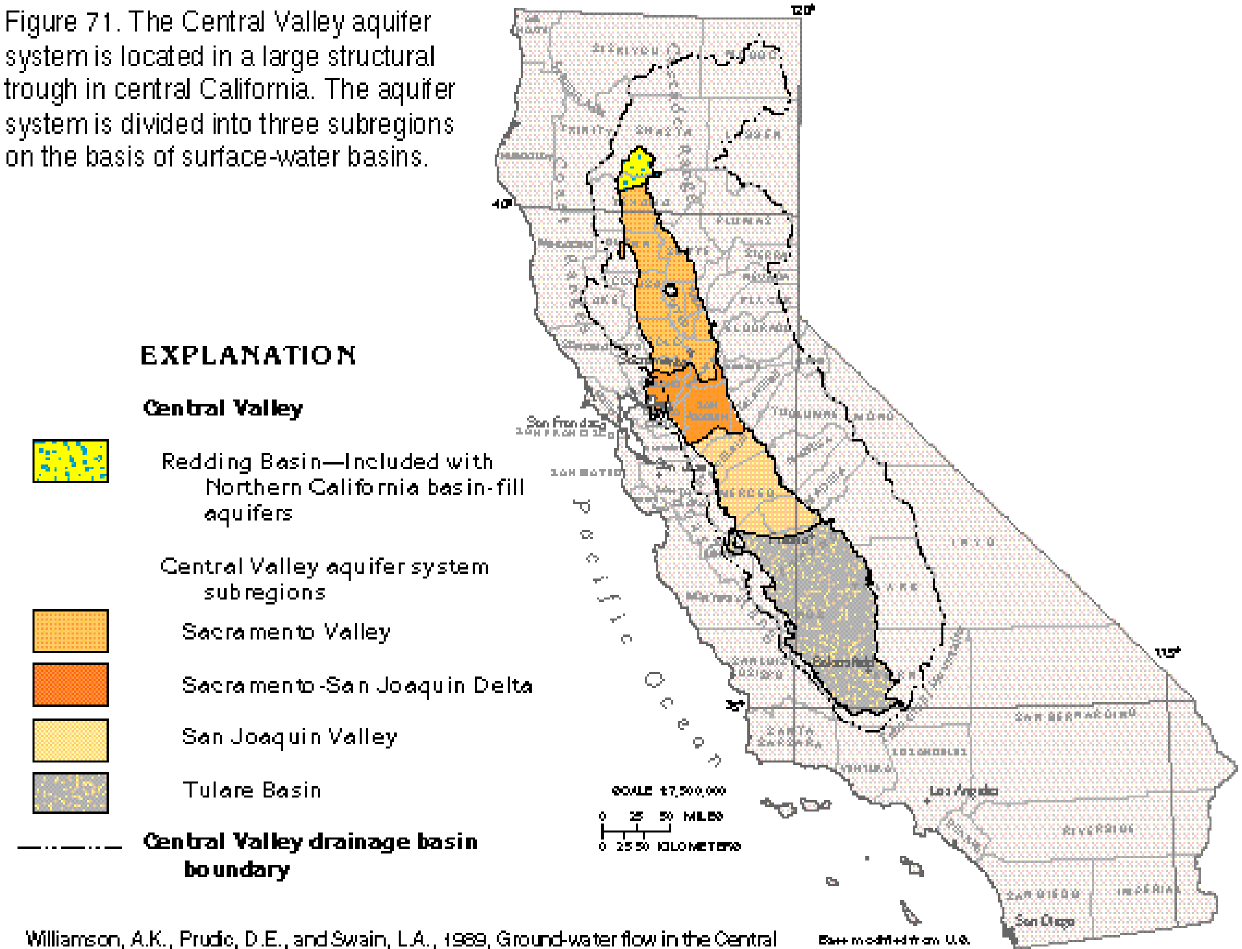
CENTRAL VALLEY AQUIFER SYSTEM

(Full report at: http://pubs.usgs.gov/ha/ha730/ch_b/B-text3.html)

