UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

GROUND WATER IN THE SAN JOAQUIN VALLEY, CALIFORNIA

Kunkel, Fred

OPEN-FILE REPORT

Presented at
California Irrigation Institute
Fresno, California
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CONTENTS

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By Fred Kunkel and Walter Hofmann[2]

INTRODUCTION

Ladies and gentlemen, it is a pleasure to be invited to attend this Irrigation Institute conference and to describe the Geological Survey's program of ground-water studies in the San Joaquin Valley.

The U.S. Geological Survey has been making water-resources studies in cooperation with the State of California and other agencies in California for more than 70 years. Three of the earliest Geological Survey Water-Supply Papers--numbers 17, 18, and 19--published in 1898 and 1899, describe "Irrigation near Bakersfield," "Irrigation near Fresno," and "Irrigation near Merced." However, the first Survey report on ground-water occurrence in the San Joaquin Valley was "Ground Water in the San Joaquin Valley," by Mendenhall and others. The fieldwork was done from 1905 to 1910, and the report was published in 1916 as U.S. Geological Survey Water-Supply Paper 398.

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[1]Approved by the Director of the Geological Survey for release to the open file April 4, 1966.

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The current series of ground-water studies in the San Joaquin Valley was begun in 1952 as part of the California Department of Water Resources-U.S. Geological Survey cooperative water-resources program. The first report of this series is Geological Survey Water-Supply Paper 1469, "Ground-Water Conditions and Storage Capacity in the San Joaquin Valley." Other reports are Water-Supply Paper 1618, "Use of Ground-Water Reservoirs for Storage of Surface Water in the San Joaquin Valley;" Water-Supply Paper 1656, "Geology and Ground-Water Features of the Edison-Maricopa Area;" Water-Supply Paper 1360-G, "Ground-Water Conditions in the Mendota-Huron Area;" Water-Supply Paper 1457, "Ground-Water Conditions in the Avenal-McKittrick Area;" and an open-file report, "Geology, Hydrology, and Quality of Water in the Terra Bella-Lost Hills Area."

In addition to the preceding published reports, ground-water studies currently are being made of the Kern Fan area, the Hanford-Visalia area, the Fresno area, the Merced area, and of the clays of Tulare Lake. Also, detailed studies of both shallow and deep subsidence in the southern part of the San Joaquin Valley are being made by the Subsidence Research Section at Sacramento, and research on permeability and specific yield in the San Joaquin Valley is being done by our hydrologic laboratory at Denver.

These water-resources studies show that the San Joaquin Valley contains the largest ground-water basin in the State. The floor of the valley and the surrounding water-bearing highlands constitute about 13,600 square miles of area. The gross quantity of fresh ground water stored in the deposits beneath this area, to a depth of 1,000 feet or to the base of the fresh water, whichever is the lesser, has been computed as 571 million acre-feet, or about 57 percent of the total ground water stored in all the ground-water basins in California. Pumpage from this underground reservoir in 1955-56, the latest year for which figures are available, was 9 million acre-feet, or about 8 billion gallons per day.

To place these figures in perspective let us consider: That the total pumpage of ground water in the United States in 1955 was 30 billion gpd (gallons per day), that, of the 30 billion gpd, more than one-half or 15.6 billion gpd was used in five Western States, and that, of the 15.6 billion gpd, nearly two-thirds or 10 billion gpd was used in California. Therefore, from these figures, we can see that the 8 billion gpd of water used in the San Joaquin Valley is not only a major part of the total ground-water pumpage in California but a major part of all the ground water used in the United States.

GEOLOGY

So that you may better understand the San Joaquin Valley ground-water basin, I would like to briefly describe the geologic structure and history of the valley.

Our studies show that the Central Valley of California of which the San Joaquin Valley is the southern part, is a canoe-shaped trough with a lip on the west side. The San Joaquin Valley is bounded by the Sierra Nevada on the east, the Tehachapi and San Emigdio Mountains on the south, and the Coast Ranges on the west.

For the purposes of describing the ground-water reservoir, the rocks and deposits that form the San Joaquin Valley can be differentiated into two broad groups--(1) the consolidated and semiconsolidated rocks and (2) the unconsolidated deposits.

