HYDROGEOLOGY OF THE SAN LUIS VALLEY, COLORADO AN OVERVIEW—AND A LOOK AT THE FUTURE

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A note from the author—During the period 1966–1980, I was either collecting data, interpreting data, or writing reports regarding the San Luis Valley. Other duties at other locales prevented me from working nearly full time on the valley, as I did from 1966 to 1972. In any case, I devoted considerable time and effort investigating the valley's water resources and, therefore, I am both honored and pleased to author this paper for GSA. The U.S. Geological Survey transferred me to Alamosa 30 years ago when I was appointed Project Chief of a 5-year hydrologic study of the San Luis Valley. I departed Colorado in 1972. I returned to the valley in 1979 to testify in a trial regarding rules and regulations proposed by the Colorado State Engineer, and once again in 1991 to testify in the AWDI trial. Even though the AWDI trial process familiarized me with some post-1979 hydrologic studies, my knowledge of studies conducted during the last 10 to 15 years is somewhat limited. Therefore, I apologize for the somewhat "dated" data, as well as omissions and/or errors in the following overview of the valley's hydrology.

INTRODUCTION

The San Luis Valley is a large intermontane valley about 100 miles long and 50 miles wide. It occupies an area of approximately 3,200 square miles and has an average altitude of about 7,700 feet. The valley is bounded on the east and west by mountains with some peaks exceeding an altitude of 14,000 feet. Most of the valley floor is bordered by alluvial fans; the most extensive being the Rio Grande fan. The valley floor is a nearly featureless plain except for the San Luis Hills, sand dunes, and playa lakes.

The valley's natural vegetation consists mainly of phreatophytes and xerophytes plus deciduous trees that occur adjacent to the perennial streams. The phreatophytes occupy about 1,100 square miles (more than one-third of the valley floor), and grow in areas where the depth to water below the land surface is 12 feet or less. Rather sparse xerophytes inhabit the slopes of the alluvial fans as well as uncultivated areas bordering the central part of the valley. The area covered by xerophytes and short range grass is about 1,000 mi^2.

Most of the streamflow is derived from snowmelt from about 4,700 mi^2 of watershed in the surrounding mountains. The northern part of the valley is internally drained and is referred to as the "closed basin". The lowest part of the closed basin is known locally as the "sump". The southern part of the valley is drained by the Rio Grande and its major tributary the Conejos River.

The climate of the San Luis Valley is arid and is characterized by cold winters, moderate summers, and much sunshine. The average annual precipitation is about 7.5 inches and potential evapotranspiration exceeds 40 inches. Average annual temperature is about 42°F, with extremes of -50°F and 91°F. Due the to short growing season (90–120 days), crops are restricted mainly to barley, oats, hay, potatoes, and other vegetables. These crops are cultivated and irrigated in an area comprising about 1,000 mi^2.

The San Luis Valley has been occupied and utilized for a rather long time span. Folsom campsites (ca. 10,900–10,300 yr. B.P.) located near playa lakes, have been described by Jodry and others (1989). Later, the valley was a hunting ground for Indians including the Ute and Jicarilla Apache tribes. Spanish settlers first entered the valley between 1630 and 1640. For about 250 years the valley was utilized for rather limited farming, cattle grazing, and hunting. The cultivation of crops was not very extensive until the 1890's. Artesian water was discovered about 1887, and within four years, approximately 2,000 flowing wells had been developed. By 1904, there were more than 3,200 flowing wells, and by 1916, it was estimated there were 5,000. The author reported that by 1980 there were nearly 7,700 wells withdrawing water from the confined (artesian) aquifer. In addition, there were about 2,300 pumped wells in the unconfined aquifer.

The extensive development of the valley's aquifers concurrent with development of a large surface-water irrigation system has created a number of hydrologic and legal problems. Some areas of the valley are waterlogged due to inadequate drainage, and large amounts of water are consumed by nonbeneficial evapotranspiration. The proper conjunctive use of ground water and surface water has been, and will continue to be, of prime importance to the management of the valley's water resources.

GEOLOGY

The San Luis Valley is a north-trending structural depression downfaulted on the eastern border and hinged on the western side. The valley is underlain by as much as 12,000 feet of clay, silt, sand, gravel, and interbedded volcanic flows and tuffs. The alluvial deposits are coarse and permeable near the bordering mountains and grade to fine-grained, less permeable deposits toward the center of the valley. Lenticular clay beds of probable lacustrine origin form a “clay series” that occurs throughout much of the central and northern parts of the valley at depths ranging from 20 to 120 feet below the land surface. Lenticular clays exist throughout the valley fill at varying depths, but the clay series probably represents the most laterally persistent and identifiable sequence of clay beds.

Data obtained from geophysical surveys and oil test holes indicate the valley-fill deposits overlie relatively impermeable crystalline rock, which has been faulted into a north-trending series of en echelon horsts and grabens.