INTRODUCTION

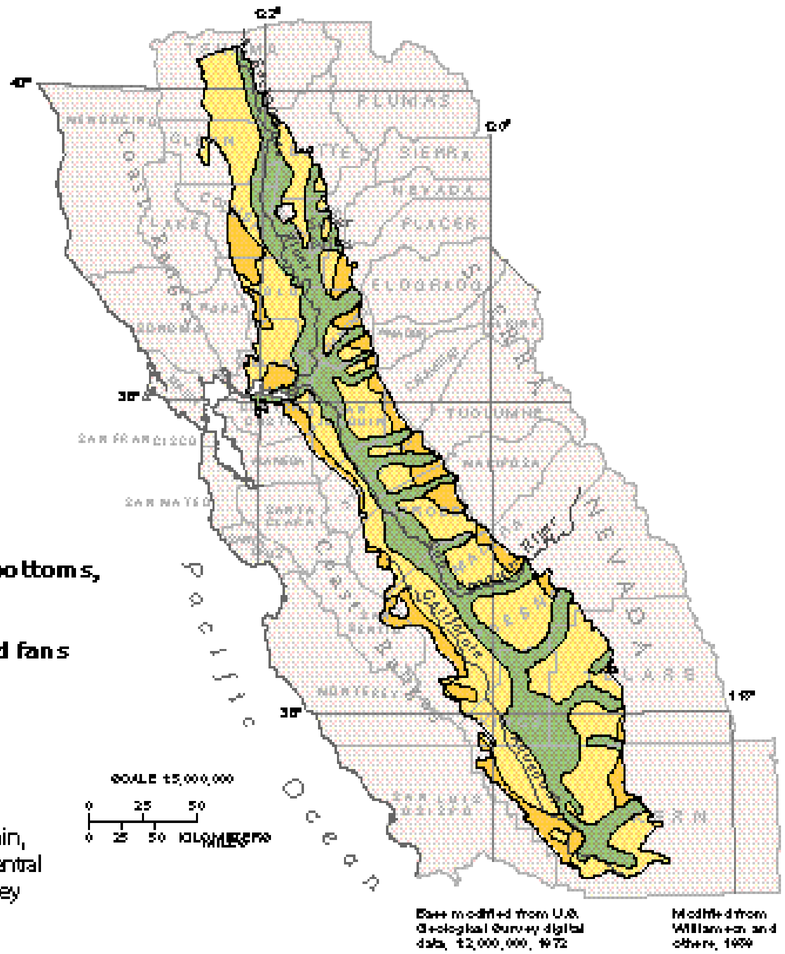
The Central Valley of California (fig. 71) is a structural trough about 400 miles long and from 20 to 70 miles wide, extending over more than 20,000 square miles. The trough is filled to great depths by marine and continental sediments, which are the result of millions of years of inundation by the ocean and erosion of the rocks that form the surrounding mountains. Sand and gravel beds in this great thickness of basin-fill material form an important aquifer system. From north to south, the aquifer system is divided into the Sacramento Valley, the Sacramento-San Joaquin Delta, and the San Joaquin Valley sub-regions, on the basis of different characteristics of surface-water basins.

Figure 71. The Central Valley aquifer system is located in a large structural trough in central California. The aquifer system is divided into three subregions on the basis of surface-water basins.



Williamson, A.K., Prudic, D.E., and Swain, L.A., 1989, Ground-water flow in the Central Valley, California: U.S. Geological Survey Professional Paper 1401–D, 127 p.

Figure 72. The valley floor is flat to slightly rolling, and consists of alluvial fans and plains, river flood plains, and dry lake bottoms. Much of the valley floor is surrounded by dissected uplands that are slightly rolling to hilly.



Williamson, A.K., Prudic, D.E., and Swain, L.A., 1989, Ground-water flow in the Central Valley, California: U.S. Geological Survey Professional Paper 1401-D, 127 p.

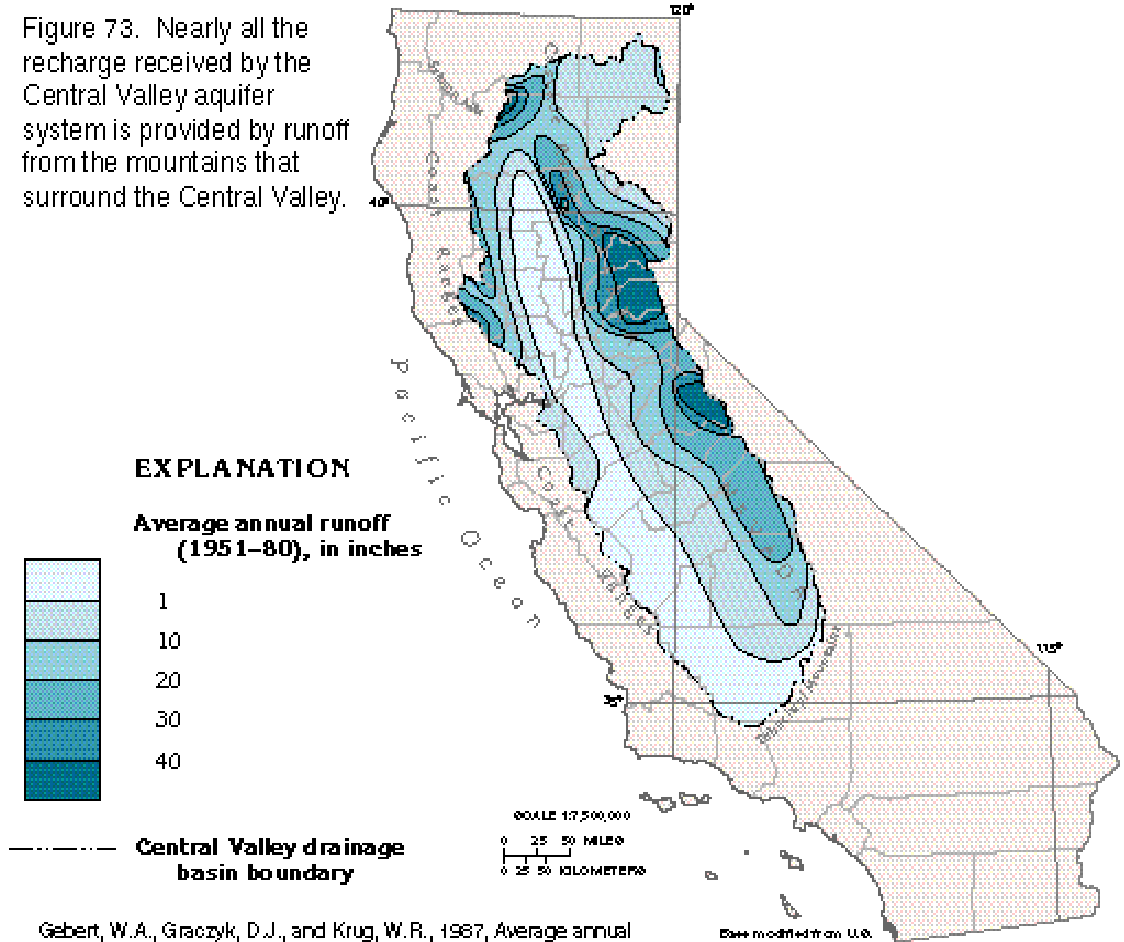
The Central Valley is bounded on the west by the Coast Ranges and on the east by the Cascade Range and the Sierra Nevada. The valley has only one surface-water outlet, the Carquinez Strait east of San Francisco Bay. Much of the valley is surrounded by dissected uplands formed by erosion of coalesced alluvial fans at the base of the mountains (fig. 72) where the terrain ranges from hilly to slightly rolling. The valley floor, which consists primarily of alluvial deposits and flood-plain deposits of the major rivers, is relatively flat to gently rolling and is generally below an altitude of 500 feet. Lake beds in the southern end of the valley become partially to completely flooded in wet years. A prominent feature, Sutter Buttes - a remnant of a volcanic plug - rises nearly 1,500 feet above the valley floor in the central Sacramento Valley.

