Appendix D

Groundwater Conditions and Water Transfers in the Exchange Contractor's Service Area West of the San Joaquin River

Water Transfer Program for the San Joaquin River Exchange Contractors Water Authority, 2014–2038

Draft
May 2012

GROUNDWATER CONDITIONS AND WATER TRANSFERS IN THE EXCHANGE CONTRACTOR'S SERVICE AREA WEST OF THE SAN JOAQUIN RIVER

prepared for
San Joaquin River Exchange
Contractors Water Authority
Los Banos, California

by
Kenneth D. Schmidt and Associates
Groundwater Quality Consultants
Fresno, California

October 2011

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

GROUNDWATER CONDITIONS AND WATER TRANSFERS IN THE EXCHANGE CONTRACTOR'S SERVICE AREA WEST OF THE SAN JOAQUIN RIVER

GROUNDWATER CONDITIONS

Regional Conditions

Information on regional groundwater conditions in the part of the SJREC service area west of the San Joaquin River was provided by Davis and Poland (1957), Hotchkiss and Balding (1971), and Belitz and Heimes (1990). Kenneth D. Schmidt and Associates (KDSA) provided updated information for the SJREC service area. Subsurface geologic conditions were discussed in a KDSA 1997 report prepared for the CCID. Groundwater levels and flow directions, aquifer characteristics, and groundwater quality were discussed in a 2007 KDSA report prepared for the SJREC. Lastly, transfer pumpage and the impact on water levels for 2008, 2009, and 2010 were discussed in annual KDSA reports prepared for the CCID.

The Corcoran Clay is a regional, laterally extensive, confining bed beneath much of the west side of the San Joaquin Valley. Regionally, this clay has been used to separate an upper aquifer from an underlying lower aquifer. Water-level maps have been prepared for both aquifers. In general, groundwater in the upper aquifer in the south part of the area flows from the SJREC service area west of the San Joaquin River into Madera County.

North of Highway 152, groundwater in the upper aquifer usually flows toward the San Joaquin River. The most important sources of groundwater recharge are deep percolation of excess applied irrigation water and canal seepage. Additional sources are streamflow seepage and groundwater inflow.

The direction of groundwater flow is generally downward from the upper aquifer to the lower aquifer, except near to the north end of the CCID service area. Groundwater in the lower aquifer south of Highway 152 flows to the south or southwest, and out of the SJREC service area. In much of the area north of Highway 152, groundwater in the lower aquifer moves toward the San Joaquin River.

Although groundwater in the lower aquifer is widely tapped in the Panoche Water District, Westlands Water District, and in the western part of Madera County, there is little pumpage from this aquifer in the SJREC service area west of the San Joaquin River. Thus most of the pumpage in this service area is from the upper aquifer.

Land subsidence in the area has resulted from excessive pumpage of groundwater from the lower aquifer. Even though there has been little pumpage from the lower aquifer in the SJREC service area, subsidence has occurred due to lower aquifer pumpage in adjoining areas.

Groundwater Quality

Upper Aquifer. Hotchkiss and Balding (1971) compared the quality of groundwater to that of streams in the west part of the Tracy-Dos Palos area. They indicated that the bicarbonate-type groundwater bodies were recharged by the intermittent streams that had the largest drainage basins, namely, Del Puerto, Orestimba, San Luis, and Los Banos Creeks. The TDS concentrations in groundwater of the bicarbonate type often ranged from about 400 to 600 mg/l, and increased in the downgradient direction, from west to east.

However, better quality groundwater is present in the upper aquifer to the east, where recharge from the San Joaquin River and Mendota Pool are significant. There are areas of sulfate-type groundwater in the central and southern parts of the Tracy-Dos Palos area. There is a chloride-type groundwater in the Grassland Water District, east of Gustine and around Dos Palos. Sodium chloride type groundwater extends from near Mendota northward to Dos Palos.

There are transitional types of water (bicarbonate-sulfate and sulfate-bicarbonate) such as near Gustine, and these represent mixtures of water from various sources. In the vicinity of Los Banos, most of the transitional type groundwater is sulfate-chloride and bicarbonate-sulfate, but near the San Joaquin River it is chloride-bicarbonate in type. The TDS concentrations in the transitional type groundwater range from about 400 to 4,200 mg/l.

Because DMC water has been used for irrigation for decades, the quality of this water has influenced groundwater quality in the upper aquifer throughout the service area.