The bordering Sangre de Cristo Mountains on the east are composed of igneous, metamorphic, and sedimentary rocks, whereas the San Juan Mountains on the west consist mainly of volcanic flows, tuffs and breccias. Many of the lava flows and tuffs from the San Juans dip generally eastward under the valley flow where they are incorporated in the valley-fill deposits.

WATER BUDGET

About 2,800,000 acre-feet of water enter and leave the San Luis Valley each year. Table 1 is a generalized water budget for the valley.

The most important source of water to the valley is surface-water inflow. It provides, directly or indirectly, nearly all the water used for irrigation. Not only is the surface water applied directly to the irrigated land, but it also supplies most of the recharge to the valley’s aquifers. Precipitation on the valley floor, which results mainly from low intensity storms, can be considered only a small part of the water supply and serves only as a supplemental source for irrigation and ground-water recharge. Ground-water inflow is not included in table 1 due to its small magnitude.

Table 1. Generalized annual water budget for San Luis Valley (1924–1969)

[All values in acre-feet/yr]

WATER IN		WATER OUT	
Precipitation	1,220,000	Evapotranspiration	2,420,000
Surface-water inflow	1,580,000	Surface-water outflow	330,000
		Ground-water outflow	50,000
TOTAL	2,800,000	TOTAL	2,800,000

SURFACE WATER

Surface water is a major source of water for irrigation in the San Luis Valley. It is distributed for irrigation through a system of canals and laterals having an aggregate length exceeding 150 miles. As shown in table 1, annual surface-water inflow to the valley averages 1,580,000 acre-ft. However, it can vary considerably. For example, it ranged from a low of 743,000 acre-ft in 1951 to a high of 2,783,000 acre-ft in 1941.

A large percentage of the annual surface-water inflow occurs during the snowmelt runoff period (April-June). On the Rio Grande, for example, more than 70 percent of the annual inflow occurs between April 1 and July 30. After the snowmelt runoff, streamflow declines during the summer with minor fluctuations caused by precipitation.

GROUND WATER

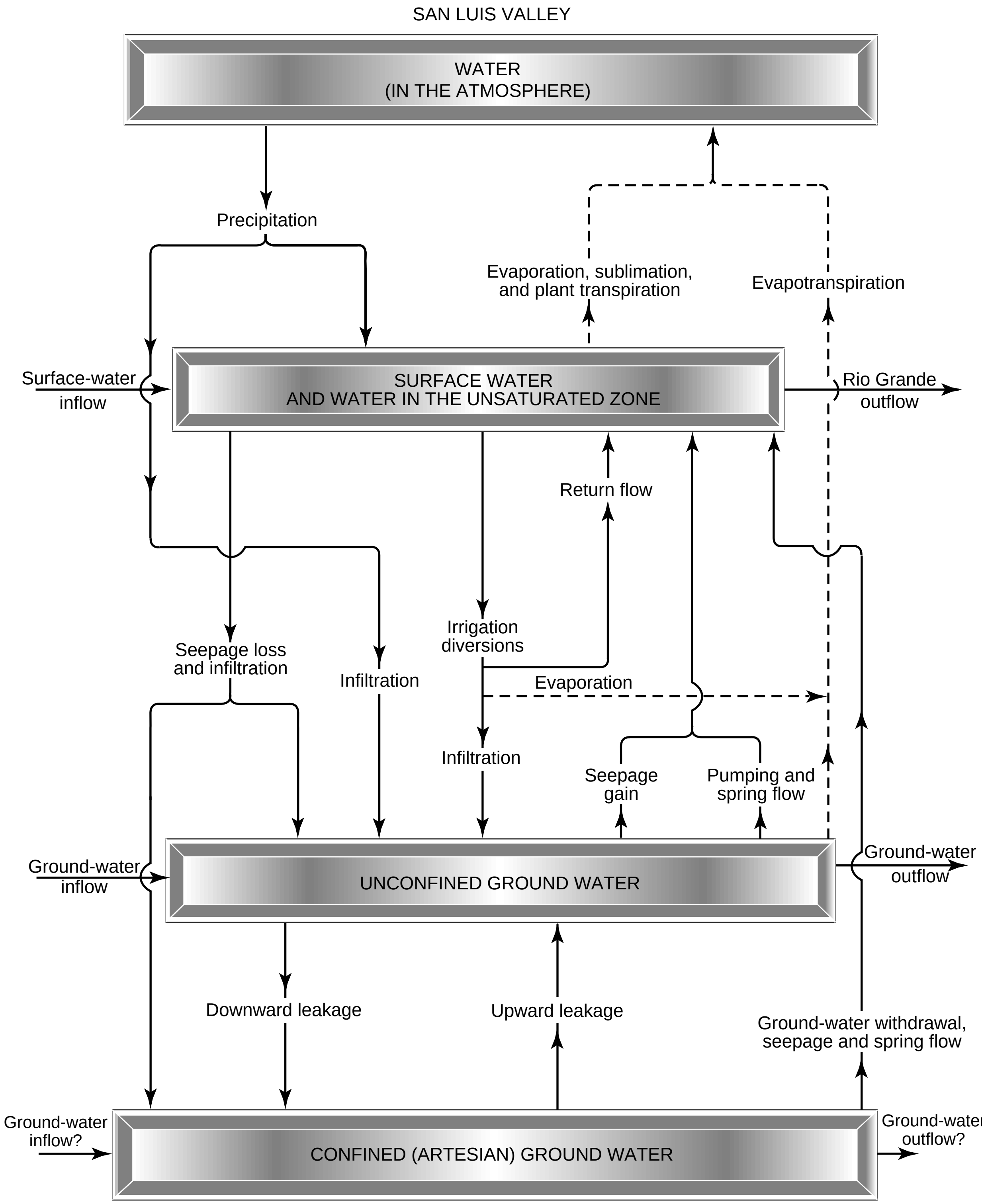
Ground water occurs in both unconfined and confined aquifers in the San Luis Valley. Although the rock materials making up these aquifers are similar, their storage characteristics and head responses to stress are quite different.