The Sacramento River drains the northern end of the Central Valley, and the San Joaquin River drains much of the middle third. The two rivers join in the Sacramento - San Joaquin Delta and empty into the upper end of San Francisco Bay. The southern end of the valley is occupied by the Tulare Basin, in which drainage is completely internal and the inflowing water is removed by evapotranspiration.

The climate of the Central Valley is Mediterranean and Steppe, characterized by hot summers and mild winters, thus allowing for a year-around growing season; at least one crop is under cultivation at all times. About 85 percent of the precipitation falls from November to April. Most of the precipitation that falls on the valley floor evaporates before it can infiltrate downward to become recharge. Much of the moisture that moves inland from the Pacific Ocean is intercepted by the Coast Ranges, so that annual precipitation in the valley is relatively low. Annual precipitation decreases from north to south, with an average of about 23 inches in the northern part of the Sacramento Valley, to about 6 inches in the southern part of the San Joaquin Valley. Rainfall amounts vary greatly from year to year. Annual precipitation is exceeded by potential evapotranspiration throughout the entire valley, which causes a net annual moisture deficit.

In contrast, the mountains that surround the Central Valley intercept moisture from eastward-moving weather systems and have an annual surplus of moisture in the form of rain and snow. Precipitation can exceed 80 inches annually in the Sierra Nevada. Annual runoff from rainfall and snowmelt is approximately 32 million acre-feet; most of the runoff originates in the Cascade Range and the northern Sierra Nevada (fig. 73). This water flows to the valley in perennial streams and provides nearly all the average annual 12 inches of recharge the valley aquifer system receives. Runoff from the Coast Ranges is principally on the western slopes to the Pacific Ocean.

Figure 73. Nearly all the recharge received by the Central Valley aquifer system is provided by runoff from the mountains that surround the Central Valley.



Gebert, W.A., Graczyk, D.J., and Krug, W.R., 1987, Average annual runoff in the United States, 1951–80: U.S. Geological Survey Hydrologic Investigations Atlas HA–710, scale 1:7,500,000, 1 sheet

GEOLOGIC SETTING

The Central Valley and surrounding area is the product of a complex series of geologic events. The surrounding area has undergone mountain building, faulting, and erosion, and the valley has been inundated several times by the Pacific Ocean.

The Sierra Nevada, which forms the eastern side of the valley, is the eroded edge of a huge tilted block of crystalline rock that also partially defines the base of the valley sediments (fig. 74). Embedded in the granite and related plutonic rocks of the mountains are metamorphosed sedimentary and volcanic rocks of Ordovician to Late Jurassic age. The uplift that formed the Sierra Nevada probably took place between Late Jurassic and Late Cretaceous time.

The northeast corner of the basin is the southern terminus of the Cascade Range. This is an area of lava plateaus and volcanos, some of which have been active in modern times. Geologically, this area of the basin is relatively young; most of the volcanic activity was during late Tertiary to Holocene time.

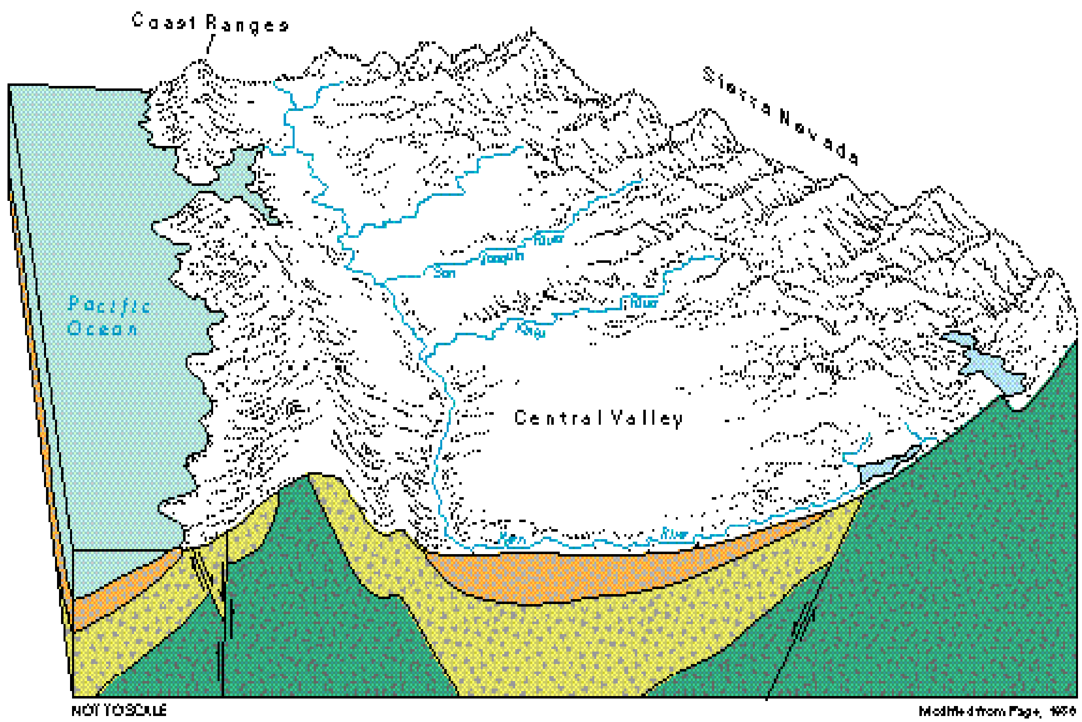
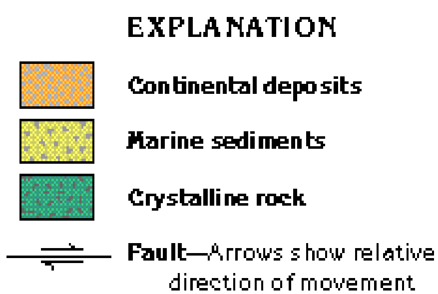


