,100 acre-ft in 1990 (Coache, 1990, p. 5), about 529,800 acre-ft in 2000 (Coache, 2000, p. 5), and about 541,300 acre-ft in 2005 (Coache, 2005, p. 5). Surface water from Lake Mead contributed at least 80 percent of the water used in the valley during this same period (1990–2005) for each of these years.

Water Development History

The earliest known people to use water in Las Vegas Valley were the Anasazi, Mojave, and Paiute tribes (Wood, 2000, p. 2). Near the Old Spanish Trail (Mendenhall, 1909, p. 26), the area was named Las Vegas, which is Spanish for "the meadows", due to the lush grassy vegetation surrounding large springs near the center of the valley. In 1844, John C. Fremont described the area as having "…two narrow streams of clear water, 4 or 5 ft deep, with a quick current, from two singularly large springs" (Mendenhall, 1909, p. 92). The next few years saw failed lead mining and farming attempts, but by 1865 the first productive ranch was established. A railroad was built to the valley in 1905 because of its location between Los Angeles and Salt Lake City and its readily available water supply to operate the steam locomotives. Growth of the railroad increased the demand for water, and in 1905 the first well was drilled by the Las Vegas & Tonopah Railroad (Maxey and Jameson, 1948, p. 5; Wood, 2000, p. 8). By 1912, about 125 wells had been drilled in Las Vegas Valley, of which more than half were flowing-artesian wells (Pavelko and others, 1999, p. 52).

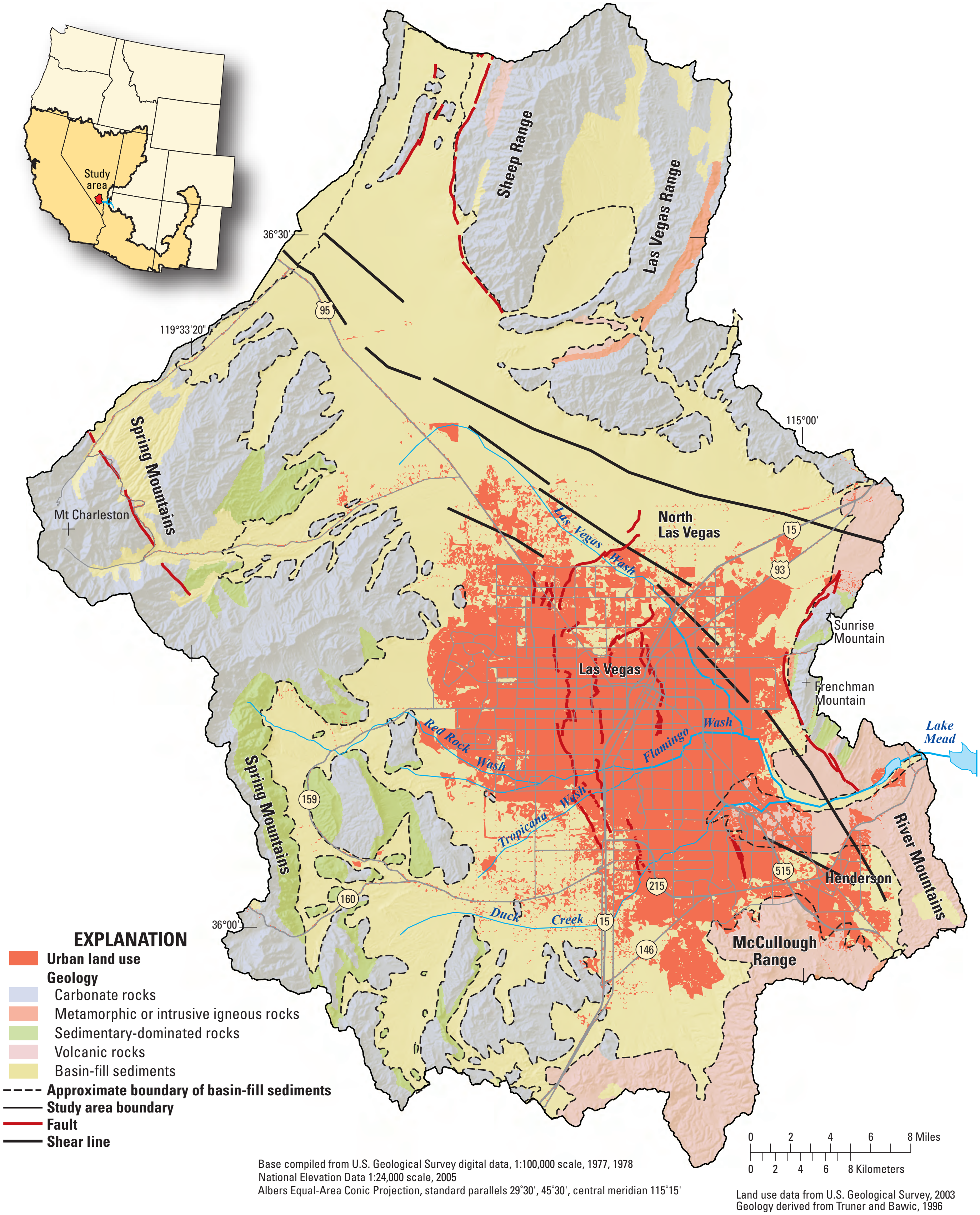

Figure 1. Physiography, land use, and generalized geology of Las Vegas Valley, Nevada.

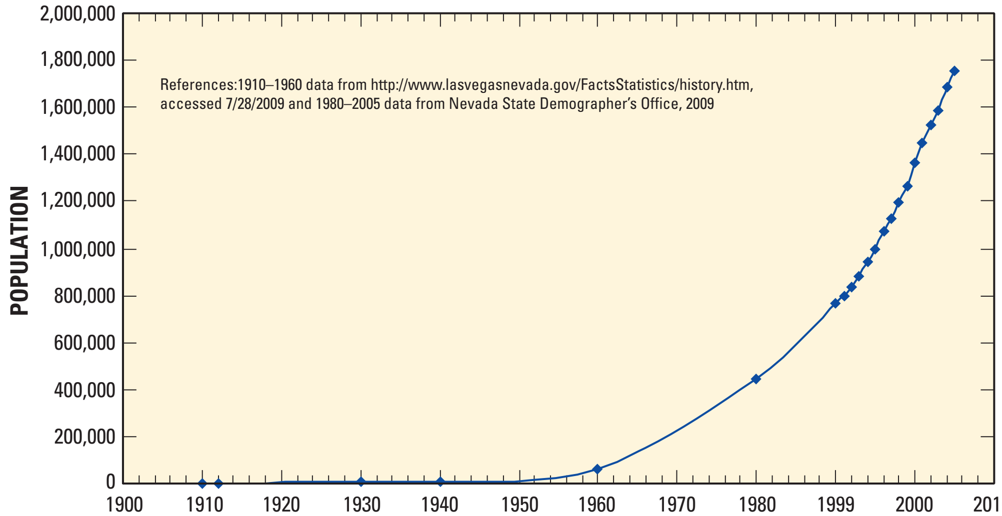

Figure 2. Historical population estimates for Las Vegas Valley, Nevada.