Artesian, or confined conditions, are created over most of the valley’s artesian basin by clay layers referred to by local well drillers as “blue clay” and by Emery and others (1971) as the “clay series”. In the southwestern part of the valley, the clay series overlaps northeastward-dipping lava flows. In this area, the uppermost lava flow is the principal confining unit, even though confined conditions exist locally between the lava flow and overlying clay units.

The aquifers are recharged by infiltration of applied irrigation water, canal leakage, seepage from mountain streams that flow across the permeable alluvial fans, and infiltration of precipitation. The major discharge from the unconfined aquifer is by pumping wells, seepage to streams, and evapotranspiration. Discharge from the confined aquifer is by wells, springs, and upward leakage through the clay series into the unconfined aquifer.

Water in the Unconfined Aquifer

Unconfined ground water occurs nearly everywhere in the valley. The depth to water below the land surface is 12 feet or less over about one-half of the valley. However, in parts of the southern San Luis Valley, the depth to water exceeds 300 feet. Because of abundant recharge from surface water, little long-term fluctuation in the water table has occurred. The unconfined aquifer is the principal source of ground water for irrigation, supplying 80 percent of all large capacity (yield more than 300 gpm) wells.



Generalized hydrologic flow diagram of San Luis Valley

Water in the Confined Aquifer

Confined ground water occurs under nearly one-half of the valley. Flowing wells can be obtained in an area of approximately 1,400 mi^2. Of the 650 large-capacity irrigation wells tapping the confined aquifer, 99 range in depth from 1,000–2,000 feet, and 21 are more than 2,000 feet deep. Most of these deep wells flow, some exceeding 3,000 gpm.

THE FUTURE

In 1986, American Water Development Incorporated (AWDI) applied to the State of Colorado for rights to pump 200,000 acre-ft of water per year from the San Luis Valley's aquifers. This water was to be transported via pipeline to the Denver vicinity. The application was dismissed in 1991, following a lengthy and costly trial.

Experts on both sides of the AWDI case relied heavily on data and reports produced by the Geological Survey's 1966–72 hydrologic study of the valley. During the course of the $1 million 6-year study, an impressive amount of useful hydrologic data was collected, and at least nine reports were published. The nonbiased data and interpretations served as a solid framework for consultants and water managers to build upon.

As the World's population increases, the demand for food will stimulate more efficient use of cropland and irrigation water. More than 25 years ago, I was informed by the Texas Commissioner of the Rio Grande Compact that the people in the Lower Rio Grande Valley could produce 2 to 3 times the amount of crops produced in the San Luis Valley—with the same amount of water used in the valley. He further stated that he was going to spend the rest of his life "going after that water".

There is little doubt that the water resources of the San Luis Valley will continue to be sought by entities outside the valley—both within Colorado and elsewhere.

The valley's water resources need to be better described and monitored. The author recommends continued data collection and study of the San Luis Valley's water resources. Among items to pursue, I list the following: (not necessarily in order of importance):

Surface-water inflow (more rim-inflow gaging stations)
Vertical hydraulic conductivity determinations (aquifer interconnection)
Evapotranspiration studies (field measurements)
Land subsidence monitoring (subsidence monitoring wells, etc.)
Aquifer storage coefficients (aquifer tests, etc.)
Confined & unconfined aquifer head measurements (continue and expand)
Quality of ground- and surface-water monitoring and studies
Stream-aquifer connection
Ground-water withdrawal and consumptive use

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