Figure 74. The Central Valley is a large structural trough that has been partially filled by marine sediments and continental deposits. The Sierra Nevada, which forms most of the eastern boundary of the valley, is the edge of a huge tilted granite block. The Coast Ranges, which form most of the western boundary, consist, for the most part, of folded and faulted marine rocks.

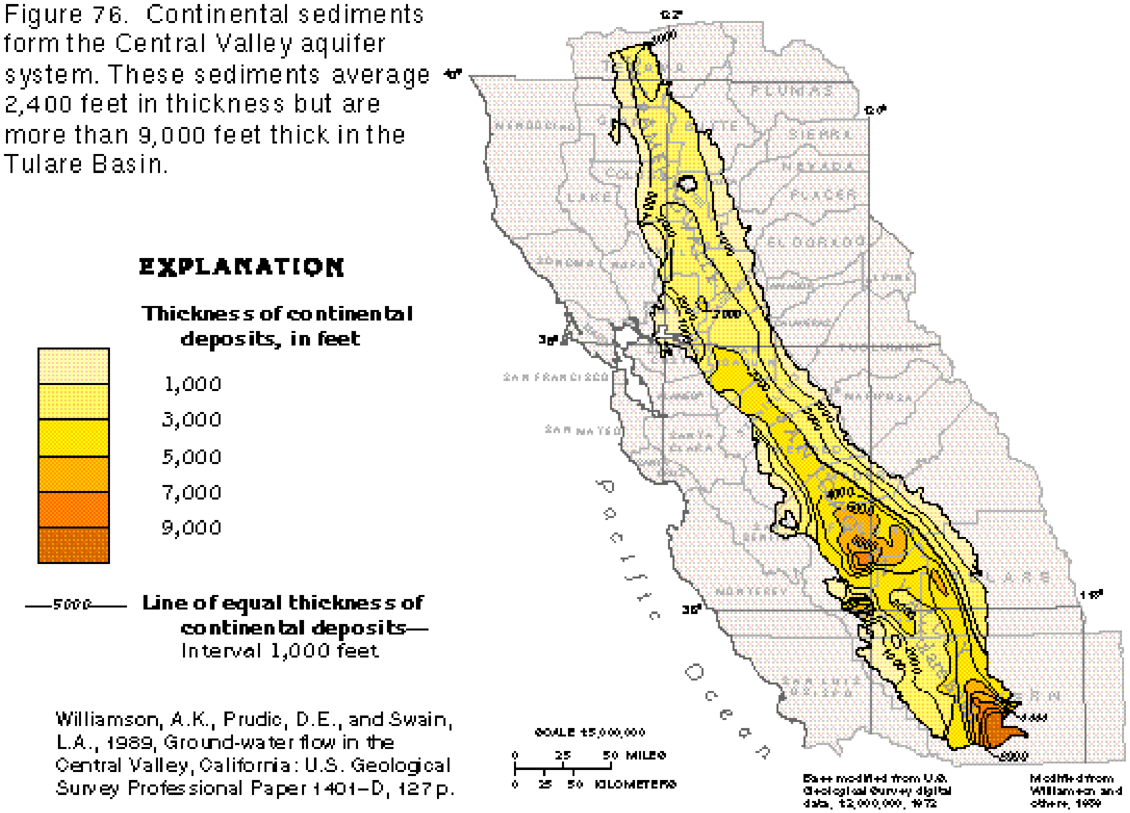


Page, R.W., 1986, Geology of the fresh ground-water basin of the Central Valley, California, with texture maps and sections: U.S. Geological Survey Professional Paper 1401–C, 54 p.

The northwest corner of the Central Valley is bounded by metamorphosed volcanic rocks of Paleozoic and Mesozoic age. These rocks form a minor part of the valley boundary. The western side of the valley is bounded by the Coast Ranges, which are formed primarily of folded and faulted marine sedimentary rocks of Mesozoic age, which were uplifted during Tertiary time. Mesozoic marine sedimentary rocks and continental deposits underlie the Tehachapi Mountains that bound the valley to the south.

A huge volume of sediments, which is as thick as about 50,000 feet in the Sacramento Valley and about 32,000 feet in the Tulare Basin, fills the Central Valley. These sediments are marine and continental in origin; the marine sediments are the product of deposition during inundations by the Pacific Ocean, and the continental sediments were derived by erosion of the rocks that formed the surrounding mountains.