The construction of Boulder Dam (later named Hoover Dam) and Lake Mead began on the Colorado River in 1932. This large-scale project, which provides water and power to Las Vegas, brought in workers from all over the country, thereby accelerating growth in the valley. Industry, including military and gambling, were attracted to Las Vegas throughout the 1940s and 1950s by the availability of land, water, and electrical power. Groundwater development rapidly increased in the valley in the early 1940s and water levels declined in response. Rangeland and agricultural land was urbanized. In 1942, the City of Henderson constructed a pipeline to import Lake Mead water for industrial needs, and in 1955, the Las Vegas Valley Water District began using this pipeline to supplement it's public supply (Wood, 2000, p. 11).

In 1971, the Southern Nevada Water Project constructed a second, larger pipeline to import water from Lake Mead to meet additional water demands of the expanding population (Harrill, 1976, p. 21). Prior to construction of this pipeline, groundwater was the main source of supply for Las Vegas Valley. Projected population growth and federal limits on the importation of water from Lake Mead to the valley ensure a continued need for local groundwater resources (Pavelko and others, 1999, p. 63). Artificial recharge of Colorado River water through injection wells began in 1987, and nearly 16,000 acre-ft/yr was recharged in 2005 (Coache, 2005, p. 4).

Hydrogeology

Basin and Range extensional faulting during the Pliocene epoch broke up Precambrian- and Paleozoic-age carbonate rocks, Permian- through Jurassic-age clastic rocks, and early Tertiary-age igneous rocks into blocks that surround and underlie Las Vegas Valley. Carbonates, siltstone, and sandstone are the primary rock types to the west, north and east; while Tertiary-age volcanic rocks overlie Precambrian-age metamorphic and granitic rocks to the south and southeast (fig. 1). Sediment derived from these rocks fill the basin. Carbonate rocks may transmit groundwater through fractures and solution channels to the basin-fill deposits in the valley, but the other consolidated rocks in the area are likely to be barriers to groundwater flow.

Material eroded off the steep, uplifted mountain blocks has filled the basin with gravel, sand, silt and clay to thicknesses from 3,000 to 10,000 ft (Page and others, 2005, p. 47-48). The basin is interpreted to consist of a deeper depression (5,000 to 13,000 ft deep) beneath most of Las Vegas Valley (Page and others, 2005, fig. 6A) and, on the basis of geophysical data (Morgan and Dettinger, 1996, p. B22), a shallower consolidated-rock surface (less than 1,000 ft deep) on the western side of the valley.

Semiconsolidated material fills most of the valley, and the boundary between Quaternary- and Tertiary-age sediments is not known. The uppermost 1,000 ft of unconsolidated basin-fill deposits are the most productive part of the valley's groundwater system and generally consist of coarse-grained deposits associated with alluvial fans near the mountain fronts grading to predominantly fine-grained lacustrine or playa deposits interfingered with poorly sorted material and thin layers of sand and gravel in the lower parts of the valley (Plume, 1989, p. A10). The basin-fill deposits generally have higher hydraulic conductivities on the northern and western sides of the valley, where basin-fill sediments are derived mostly from carbonate rocks, than on the southern and eastern sides, where sediments are derived from mostly volcanic rocks (Kilroy and others, 1997, p. 9). Layers of sediment are laterally discontinuous because of the varying depositional environments. The precipitation of calcium carbonate from water in the alluvium has formed layers of cemented sediment (caliche) in the subsurface throughout the valley (Covay and others, 1996, p. 16).

Conceptual Understanding of the Groundwater System

The Las Vegas Valley is an open, sediment-filled basin with a complex aquifer system due to laterally and vertically discontinuous layers of clay, silt, sand, gravel, and caliche (fig. 3). Consolidated carbonate-rock aquifers are likely present beneath the sediments, but are not currently used as sources of water supply. The basin-fill deposits contain shallow and near-surface aquifers underlain by a more productive aquifer, called the developed-zone aquifer by Morgan and Dettinger (1996, p. B23) and the principal aquifer by Harrill (1976, p. 11). The most productive part of the basin-fill aquifer is within the uppermost 1,000 ft of sediments on the western side of the valley. The composite depth to water ranges from about 45 to 210 ft in the northern & northwestern parts of the valley, from about 20 to 510 ft in the west-central part, from 0 to about 75 ft in the central part, from about 15 to 110 ft in the east-central part, from flowing (above land surface) to about 30 ft in the southeastern part, and from about 30 to 380 ft in the southern part of the basin (U.S. Geological Survey, 2009a; Nevada Department of Water Resources, 2009; Las Vegas Valley Water District, 2009).

Shallow groundwater can occur within the upper 30 ft of laterally heterogeneous saturated sediments (Van Denburgh and others, 1982, p. 9) although these sediments generally have low hydraulic conductivity and the water is usually prevented from moving deeper than about 50 ft below land surface by impermeable clays or caliche deposits (Southern Nevada Water Authority, 2007). The shallow aquifer is recharged primarily by infiltration of excess irrigation water applied to urban landscapes; this recharge has greatly increased the extent of the shallow aquifer from that of under predevelopment conditions although it is also locally sustained by upward leakage from the deeper aquifer (Malmberg, 1965). Discharge from the shallow aquifer is by evapotranspiration (ET) and by seepage into Las Vegas Wash (Covay and others, 1996, p. 44). In some areas to the northwest of Las Vegas, the shallow aquifer is perched as a consequence of declining water levels in deeper aquifers resulting from groundwater withdrawals. Water in the shallow aquifer is not used as a drinking-water supply.

A near-surface aquifer is present locally within approximately the upper 200–300 ft of primarily fine-grained sediment in the central and eastern parts of Las Vegas Valley. Water occurs in lenses of sand and gravel interbedded with thicker layers of clay and silt that impede downward movement to the underlying principal aquifer. Under natural conditions, recharge was mostly by upward flow from the deeper confined aquifer, but with development, the near-surface aquifer is now also recharged by infiltration of excess irrigation water, leaking sewer lines, and industrial wastewater (Harrill, 1976, p. 11 and fig. 4).

The principal aquifer typically extends from depths of about 200–300 ft to about 1,000 ft below land surface in the central part of the valley and from the water table to about 1,000 ft below land surface along the sides of the valley. Layers and lenses of sand and gravel become separated by layers of clay and silt that create semiconfined to confined conditions toward the middle of the valley (Harrill, 1976, p. 11). The principal aquifer is more productive than the near-surface aquifer and is a source of public-supply water for Las Vegas Valley. Estimates of transmissivity for the principal aquifer range from 500 ft^2/d in the eastern part of the valley (Morgan and Dettinger, 1996, fig. 3.3.1-2) to greater than 14,000 ft^2/d in the western part (Plume, 1989, p. A10-A11). Transmissivity values based on aquifer test results from the northwestern part of the valley have been estimated to be as high as 30,000 ft^2/d (Joseph Leising, Southern Nevada Water Authority, written commun., 2009).

Water in basin-fill deposits deeper than about 1,000 ft probably constitutes a large percentage of the valley's storage capacity, but this deep aquifer is less permeable than the overlying material and yields little water to wells (Morgan and Dettinger, 1996, p. B23). Groundwater likely moves into and out of the deep aquifer from the surrounding and underlying consolidated rock and the overlying principal aquifer.