The consolidated rocks underlie and surround the main valley area and contain the unconsolidated deposits. In other words the consolidated rocks form the bathtub and the unconsolidated deposits are contained in the tub. Because the consolidated rocks form the highland and mountain areas, they receive the major part of the precipitation that falls within the drainage area. It is the surface-water runoff from these rocks that flows onto and recharges the large fresh ground-water body that is contained in the unconsolidated deposits. This surface runoff also carries the material eroded from the mountain block onto the valley plain to add to the accumulation of the unconsolidated deposits.

Geologic Units

Differentiation of only two geologic units provides insufficient information to describe the ground-water reservoir. Consequently, on the basis of surface geologic mapping and an analysis of electric logs made in more than 5,000 oil, gas, and water wells, the rocks and deposits are subdivided into 5 main units. They are (1) the granitic and metamorphic rocks of pre-Tertiary age that form the Sierra Nevada; (2) the Franciscan Formation and associated igneous and metamorphic rocks of Jurassic and Cretaceous age that form the core of the Coast Ranges; (3) the marine sedimentary rocks of Cretaceous age that crop out in the Coast Ranges; (4) the marine sedimentary rocks of Tertiary age that crop out in the Coast Ranges and along the southeastern side of the San Joaquin Valley. Included in this unit are some interbedded continental deposits of Tertiary age that contain salty water; and (5) unconsolidated continental deposits of Tertiary and Quaternary age.

Geologic History

To better understand the relation of the geologic units to each other, we might briefly review the geologic history of the San Joaquin Valley.

The oldest rocks in the area are the granitic and associated metamorphic rocks, which form the Sierra Nevada and underlie the eastern side of the valley, and the intensely deformed Franciscan Formation and associated igneous and metamorphic rocks, which underlie the Coast Ranges and western side of the valley.

Collectively, these rocks form the basement complex of the area. This basement was covered by a shallow inland sea during the Cretaceous age about 60 to 120 million years ago. Material eroded from the surrounding mountains was deposited in this sea to form the marine sedimentary rocks.

As time progressed in the Cretaceous, the boundaries of the sea were shifted by widespread earth tilting, folding, and faulting. In addition, the weight of the accumulating sediments caused or contributed to the downwarping of the trough that ultimately formed the ground-water basin of the San Joaquin Valley. By the Eocene, about 60 million years ago, a continuous arm of the sea extended from what is now Mendocino County, through the Central Valley, to the Los Angeles area. Deposition of sedimentary materials continued, and the weight of the accumulating sediments contributed to farther downwarping of the trough.

In the Oligocene, about 40 million years ago, the sea was more restricted than in the Eocene, but subsidence of the trough and deposition of marine sediments continued.

In Miocene time, about 25 million years ago, erosion of material from the rising block of the Sierra Nevada was rapid enough to fill the trough of the valley and move the sea westward. And by Pliocene time, about 10 million years ago, much of what was to become the Central Valley was occupied by a swamp that was progressively filled with clay, silt, sand, gravel, and boulders eroded from the rising block of Sierra Nevada on the east and, to a lesser degree, the Coast Ranges on the west.

This erosion and deposition has continued to the present day, as we can see after any period of heavy precipitation and runoff. However, it was only within the last 2 or 3 million years that the Coast Ranges rose high enough to force out the sea. It was during this time that the California landscape and the Golden Gate, as we know them, began to form. Also, for much of the time during the last few million years part of the valley trough has been occupied by fresh-water lakes, the most recent being Tulare and Buena Vista Lakes.

In the San Joaquin Valley the total thickness of sedimentary fill, both marine and continental, on top of the basement rocks is about 25,000 feet. The upper 2,000 to 3,000 feet are the unconsolidated continental deposits of Tertiary and Quaternary age. However, locally the thickness of the unconsolidated continental deposits is as great as 10,000 to 12,000 feet.

The unconsolidated deposits are mostly poorly to well sorted silt, sand, and gravel laid down on alluvial fans. However, in much of the central and western part of the valley the deposits are fine-grained clay and silt laid down in the lakes and swampy lands that occupied parts of the valley for most of the last 2 or 3 million years. The most extensive and best known of these clay beds is the Corcoran Clay Member of the Tulare Formation. Current studies show the existence of several other clay beds, however, none of them is as extensive as the Corcoran.