Figure 76. Continental sediments form the Central Valley aquifer system. These sediments average 2,400 feet in thickness but are more than 9,000 feet thick in the Tulare Basin.



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The ancestral Central Valley was, at least in part, inundated by the Pacific Ocean until 2 million to 3 million years ago. The location, depth, and age of marine sediments in the valley indicate that nearly the entire valley was covered by the sea during Paleocene and Eocene time. As sea level declined, the area covered by the ocean decreased until only the southern end of the basin was still under water in Pliocene time. During Pleistocene and Holocene time, the sea completed its retreat, and all oceanic deposition ceased. In total, the ocean left behind deposits that ranged in thickness from about 25,000 feet in the Sacramento Valley to about 20,000 feet in the San Joaquin Valley. These deposits are mostly consolidated and have minimal permeability.

From the time when the valley first began to form, sediments derived from erosion of igneous and metamorphic rocks and consolidated marine sediments in the surrounding mountains have been transported into the valley by streams. These continental sediments are as thick as 9,000 feet at the southern end of the valley and have an average thickness of about 2,400 feet (fig. 76). The continental sediments consist mostly of fluvial, basin-fill, or lake deposits of sand and gravel inter-bedded and admixed with clay and silt. Depending upon location, deposits of fine-grained materials-mostly clay and silt-make up as much as 50 percent of the thickness of the valley-fill sediments.

Drainage Basins

Three hydrologic sub-regions coincide with drainage basins within the Central Valley. These sub-regions are hydraulically connected and compose the Central Valley aquifer system and associated surface-water drainages. The northernmost sub-region is the Sacramento Valley, which extends over the northern one-third of the Central Valley and is drained by the Sacramento River. Although the Redding Basin extends over about 500 square miles at the northern end of the Sacramento Valley and is a topographic extension of the valley, it is not included as part of the Central Valley aquifer system because of its separate ground-water flow system. Adjoining the Sacramento Valley to the south is the Sacramento - San Joaquin Delta sub-region, where a network of meandering channels has formed at the junction of the Sacramento and the San Joaquin Rivers. The

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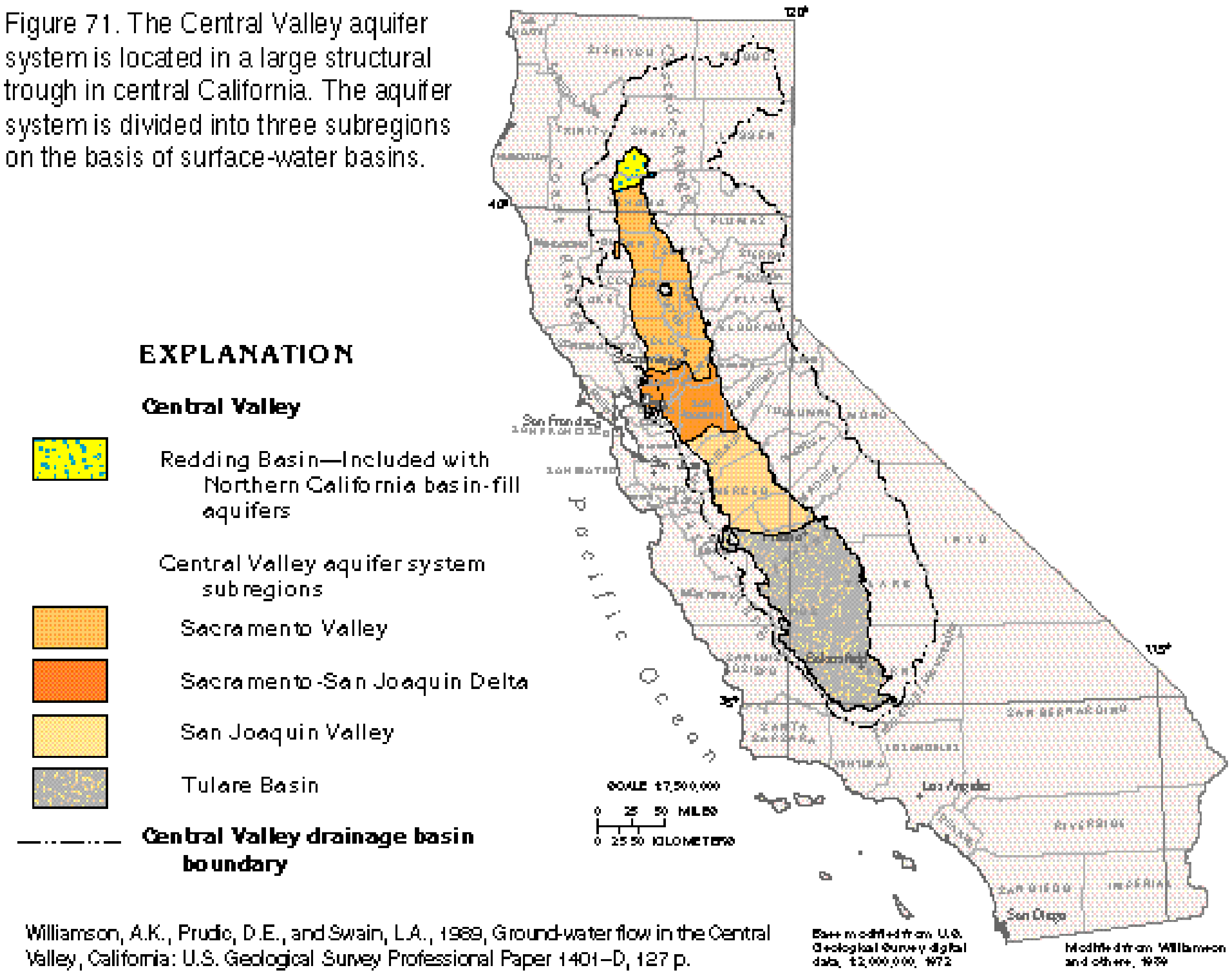