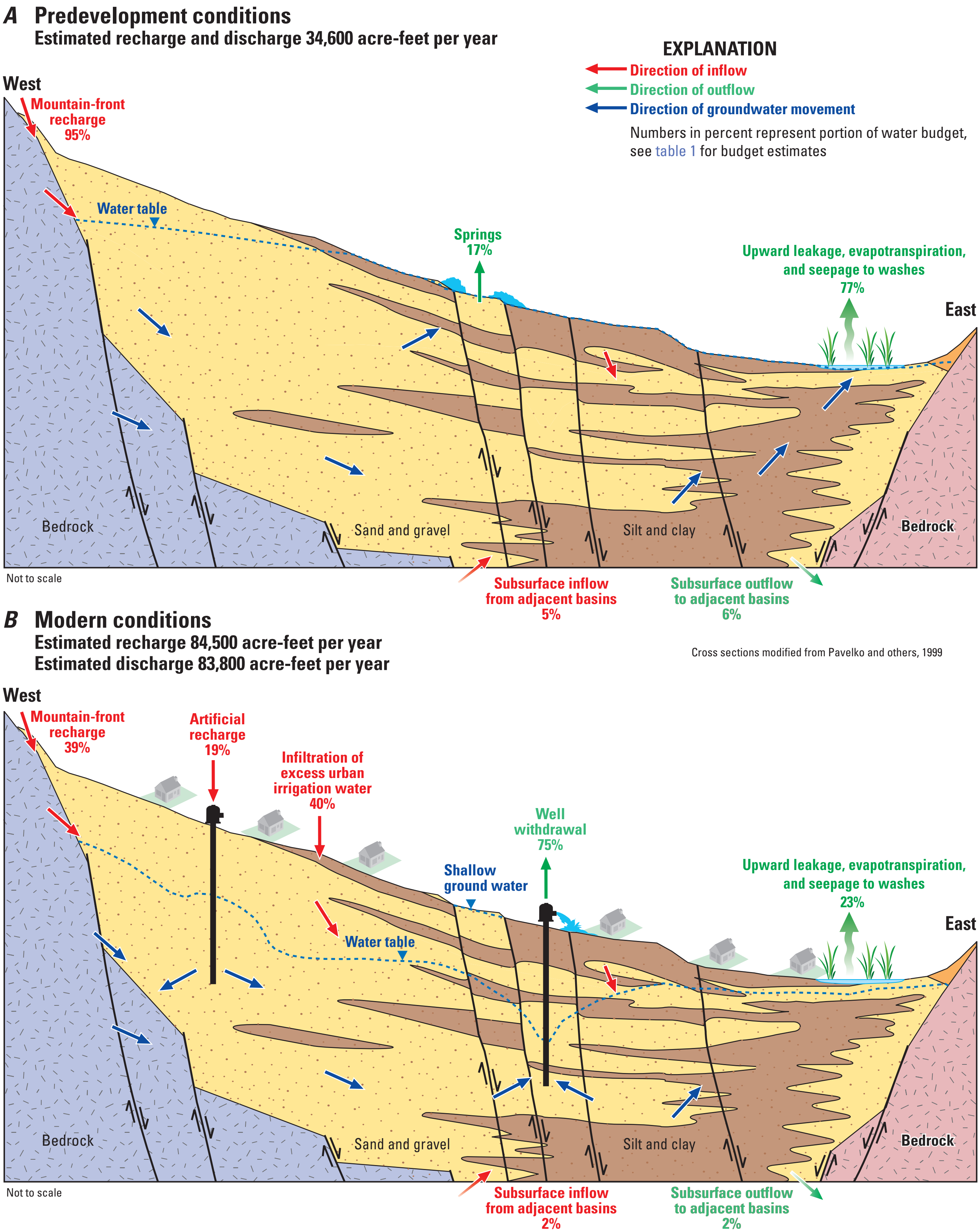

Figure 3. Generalized cross-sections for Las Vegas Valley, Nevada, showing the basin-fill deposits and components of the groundwater flow system under (*A*) predevelopment conditions and (*B*) modern conditions.

Water Budget and Groundwater Flow

Prior to urban development in Las Vegas Valley, recharge to the basin-fill deposits originated primarily as precipitation on the Spring Mountains and the Sheep Range (Bell, 1981, p. 22). This natural recharge entered the principal aquifer along the mountain front either as subsurface inflow from fractures in the consolidated rock, as runoff from the rock, or by a combination of these paths. Under predevelopment conditions, groundwater flowed from the northwest and west across the valley to the southeast and east (fig. 4) (Harrill, 1976, fig. 23). Discharge from the basin-fill aquifer system was by springflow, subsurface outflow to adjacent basins, and ET. Stream channels (washes) in Las Vegas Valley were generally dry, except during floods, with the exception of flow supported by discharge from the larger springs in the central part of the valley (Wood, 2000, p. 2 and fig. 3; Jones and Cahlan, 1975, p. 3-4 and 8).

Estimates of natural recharge along the mountain fronts to Las Vegas Valley made in previous studies and listed by Lopes and Evetts (2004, appendix 1) range from 25,000 to 35,000 acre-ft/yr. Donovan and Katzer (2000) calculated about 51,000 acre-ft of natural recharge to the valley using a modified Maxey-Eakin methodology (Maxey and Eakin, 1949; Eakin and others, 1951) that accounted for greater total precipitation at high elevation in the surrounding mountain blocks. Mountain-front recharge of 33,000 acre-ft/yr was simulated by a groundwater flow model for the valley constructed by Morgan and Dettinger (1996, p. B70), and that value is used in the predevelopment groundwater budget listed in table 1. About 1,600 acre-ft/yr is estimated to enter Las Vegas Valley as subsurface inflow from basins to the southwest (Glancy, 1968).

Discharge from the principal aquifer under predevelopment conditions was primarily by the upward leakage of water to the near-surface and shallow aquifers and then by ET. Evapotranspiration of about 27,000 acre-ft/yr was estimated by Malmberg (1965, table 17) and a value of 24,000 acre-ft/yr was simulated in the model of Morgan and Dettinger (1996, p. B75). Devitt and others (2002) modified the estimates of where ET occurred in the valley before development, as well as estimates of consumptive-use rates, to calculate a much higher discharge by ET of about 40,000 acre-ft/yr.

Major springs in Las Vegas Valley discharged along fault scarps in the basin-fill deposits (fig. 3*A*). Offset along the faults likely caused water that was moving laterally through permeable aquifer layers to be forced upward at contacts with less permeable material (Malmberg, 1965, p. 59). Spring flow in the valley before water development began, estimated to be 6,400 acre-ft/yr by Maxey and Jameson (1948, p. 95), was simulated at 6,000 acre-ft/yr by Morgan and Dettinger (1996, p. B75). Only a small amount of springflow and ephemeral streamflow is thought to have infiltrated into the subsurface to recharge the shallow and near-surface aquifers. Subsurface outflow to the southeast of Las Vegas Valley has been estimated to range from 400 acre-ft/yr (Rush, 1968, table 7) to 2,000 acre-ft/yr (Morgan and Dettinger, 1996, p. B70).