Lower Aquifer. The chemical quality of the groundwater in the lower aquifer in the area is less well known than that of the upper aquifer. In general, for the area north of Los Banos and much of the western part of the rest of the CCID, TDS concentrations in groundwater below the Corcoran Clay are less than those in groundwater below the Corcoran Clay. However, experience in Dos Palos, Los Banos, the San Luis Canal Co. service area, Firebaugh, and Mendota indicates that higher TDS groundwater is locally present below the Corcoran Clay. High concentrations of hydrogen sulfide, iron, and manganese are present in groundwater of the lower aquifer in some areas, particularly where reducing conditions are present. These conditions are due to an oxygen deficiency in the subsurface (KDSA, 1997).

Exchange Contractor's Service Area

Subsurface Geologic Conditions

Figure 1 shows the depth to the top of the Corcoran Clay,

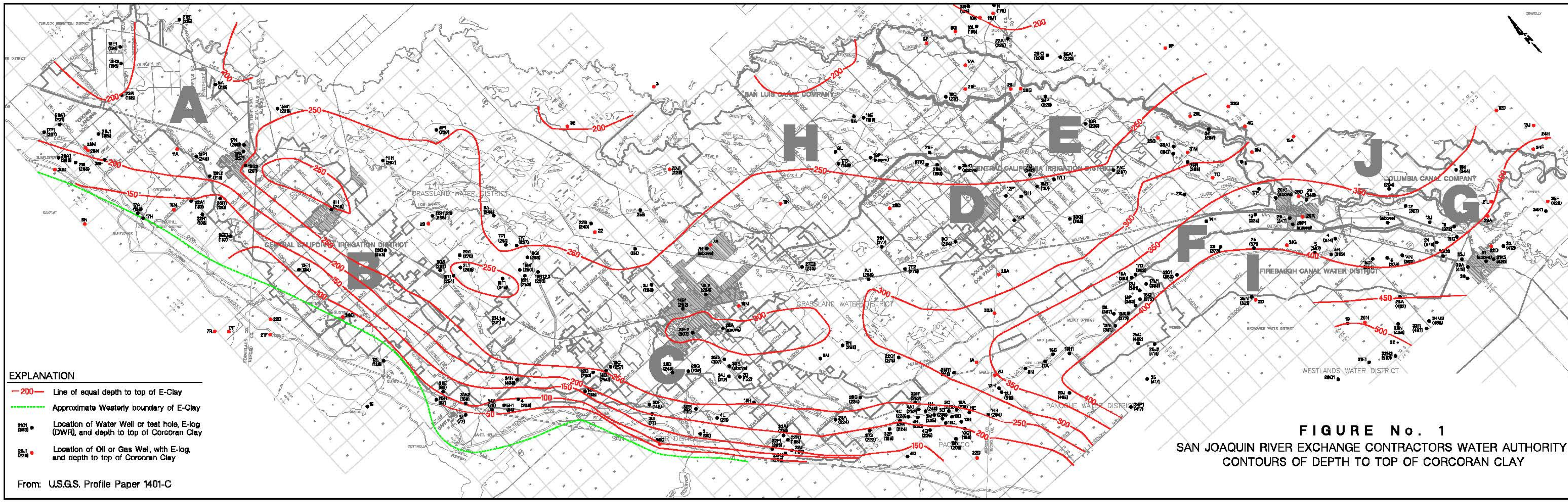


FIGURE No. 1

SAN JOAQUIN RIVER EXCHANGE CONTRACTORS WATER AUTHORITY
CONTOURS OF DEPTH TO TOP OF CORCORAN CLAY

(KDSA 1997). The Corcoran Clay lies beneath the entire CCID, except for a small area near Cottonwood Road and the west boundary of the District. The shallowest depth to the top of the clay is about 50 feet near Santa Nella. North of Fresno County, the clay is deepest near Newman, Gustine, and Los Banos, where the top is more than 250 feet deep. The top of the Corcoran Clay is commonly about 200 feet near the San Joaquin River in the area north of Fresno County. The top of the clay deepens to the south in the area, and ranges from about 400 to 450 feet deep near Mendota. In most of Fresno County, the top of the clay is generally deeper to the south and west, and the depths are the greatest in the service area.

The Corcoran Clay is less than 20 feet thick in the area northwest of Newman, and over 80 feet thick northeast of Newman. The Corcoran Clay is thickest in two areas. Northwest of Volta and south of Dos Palos, near the Delta-Mendota Canal, the clay is more than 120 feet thick. The clay averages about 60 feet thick near Mendota and much of the San Joaquin River.

Nine subsurface geologic cross sections through the service area were provided by KDSA (1997). In addition ten more site-specific subsurface cross sections have been prepared as part of studies in the Cities of Los Banos, Gustine, Newman, Firebaugh, and Santa Nella.