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southernmost sub-region is the San Joaquin Valley, which extends over two-thirds of the Central Valley. The San Joaquin River drains the northern part of the San Joaquin sub-region; the southern part, which is called the Tulare Basin, is characterized by interior drainage. The Tulare Basin is named for Tulare Lake, a lake that covered much of the basin during the Pleistocene Epoch.

Aquifers and Confining Units

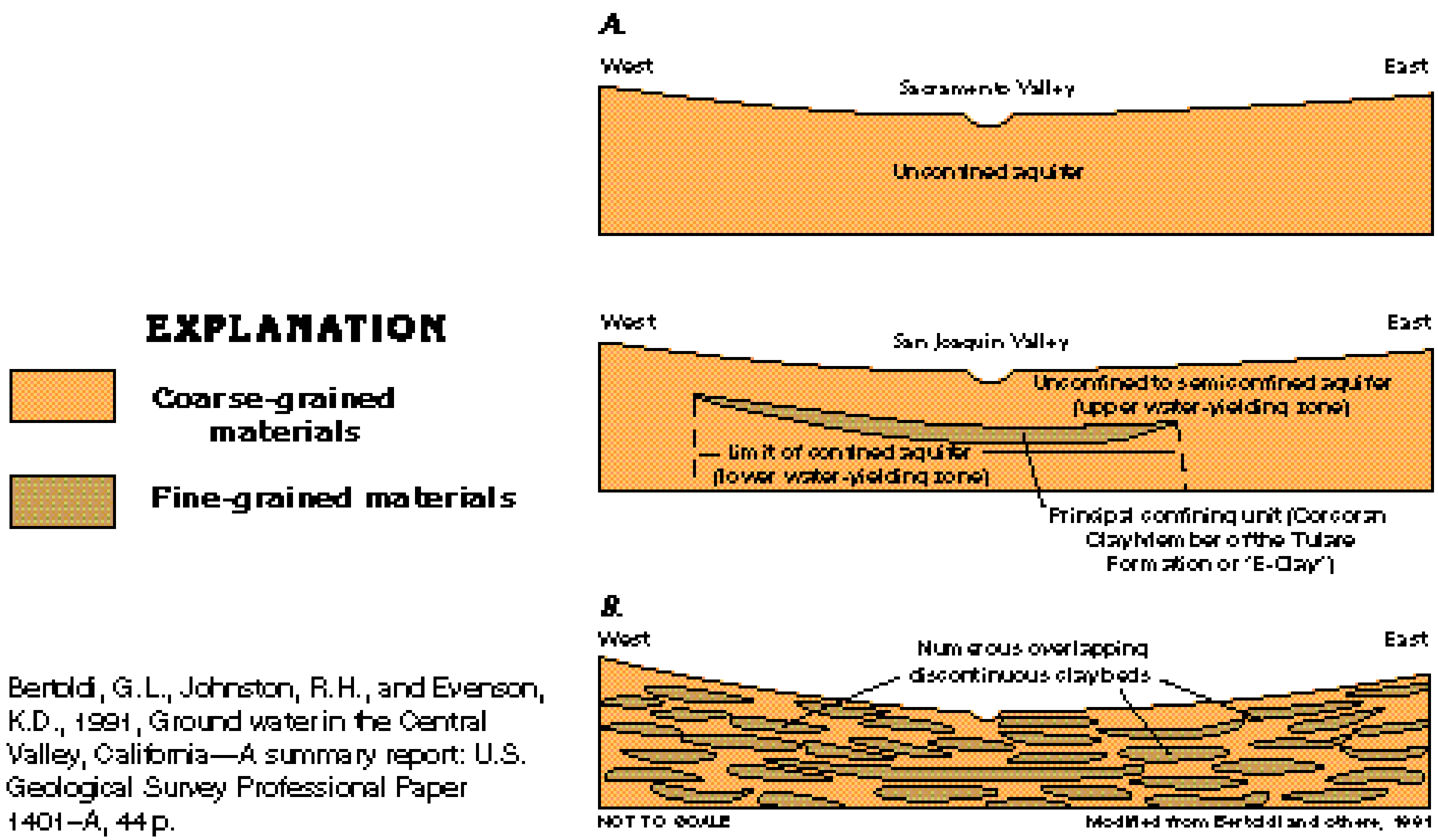
The consolidated volcanic and metamorphic rocks that surround and underlie the Central Valley are almost impermeable, and flow through them is not significant. Little water flows through the extensive deposits of consolidated marine and mixed marine and continental sediments that overlie the crystalline rocks because the permeability of the deposits is generally minimal. The marine sediments usually contain saltwater or brine, but near the northwestern, western, and southeastern margins of the San Joaquin Valley, some freshwater is withdrawn from these deposits.

The Central Valley aquifer system is formed primarily of sand and gravel with significant amounts of silt and clay, all of which have been eroded mainly from older rocks at the boundaries of the valley. The environments in which the continental sediments were deposited varied, but most were deposited in fluvial environments; however, the deposits contain some lacustrine beds. Locally, volcanic rocks and dune deposits are part of the aquifer system. Specific geologic formations can be related to specific aquifers within the Central Valley aquifer system only with difficulty because many of the formations are lithologically similar, and cannot be distinguished easily in the subsurface.