The Las Vegas Valley groundwater flow system has been greatly altered since the early 1900s, when water development began. Discharge from mostly flowing wells in the central part of the valley was almost 15,000 acre-ft in 1912 (Pavelko and others, 1999, p 52). Artesian pressures and the flow from springs declined as a result of the discharge from flowing wells and probably as a consequence of upward seepage from the lower sections of wells that were cased only at upper intervals (Carpenter, 1915, p. 41, p. 40-41). Groundwater pumping rates have exceeded the estimated range of natural recharge rates since the early 1950s (Pavelko and others, 1999, p. 61; Wood, 2000, figs. 2 and 5), and annual withdrawals from wells increased to a maximum of about 86,000 acre-ft in 1968 (Coache, 2005, table 7). Discharge from the largest artesian springs in the central part of the valley had virtually ceased by 1962 as a result of the pumping (Domenico and others, 1964, p. 25).

The northwestern part of Las Vegas Valley has been a major groundwater pumping area since the 1970s, and water-level declines of more than 300 ft were measured in the area by 1990 (fig. 5) (Burbey, 1995, figs. 8 and 9). Water-level declines ranging from 100 to 200 ft have been measured in the central and southeastern parts of the valley (Henderson). Pumping has created large cones of depression, both in the near-surface and principal aquifers, which have disrupted the natural direction of groundwater flow (Covay and others, 1996, p. 48). Instead of flowing generally to the southeast (fig. 4), some of the groundwater now moves toward major pumping centers. In some areas of the central part of the valley, the natural upward hydraulic gradient has been reversed such that there is little to no upward leakage from the principal aquifer. This reversal of gradient may allow leakage of poor-quality water from the land surface to the principal aquifer used for public supply (Dettinger, 1987, p. 18; Bell, 1981, p. 23, 25, and 32).

Land subsidence of more than 5 ft has resulted from groundwater withdrawals and the consequent lowering of hydraulic heads and compaction of fine-grained layers in the basin-fill deposits in areas of Las Vegas Valley. Synthetic aperture radar interferometry (InSAR) data indicate that land subsidence has occurred along a north-south trending zone punctuated by local “bowls” that are bounded by Quaternary-age faults in the central part of the valley (Bell and others, 2002, fig. 7). Although most of the withdrawals are from wells completed in the coarse-grained deposits west of the areas of maximum subsidence, it is hypothesized that these wells have intercepted groundwater that under natural conditions would have sustained the pore-water pressures in the down-gradient, fine-grained part of the aquifer system.

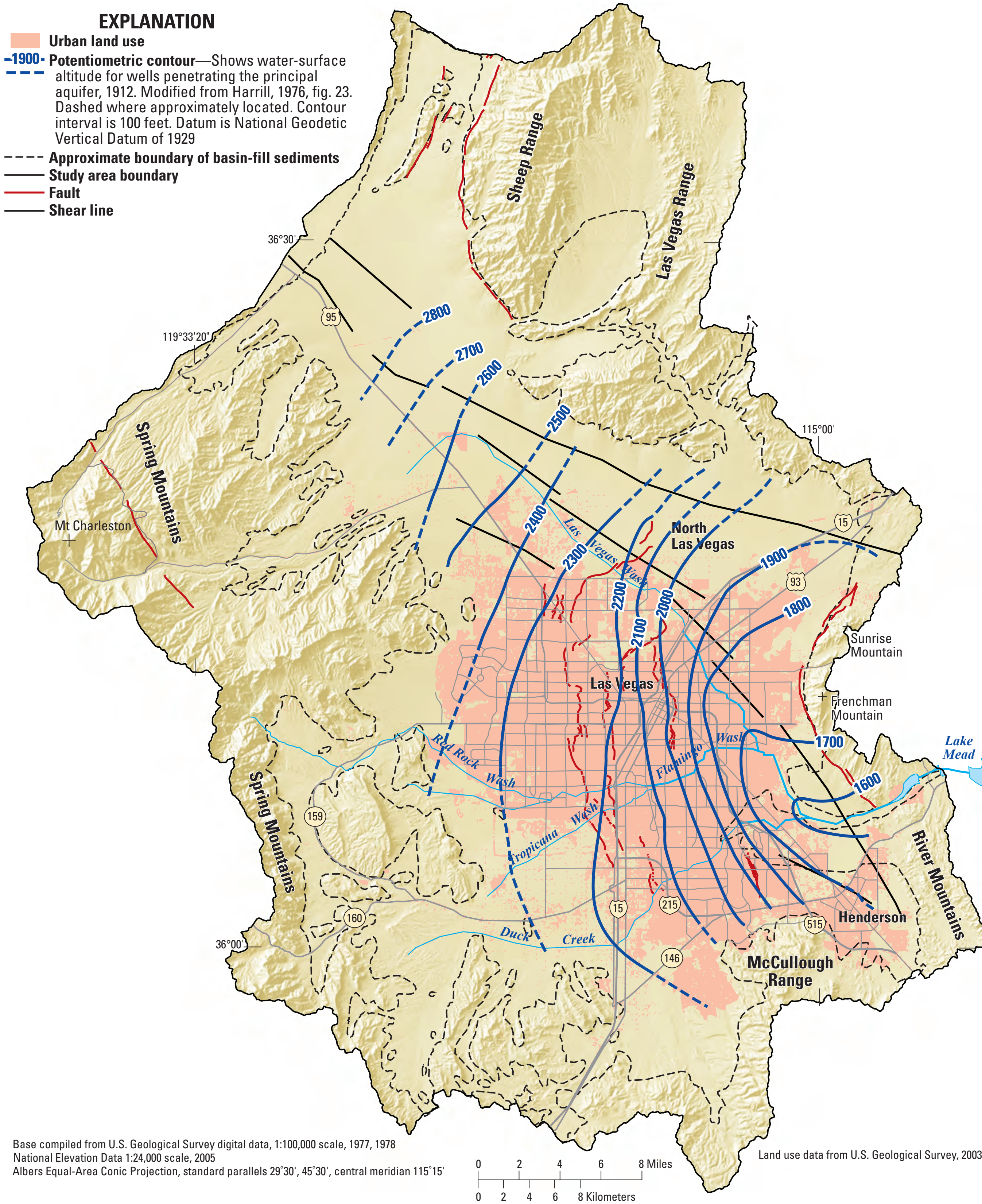

Figure 4. Approximate potentiometric surface in the principal basin-fill aquifer in Las Vegas Valley, Nevada, under predevelopment conditions.