Water Levels

KDSA (1997) provided a series of representative water-level elevation and direction of groundwater flow maps for the Exchange Contractor's service area. Maps were prepared for the upper aquifer (above the Corcoran Clay) for Fall 1981, Spring 1986, and Spring 1992. These represented normal or average conditions, a wet period, and a severe drought, respectively. Water-level elevation and direction of groundwater flow maps were prepared for the lower aquifer (below the Corcoran Clay) for Fall 1981 and Spring 1992. These two maps represented non-drought and drought conditions, respectively. In addition, a number of water-level hydrographs for six sub-areas in the Exchange Contractor's service area were provided. These were interpreted in terms of long-term water-level trends and groundwater overdraft.

Upper Aquifer. Figure 2 show water-level elevations and the direction of groundwater flow for the upper aquifer for Spring 2006. Groundwater was moving into the service area from the west. In Spring 2006 there was a groundwater divide east of Dos Palos. South of Highway 152, groundwater was flowing north-east and into Madera County. North of Highway 152, groundwater was moving northerly and toward the San Joaquin River from both sides of the river.

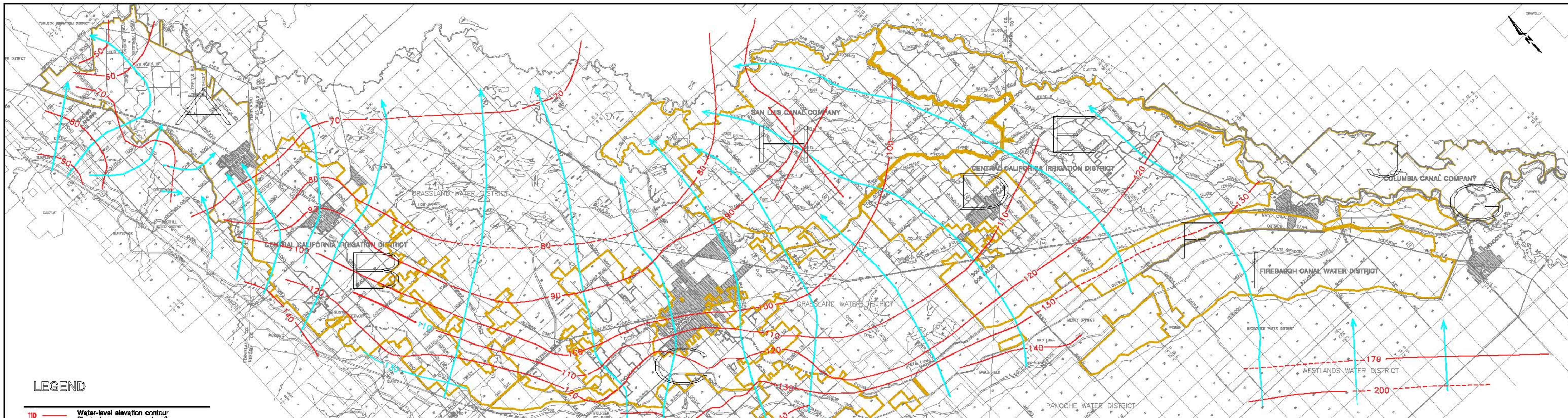


FIGURE No. 2
SAN JOAQUIN RIVER EXCHANGE CONTRACTORS WATER AUTHORITY
WATER LEVEL ELEVATION AND DIRECTION OF
GOUNDWATER FLOW FOR THE UPPER AQUIFER
(SPRING 2006)

During droughts, some groundwater locally flows out of the service area to the west. For example, this occurs west of Newman.

Lower Aquifer. In most parts of the Exchange Contractors service areas, few wells tap strata only below the Corcoran Clay. However, there are a number of wells that tap strata both above and below the Corcoran Clay, in western Madera County and in the area west of Newman and Gustine. These wells are termed composite wells. Water levels in these wells generally are significantly lower than those in nearby wells that tap only the upper aquifer. The water levels in these composite wells normally compare favorably with water levels in wells that tap strata only below the Corcoran Clay, such as in the Panoche and Westlands Water Districts. For these reasons, water-level measurements for selected composite wells were used, in addition to measurements for wells tapping only the lower aquifer, to prepare water-level elevation maps for the lower aquifer.

The Fall 1981 water-level elevation and direction of groundwater flow map prepared by KDSA (1997) for the lower aquifer indicated a number of features which weren't previously well known. First, a groundwater divide was present in the area between Mendota and a point near the San Joaquin River northeast of Los Banos. The divide extended through Sub-Area E. Groundwater northeast of this divide was moving to the northeast and into the Madera area. Southwest of this divide, groundwater was moving southwest and out of the CCID toward the Firebaugh Canal Water District and Panoche Water District. The groundwater flow directions in Fall 1981 were primarily toward pumping depressions due to pumping of groundwater from below the Corcoran Clay in the Madera area, in the Panoche Water District, and in the Westlands Water District. There has been little pumping of water from the lower aquifer in Sub-Areas E and G, due to high salinity. Beneath and adjacent to the groundwater divide, there has been significant downward flow of groundwater from the upper aquifer through the Corcoran Clay. This has provided a significant source of recharge to groundwater in the lower aquifer. Northwest of the Stanislaus-Merced County line, groundwater in the lower aquifer was indicated to flow upward into the upper aquifer. This was the only known part of the Exchange Contractor's service area where there was upward flow of groundwater from the lower to the upper aquifer.