Beds and lenses of fine-grained materials, such as silt and clay, constitute a significant percentage of the Central Valley aquifer system. In most parts of the valley, fine-grained materials compose 50 percent or more of the aquifer system. The most extensive clay bed, which is informally named the "E-clay" consists primarily of the Corcoran Clay Member of the Tulare Formation and underlies much of the western San Joaquin Valley. Because beds of silt and clay do not readily transmit water under natural conditions, they act as barriers to vertical flow and cause differences in hydraulic head with depth.

Early investigators thought that the Sacramento Valley contained a single unconfined aquifer and that the San Joaquin Valley contained an upper unconfined to semi-confined aquifer separated from a lower aquifer confined by the Corcoran Clay or "E-clay". However, recent investigations indicate that the Central Valley contains a single heterogeneous aquifer system that contains water under unconfined, or water-table, conditions in the upper few hundred feet; these conditions grade into confined conditions with depth. The confinement is the result of numerous overlapping lens-shaped clay beds. Geophysical well logs indicate that the "E-clay," although probably the largest single confining bed, constitutes only a small percentage of the total thickness of clay layers in the aquifer system. This indicates that the significance of the "E-clay" as a barrier to vertical flow may have been exaggerated. Further, the difference in hydraulic head directly above and below the "E-clay" is small when compared to head differences within intervals of the deep parts of the aquifer system. (fig. 78).

Figure 78. According to early concepts of the aquifer system (A), it was generally considered to be unconfined in the Sacramento Valley and confined where the Corcoran Clay Member of the Tulare Formation, or “E-clay,” is present in the San Joaquin Valley. However, recent studies suggest that the entire aquifer system is a single heterogeneous system (B) in which vertically and horizontally scattered lenses of fine-grained materials provide increasing confinement with depth.

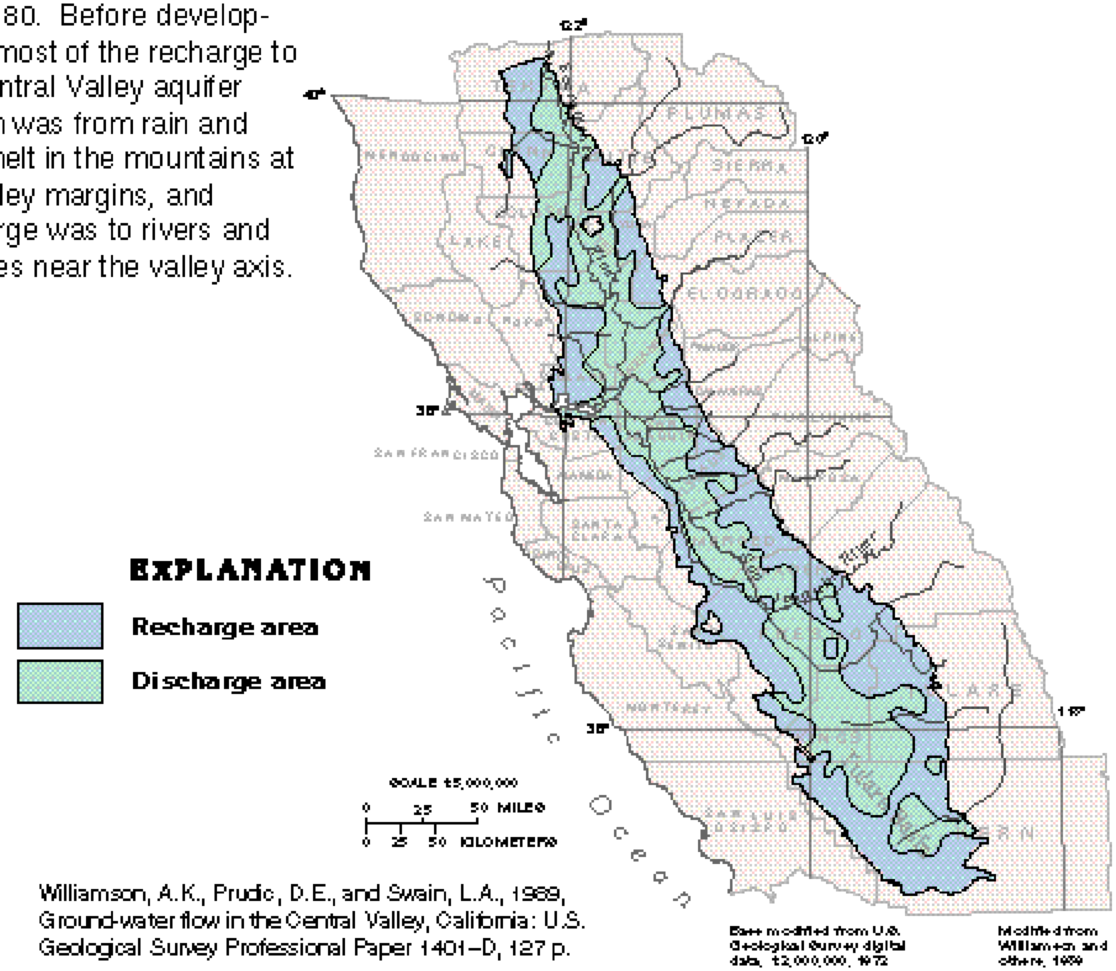


Bertoldi, G.L., Johnston, R.H., and Evenson, K.D., 1991, Ground water in the Central Valley, California—A summary report: U.S. Geological Survey Professional Paper 1401-A, 44 p.