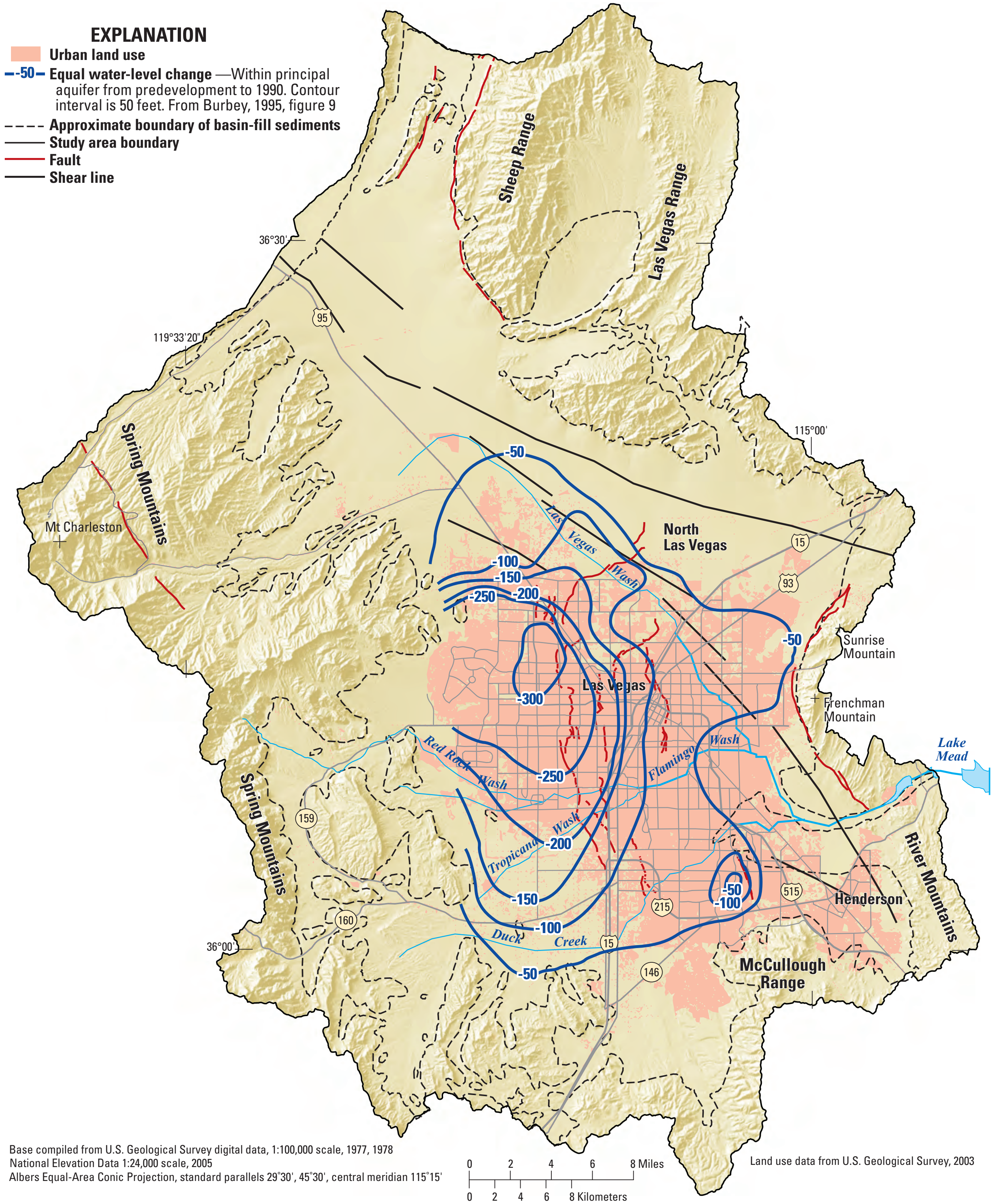

Figure 5. Groundwater-level declines from predevelopment conditions to 1990 in Las Vegas Valley, Nevada.

This results in less hydraulic pressure to support the fine-grained material in areas that have undergone land subsidence. Earth fissures, a type of subsurface ground failure resulting from sediment compaction and coincident pulling apart of the subsurface materials, are associated with groundwater withdrawals in Las Vegas Valley (Pavelko and others, 1999, p. 55-56). Earth fissures were documented as early as 1925 (Bell and Price, 1991, p. C-1) and the potential exists for these features to create pathways between water at the land surface and in the shallower aquifers to water in the deeper aquifers.

In 1971, additional water from Lake Mead was imported for public supply in Las Vegas Valley. Large-scale imports began in 1972, allowing groundwater withdrawals to subsequently decrease to 71,000 acre-ft during that year from the nearly 85,000 acre-ft withdrawn in 1971 (Coache, 2005, table 7). The injection of treated Colorado River water through wells into more transmissive parts of the principal aquifer in the northwestern and central parts of Las Vegas Valley began in 1987 (Coache, 2005, table 7; Wood, 2000, p. 10 and fig. 10). Generally, the water is injected during the winter months when the demand is least. About 32,400 acre-ft of treated Colorado River water was artificially recharged in 1999 and 15,900 acre-ft in 2005 (table 1) (Coache, 2005, table 7). Artificial recharge has allowed withdrawals from wells in the valley to be held to an average of about 71,000 acre-ft/yr for the period from 1988–2005 (Coache, 2005, table 7). Water levels have recovered almost 100 ft from 1990–2005 levels in some areas, and either subsidence has slowed or the land surface has rebounded (Bell and others, 2008, p. 2 and table 1). In areas where municipal pumpage takes place, water levels have in substantial measure been restored by artificial recharge and are maintained by adjusting pumping and recharge in conjunction with extensive monitoring (Joseph Leising, written commun., 2009).

Table 1. Estimated groundwater budget for the basin-fill aquifer in Las Vegas Valley, Nevada, under predevelopment and modern conditions

[All values are in acre-feet per year (acre-ft/yr) and are rounded to the nearest hundred. Estimates of groundwater recharge and discharge under predevelopment and modern conditions were derived from the footnoted sources. The budgets are intended only to provide a basis for comparison of the overall magnitudes of recharge and discharge between predevelopment and modern conditions, and do not represent a rigorous analysis of individual recharge and discharge components. Percentages for each water budget component are shown in figure 3]

	Predevelopment conditions	Modern conditions	Change from predevelopment to modern conditions
Budget component		**Estimated recharge**	
Mountain-front recharge	[1]33,000	[1]33,000	0
Infiltration of excess urban irrigation water	0	[2]34,000	34,000
Subsurface inflow from adjacent basins	[3]1,600	[3]1,600	0
Artificial recharge of Colorado River water	0	[4]15,900	15,900
Total recharge	**34,600**	**84,500**	**49,900**
Budget component		**Estimated discharge**	
Upward leakage, evapotranspiration, and seepage to washes	[5]26,600	[2]19,000	-7,600
Well withdrawals	0	[4]62,800	62,800
Springs	[1]6,000	0	-6,000
Subsurface outflow	[1]2,000	[1]2,000	0
Total discharge	**34,600**	**83,800**	**49,200**
Change in storage (total recharge minus total discharge)	0	700	700

[1] Simulated by groundwater flow model of Morgan and Dettinger (1996).

[2] Average of 1972–81 amounts simulated by groundwater flow model of Morgan and Dettinger (1996).

[3] Listed in appendix 2 of Lopes and Evetts (2004).

[4] Water usage in 2005 (Coache, 2005, table 7).

[5] Residual amount between total estimated predevelopment recharge and estimates of other predevelopment discharge components.