GROUND WATER

Within the framework described we now can consider the occurrence of ground water in the San Joaquin Valley.

The rocks of the basement complex which are the igneous and metamorphic rocks of Jurassic and Cretaceous age for all practical purposes, contain no ground water, but form the sides and bottom of the basin that contains the marine and continental sedimentary rocks and deposits.

The marine and continental sedimentary rocks and deposits overlying the basement contain large quantities of ground water. However, with only minor exceptions, the ground water in the marine sedimentary rocks is saline-connate water. That is sea water that has never been flushed from the formations since their deposition beneath the sea. Overlying the saline water and contained in the continental deposits is the large body of fresh water that is the principal source of fresh ground water in the San Joaquin Valley.

The body of fresh water above the Corcoran Clay Member of the Tulare Formation, or where the Corcoran is absent, is unconfined or semiconfined. Beneath the Corcoran or other extensive clay beds, it is confined.

The ultimate source of ground water in the San Joaquin Valley is precipitation on the valley and its tributary drainage area. Replenishment is to the unconfined and semiconfined ground-water body (1) by infiltration of rainfall on the unconsolidated deposits, (2) by percolation from streams, (3) by underflow in the permeable materials flooring the canyons bordering the valley, and since the coming of man (4) by losses from irrigation canals and ditches and deep penetration of water applied for irrigation in excess of plant requirements.

Replenishment to the confined aquifers occurs chiefly from the unconfined and semiconfined deposits beyond the edges of the confining bed, but also in part by slow downward penetration of water through the confining bed where the head in the confined beds is now lower than in the shallower bed.

The extent of confinement is best shown by the known distribution of flowing wells which occurred throughout a substantial part of the valley in the early 1900's. At that time there were more than 500 flowing wells in the valley.

Under natural conditions the central part of the San Joaquin Valley was one vast swamp and was the sump or discharge area for virtually all the ground water in the system. Though the surface outlet of the valley is by the way of San Francisco Bay through Carquinez Strait, the strait is restricted and does not provide a major outlet for the ground water of the valley. Consequently, there was little or no movement of the ground water, except for that resulting from evaporation and evapotranspiration. This virtual stagnation of ground water resulted in the concentration of alkali over large areas of the valley.

However, beginning in about 1900, ever increasing withdrawals of ground water by wells caused extensive and progressive lowering of water levels throughout the valley. Consequently, the movement of ground water under present conditions is toward the areas of lowered water level which are (1) chiefly beneath areas irrigated by ground water pumped from wells or (2) toward natural drains in the vicinity of heavy surface-water application.

A part of the pumped ground water has been replenished by ground-water recharge. However, that part withdrawn from storage in excess of the perennial yield has been mined. This mining, up to a point however is practical, particularly if one considers that the total quantity of fresh ground water in storage is over 1/2 billion acre-feet. Also, this mining has had three beneficial aspects.

First, by dewatering the upper part of the ground-water basin much of the natural discharge that formerly wasted to the atmosphere has been salvaged by using that water for irrigation. Second, dewatering the ground-water basin has created underground storage space that can be recharged, either naturally or artificially, during periods when surplus water is available. And third, the mining of the ground water has allowed an economy to develop that now can afford the cost necessary to import water.

On the other hand, use of water in the basin has created problems. Locally, some areas have become water logged, in other areas undesirable salts have accumulated, and for large areas the withdrawal of ground water has resulted in extensive subsidence of the land surface. These and other problems are being studied by the Geological Survey in cooperation with the State of California and other public agencies as part of a continuing appraisal of the water resources of the State.

The data collected and the results of these studies are published, generally as Geological Survey water-supply papers, and provide the basic data for future water-development projects by the State or other agencies.

In the limited time available I have attempted to give you a brief description of one of California's major assets--the San Joaquin Valley ground-water basin. In recent years, the publicity and emphasis on the development of major surface-water sources may have obscured the fact that the ground-water withdrawals from the San Joaquin Valley have been and will continue to be one of the largest water resources in the State. With adequate information and proper planning this resource can be utilized to its fullest potential.