GROUND-WATER FLOW SYSTEM

Under natural, or predevelopment, conditions, recharge from rainfall and snowmelt entered the aquifer system as seepage from streams that channel runoff from the surrounding mountains into the valley. Most recharge is at the margins of the valley, and the ground water moves in the subsurface to lower altitudes and discharges into surface-water bodies that drain each basin. Before development began, the aquifer system was under steady-state conditions in which natural recharge balanced natural discharge. Ground water in the shallow part of the aquifer system flowed from areas of high altitude at the valley margins, where most of the recharge took place, down gradient to discharge into rivers and marshes near the valley axis. The aquifer system was recharged primarily by streams emanating from the Coast and Cascade Ranges and the Sierra Nevada. Most of the recharge was in the northern and eastern parts of the valley. Precipitation falling on the valley floor during the rainy season provided only a small part of the total recharge. Ground water that was not evaporated or transpired by plants discharged either into the Sacramento and the San Joaquin Rivers that drained to San Francisco Bay or into the Tulare Basin from which it was eventually removed by evaporation or transpiration. The areas of recharge and discharge in the Central Valley before development are shown in [figure 80](#).

Figure 80. Before development, most of the recharge to the Central Valley aquifer system was from rain and snowmelt in the mountains at the valley margins, and discharge was to rivers and marshes near the valley axis.



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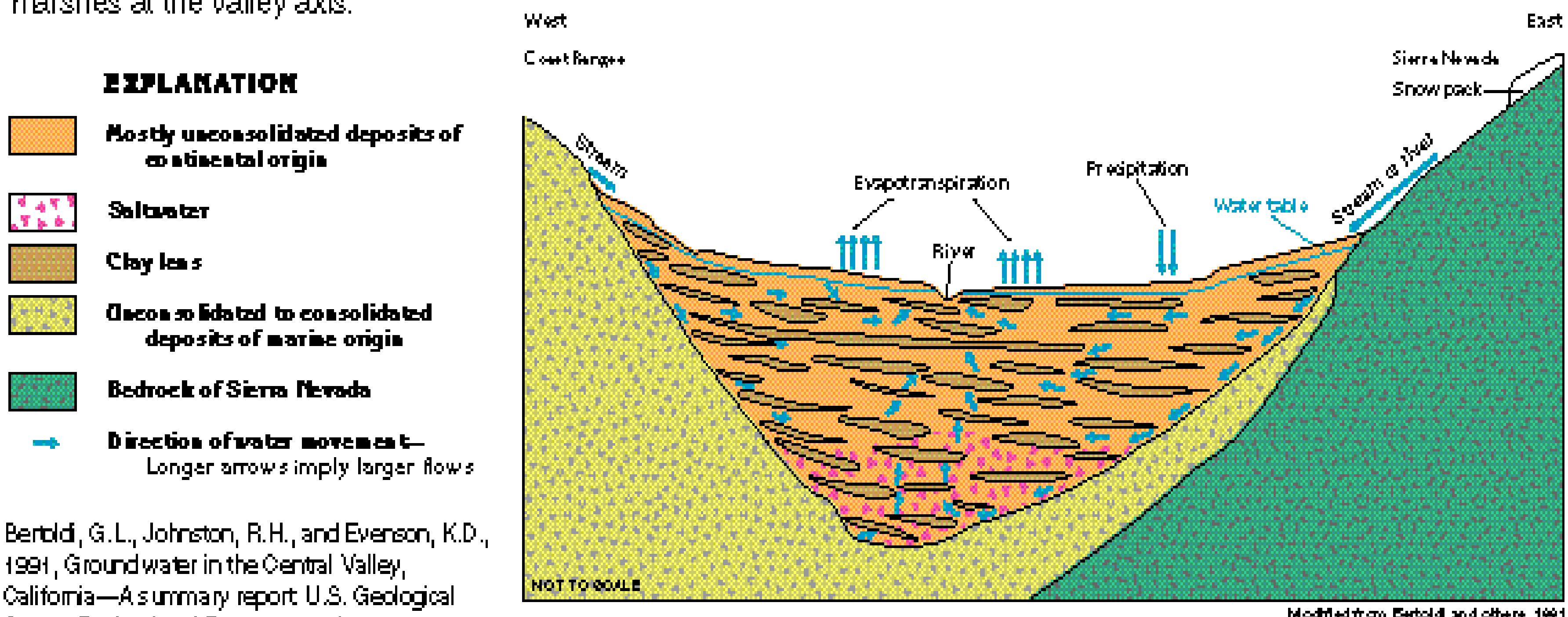
The head gradient was reversed where water left the aquifer, typically by discharge to surface-water bodies, and the hydraulic head in the water-table aquifer was less than that in the confined aquifer. The difference in hydraulic head created upward movement of the ground water toward rivers and marshes (fig. 81). Precipitation that fell on the valley floor and was not lost to evapotranspiration recharged the water-table aquifer and moved down the head gradient toward the rivers and surrounding marshes.

Upward vertical flow to discharge areas from the deep confined aquifer was impeded by confining clay beds, which caused a pressure head in the deep parts of the aquifer system. Because of the pressure head, wells that penetrated the deep aquifer in low-lying areas near the rivers and marshes flowed during the early years of ground-water development in the valley.

Figure 81. A diagrammatic hydrogeologic section shows that before development, water that recharged the aquifer at the valley margins moved downward and laterally into the aquifer system and then moved upward to discharge at rivers and marshes at the valley axis.



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