Water use in Las Vegas Valley is affected by the large population in an arid climate. About 462,000 acre-ft of imported Colorado River water and 63,000 acre-ft of pumped groundwater was used in 2005 (Coache, 2005, tables 7 and 8), mostly to irrigate the urban landscape in the valley. A minor amount of the water is actually consumed by domestic, agricultural, municipal, and industrial uses. Most of the water used in the valley either evaporates, recharges the shallow groundwater system, or flows into Las Vegas Wash as urban runoff, shallow groundwater discharge, or as treated wastewater. Wastewater from homes and businesses in Las Vegas Valley is piped to water treatment plants for processing. About 16,200 acre-ft of treated wastewater effluent was reclaimed and used to irrigate greenspace such as parks and golf courses in 2005 (Coache, 2005, table 2). The remaining treated wastewater is discharged to the lower reaches of Las Vegas Wash and the wash is now perennial as it flows into Lake Mead at a mean annual flow of about 210,000 acre-ft for years 2003–2008 (U.S. Geological Survey, 2009b).

Recharge to the shallow groundwater system, mostly from excess landscape irrigation water, was simulated at about 30,000 acre-ft in 1972, 46,000 acre-ft in 1981 (Morgan and Dettinger, 1996, p. B94), and averaged 34,000 acre-ft/yr for the period 1972–81 (table 1). Recharge from the infiltration of excess urban irrigation water was estimated to be between 50,000 and 60,000 acre-ft in 1987 (Brothers and Katzer, 1988, p. 7), and likely has continued to increase with the expansion of urban areas in the valley, especially onto the coarse-grained piedmont surfaces. This shallow groundwater would have to move through the natural barriers of fine-grained sediment and caliche to recharge the principal aquifer. Morgan and Dettinger (1996, p. B94) simulated secondary recharge water reaching the near-surface aquifer and continuing downward to the principal aquifer in some areas. The water budget listed in table 1 combines components for the shallow and principal parts of the valley's groundwater system, resulting in little change in storage. Roughly 10,000 acre-ft is estimated to be removed from aquifer storage in 2005 assuming that the principal aquifer receives no recharge from the shallow groundwater.

Effects of Natural and Human Factors on Groundwater Quality

Shallow groundwater in the Las Vegas Valley has been affected by activities at the land surface. The potential exists for contaminants from the land surface to be transported through the shallow and near-surface aquifers to the principal aquifer, where the vertical gradient is downward and where the confining layers are discontinuous or have been breached by wells or by earth movement caused by subsidence. The potential for the transport of contaminants is most likely in areas where the pumping rate in the underlying principal aquifer is high (Hines and others, 1993, p. 41).

The U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program sampled 32 shallow monitoring wells in Las Vegas Valley in 1993 (Neal and Schuster, 1996) and 22 public-supply wells completed in the deeper principal aquifer during 1993-1995 (fig. 6). Data from these samples are used to assess whether water in the principal aquifer has been affected by the overlying shallow groundwater (Lico, 1998, p. 15).

General Water-Quality Characteristics and Natural Factors

Shallow groundwater in Las Vegas Valley sampled as part of a NAWQA study is a moderately saline, magnesium, calcium-sulfate type. Sulfate concentrations were high in these samples, with a median value of 2,000 mg/L. The sulfate is likely from the dissolution of gypsum in desert soils and the recharge of treated wastewater effluent in some areas. The uranium concentration in water sampled from 5 shallow monitoring wells ranged from 7 to 56 µg/L and exceeded the drinking-water standard of 30 µg/L in 2 of the samples (Lico, 1998, fig. 3F). The source of this uranium is not known.

Concentrations of dissolved solids in water samples collected from the shallow monitoring wells ranged from 351 to 5,700 mg/L, with a median of 3,240 mg/L, although the Southern Nevada Water Authority has collected groundwater samples in eastern Las Vegas in which the concentrations of dissolved solids exceeded 10,000 mg/L (Joseph Leising, written commun., 2009). Shallow groundwater in the valley can become mineralized by ET and the dissolution of evaporite deposits. Infiltrating excess landscape irrigation water and a rising water table can dissolve salts formerly precipitated in the unsaturated sediment that can then move into the groundwater system. Water imported to Las Vegas Valley from Lake Mead has a dissolved-solids concentration of approximately 625 mg/L (Anning and others, 2007, appendix 3). Concentrations of dissolved solids exceeding 15,000 mg/L were detected in groundwater samples collected near Henderson in an area that had been an industrial complex built during World War II (Carlsen and others, 1991, p. 39).

Water from 22 public-supply wells completed in the principal aquifer as part of a NAWQA study (fig. 6) was generally a dilute calcium-sulfate type (Lico, 1998, p. 15), with pH values ranging from about 6.2 to 8.3. Sulfate concentrations in water from these wells had a median concentration of 205 mg/L, and concentrations of dissolved arsenic ranged from 1 to 11 µg/L, with a median concentration of 2 µg/L. The elevated concentrations of sulfate are likely a consequence of recharge by sulfate-enriched water from Lake Mead (Joseph Leising, written commun., 2009).

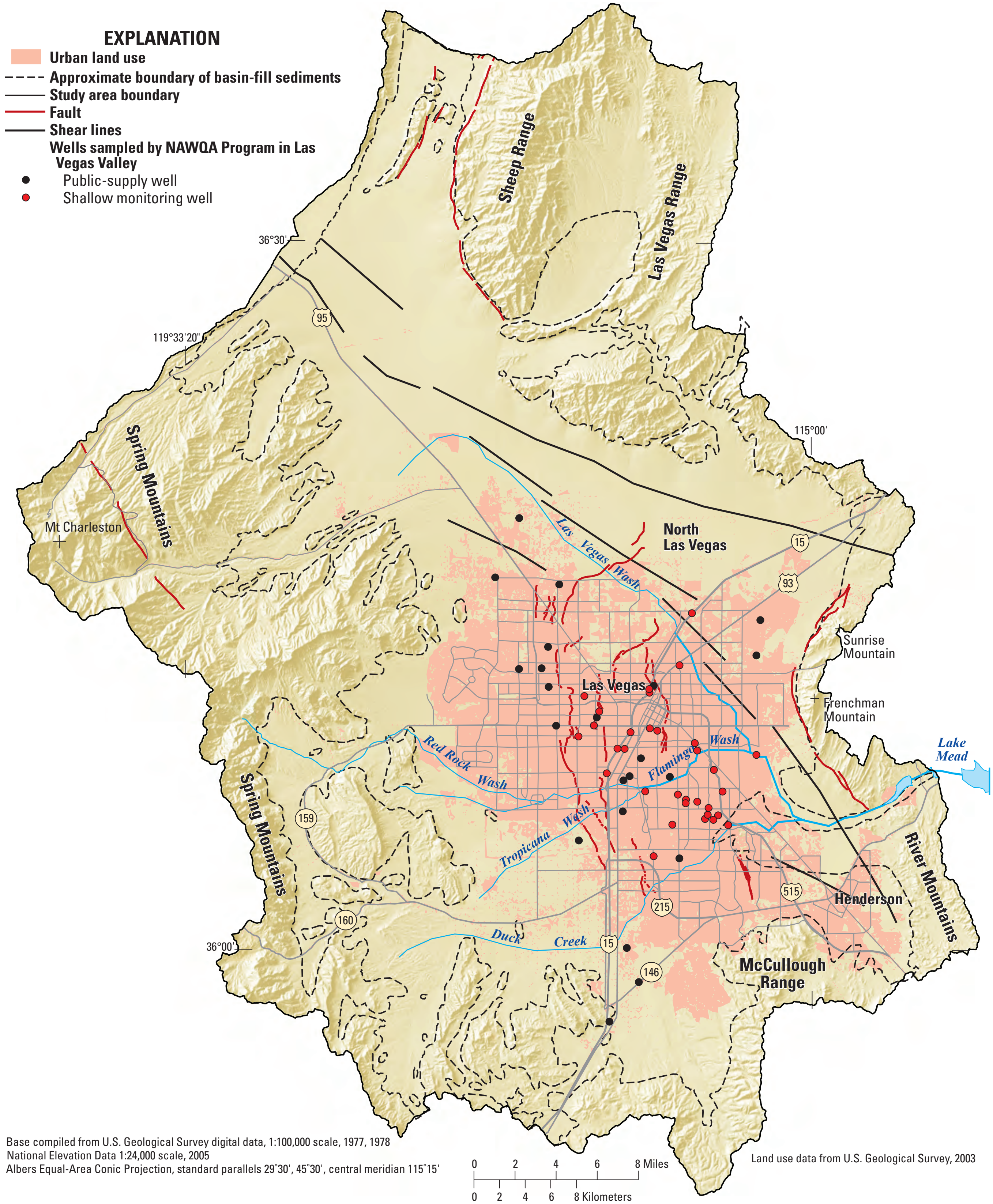

Figure 6. Location of wells sampled in Las Vegas Valley, Nevada, by the NAWQA Program.

Concentrations of dissolved solids in the principal aquifer in Las Vegas Valley typically increase from the northwestern and northern parts of the valley, where mountain-front recharge occurs, to the southeastern part of the valley, where Las Vegas Wash exits the valley (fig. 7). Dissolved-solids concentrations exceeded the secondary drinking-water standard of 500 mg/L (U.S. Environmental Protection Agency, 2008; each time a primary or secondary drinking-water standard is mentioned in this section, it denotes this citation) in samples from more than half of the 22 NAWQA sampled wells completed in the principal aquifer. The median dissolved-solids concentration in water sampled by NAWQA from the principal aquifer was 565 mg/L. The mixing of secondary recharge water and artificially recharged water imported from Lake Mead with native groundwater will likely result in an increase in dissolved-solids concentrations in parts of the principal-aquifer system in the valley.

Potential Effects of Human Factors

Factors that can affect the quality of water in the principal aquifer of Las Vegas Valley are the chemical composition of water recharged at land surface and injected into the aquifer; the reversal in hydraulic gradient caused by withdrawals from wells that can lead to downward leakage from shallow parts of the groundwater system; land subsidence resulting in the local release of poor-quality water owing to compaction of fine-grained sediments (Covay and others, 1996, p. 48); and fissures in confining layers, breaks in well casings, “leaky” well completions, and abandoned wells that allow “short circuiting” of water between aquifers (Lico, 1998, p. 21).

The effects of human activities on groundwater quality are most commonly detected in the shallow aquifer (table 2). The median nitrate concentration as nitrogen of water sampled from the 32 NAWQA monitoring wells was 4.6 mg/L, and the drinking-water standard of 10 mg/L was exceeded in 12 percent of the samples. A study of groundwater quality in the valley by Dinger (1977) showed that nitrate concentrations averaged 13 mg/L in 35 water samples from wells less than or equal to 100 ft deep and 3.2 mg/L in 250 samples from wells 100–300 ft deep. Likely sources of nitrate in shallow groundwater in Las Vegas Valley are fertilizers applied to lawns, irrigation using treated sewage effluent, and leakage from sewage disposal systems (Kaufmann, 1977, p. 85). Also, naturally occurring nitrate that has accumulated over thousands of years in desert soils can be flushed to the water table by excess irrigation water (Walvoord and others, 2003, p. 1021-1024). Hess and Patt (1977, p. 33) attributed nitrate concentrations greater than 10 mg/L in shallow groundwater in an area northwest of Las Vegas to natural sources. Nitrate concentrations as nitrogen in water from the 22 NAWQA-sampled public-supply wells were less than 2 mg/L, with a median concentration of 0.65 mg/L.

At least one volatile organic compound (VOC) was detected in 80 percent of the NAWQA samples from 31 shallow groundwater monitoring wells (1 well of 32 was not sampled) and 50 percent of the samples from 20 principal aquifer supply wells (2 principal aquifer wells were not sampled) in Las Vegas Valley. Chloroform was detected in 21 shallow groundwater samples at concentrations from 0.2 to 12 µg/L and in 10 principal aquifer samples at concentrations from 0.2 to 23 µg/L (Lico, 1998, table 2). A major source of chloroform is from the infiltration and injection of chlorinated water imported from Lake Mead and the infiltration of chlorinated groundwater applied at the land surface. Excess free chlorine in the treated water also can react with dissolved organic carbon present in the groundwater to produce chloroform. The solvent tetrachloroethylene (PCE) was detected in 8 shallow groundwater samples at concentrations from 0.2 to 89 µg/L and in 2 principal aquifer samples at concentrations of 0.4 and 21 µg/L (Lico, 1998, table 2). The drinking-water standard for PCE is 5 µg/L.

The herbicides atrazine and prometon were detected in water sampled from 3 and 5 shallow monitoring wells, respectively, and in water sampled from 2 and 1 deeper water-supply wells, respectively (Lico, 1998, table 1). These pesticides are commonly used in urban areas to control unwanted vegetation, and their presence, even at very low concentrations in a small percentage of the NAWQA-sampled wells, indicates the potential for human activities to affect the water quality of the basin-fill aquifers in Las Vegas Valley.

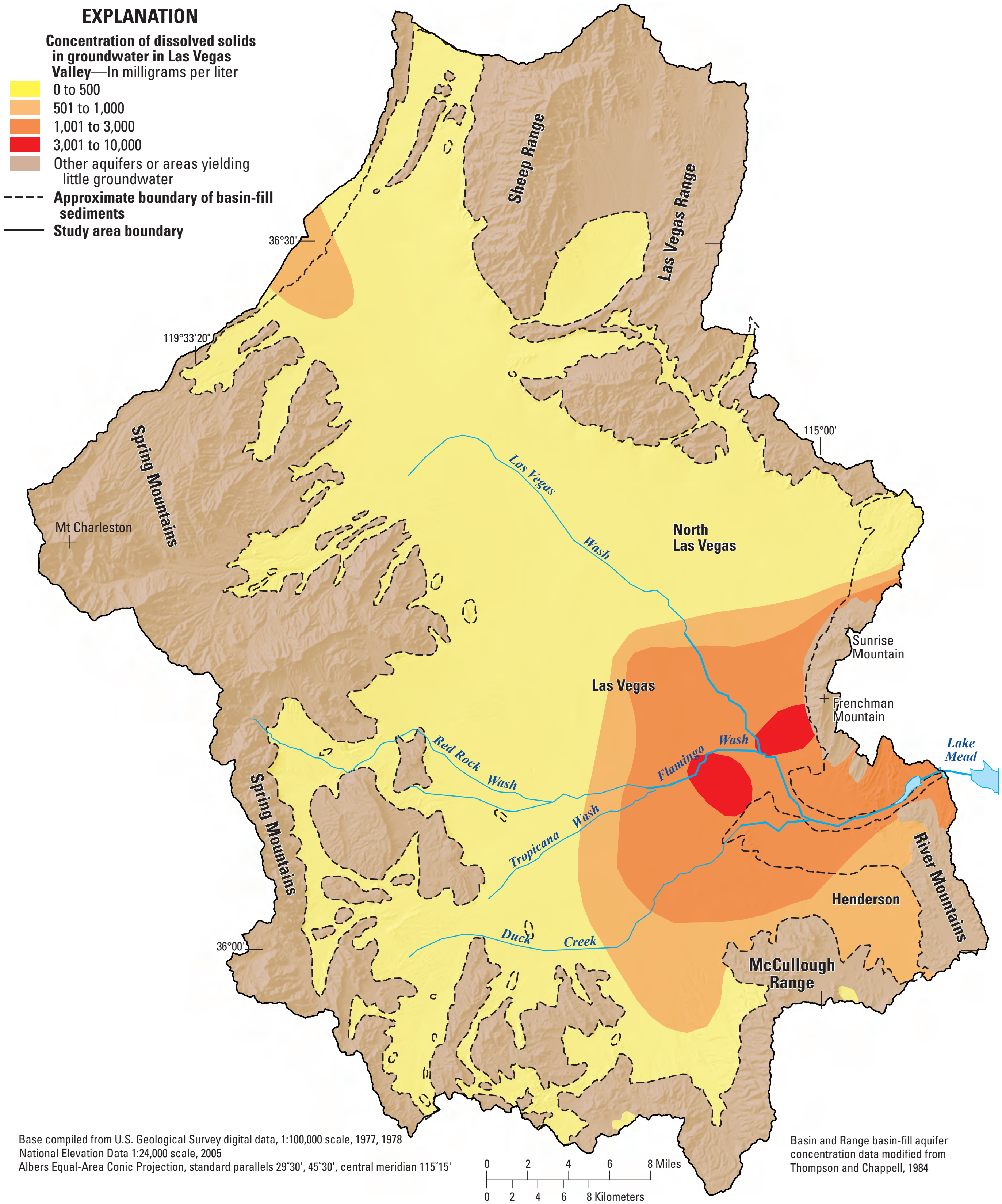

Figure 7. Concentrations of dissolved solids in groundwater in Las Vegas Valley, Nevada.

Table 2. Summary of selected constituents in groundwater in Las Vegas Valley, Nevada, and sources or processes that affect their presence or concentration.

[mg/L, milligrams per liter]

	General location	Median value or detections	Possible sources or processes
		Shallow aquifers	
Dissolved solids	Greatest in the southeast	3,240 mg/L	Evapotranspiration and dissolution
Sulfate	Basin wide	2,000 mg/L	Possibly gypsum dissolution due to irrigation with treated effluent
Nitrate	Urban areas	4.6 mg/L	Natural sources, fertilizers, treated wastewater, leaky sewer pipes, septic systems
Volatile organic compounds detections	Basin wide	71	Point sources including underground gasoline tanks and solvents from repair shops and dry cleaners
Pesticide detections	Urban areas	12	Lawn application
		Principal aquifers	
Dissolved solids	Greatest in the southeast	565 mg/L	Imported and artificially recharged Lake Mead water, dissolution
Sulfate	Central and southern	205 mg/L	Associated with altered consolidated rocks
Nitrate	Central basin/urban areas	0.65 mg/L	Natural sources, potential downward movement from shallow aquifers
Volatile organic compounds	Basin wide	40	Potential downward movement from shallow aquifers, artificially recharged Lake Mead water
Pesticide detections	Urban areas	6	Potential downward movement from shallow aquifers

Summary

Las Vegas Valley is a hydraulically open basin just east of the Spring Mountains in southern Nevada. Prior to urban development in the valley, recharge to the groundwater system originated primarily as precipitation in the headwater areas of the Spring Mountains and the Sheep Range. Groundwater flowed from the northwest across the valley to the southeast and discharged by springflow, subsurface outflow to adjacent basins, and evapotranspiration. The Las Vegas Valley aquifer system is complex due to the presence and effects of laterally and vertically discontinuous beds of clay, silt, sand, gravel, and caliche. Consolidated carbonate-rock aquifers are present at greater depth, but are not currently used as sources of water supply. The near-surface groundwater system is generally semiconfined while the deeper aquifers are confined in the central part of the valley.

Large population increases in an arid climate have resulted in a human-driven hydrologic cycle affected by groundwater pumping, artificial recharge, and secondary recharge. Pumping has created large cones of depression in parts of the valley. In areas where municipal pumping takes place, water levels have in substantial measure been restored by artificial recharge and are maintained by adjusting pumping and recharge in conjunction with extensive monitoring. Large declines in groundwater levels have caused compaction of fine-grained sediments within the principal aquifer, resulting in land subsidence of more than 5 ft and the development of earth fissures. Natural recharge to the principal aquifer is now supplemented by large volumes of secondary recharge from either pumped groundwater or imported Lake Mead water. Natural upward hydraulic gradients have also been reversed in the central part of the valley, leading to the cessation of springflow and the leakage of poorer-quality shallow groundwater into deeper aquifers.

Shallow groundwater in the Las Vegas Valley has been affected by activities at the land surface. Where the vertical gradient is downward and where the confining layers are discontinuous or have been breached by wells or by movement caused by subsidence, the potential exists for contaminants from the land surface to be transported through the shallow and near-surface aquifers to the principal aquifer. The median concentration of dissolved solids in shallow groundwater sampled by NAWQA was 3,240 mg/L. The shallow groundwater becomes mineralized as a consequence of evapotranspiration and the dissolution of evaporite deposits. Infiltrating landscape irrigation water and a rising water table can dissolve salts precipitated in the unsaturated sediment that can then move into the groundwater system. Dissolved-solids concentration in the principal aquifer typically increases from the northwestern and northern parts of the valley where mountain-front recharge occurs to the southeastern part of the valley where Las Vegas Wash exits the valley. The median dissolved-solids concentration in water sampled by NAWQA from the principal aquifer was 565 mg/L.The continued addition of artificially recharged water and secondary recharge will likely result in an increase in dissolved-solids concentrations in many parts of the groundwater system in the valley.

Other factors that can affect the quality of water in the principal aquifer of Las Vegas Valley are the chemical composition of water recharged at land surface and injected into the aquifer; the reversal in hydraulic gradient caused by withdrawals from wells that can lead to leakage from shallow parts of the groundwater system; land subsidence resulting in the local release of poor-quality water owing to compaction of fine-grained sediments; and fissures in confining layers, breaks in well casings, improper “leaky” well completions, and abandoned wells that allow “short circuiting” of water between aquifers. The effects of human activities on groundwater quality is more commonly observed in the shallow aquifer with higher median nitrate concentrations and more frequent detections of volatile organic compounds and pesticides. Likely sources of nitrate to shallow groundwater in Las Vegas Valley are fertilizers applied to lawns, irrigation using treated sewage effluent, leakage from sewage disposal systems, and the flushing of naturally occurring nitrate from the unsaturated zone. The volatile organic compound chloroform was frequently detected in the NAWQA groundwater samples. Major sources of chloroform are the infiltration and injection of chlorinated water imported from Lake Mead and the infiltration of chlorinated groundwater used for irrigation.

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