Figure 3 is a partial water-level elevation and direction of groundwater flow map for the lower aquifer for Spring 2006. Data were available for only part of the Exchange Contractor's service area. In general, the directions of groundwater flow were simi-

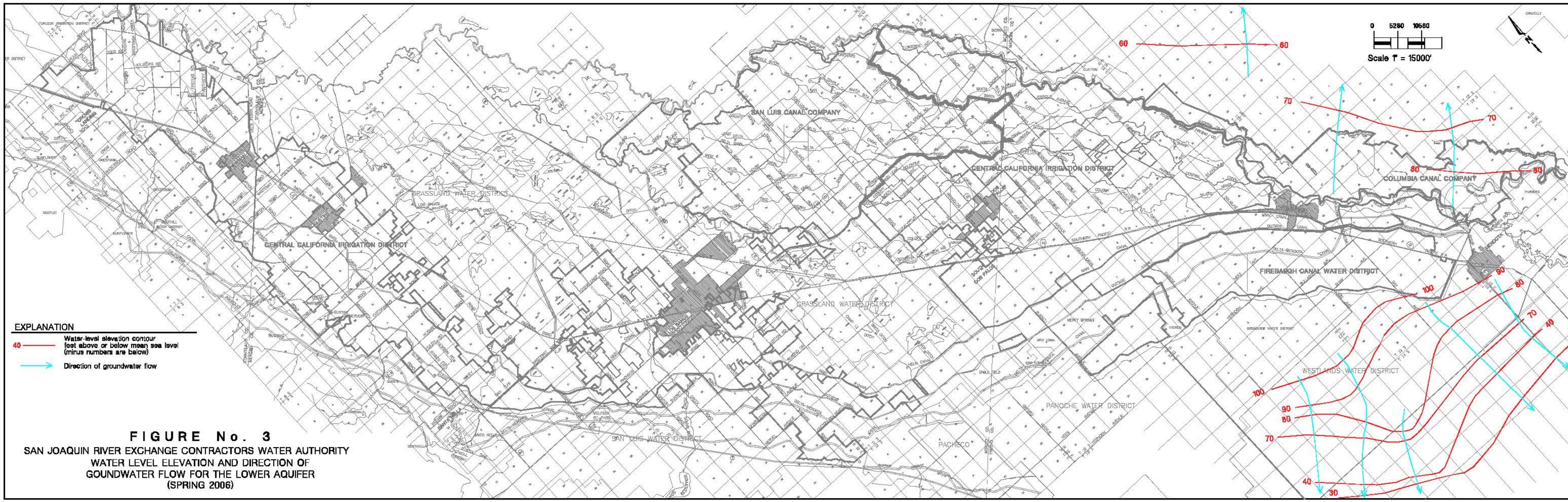


FIGURE No. 3

SAN JOAQUIN RIVER EXCHANGE CONTRACTORS WATER AUTHORITY
WATER LEVEL ELEVATION AND DIRECTION OF
GOUNDWATER FLOW FOR THE LOWER AQUIFER
(SPRING 2006)

lar to those in Fall 1986. That is, groundwater flowed away from the divide toward pumping depressions in the Madera Area and in the Panoche and Westlands Water Districts. In general, water-level elevations in the lower aquifer in the Westlands Water District were significantly higher in Spring 2006 than in 1986.

Water-Level Trends. As part of the 1997 evaluation, water-level records were obtained from the DWR, San Joaquin District, and irrigation districts in the area. The CCID prepared water-level hydrographs for a number of wells with records extending for at least several decades for the 1997 evaluation, and these were presented in Appendix A of KDSA (1997). As part of the KDSA (2007) evaluation, a number of these previously prepared water-level hydrographs were updated. Figure 4 shows the location of wells with updated water-level hydrographs, which were provided in Appendix A of the KDSA 2007 report. In order to evaluate the long-term water-level changes, a period of average hydrologic conditions is normally used. For the 2007 evaluation, the period 1962-2005 was selected.

Water-level fluctuations in confined aquifers are generally much greater than those in unconfined aquifers. Based on water-level depths and fluctuations shown on the hydrographs, the lower aquifer appears to be confined throughout the Exchange Contrac-

This Page Intentionally Left Blank

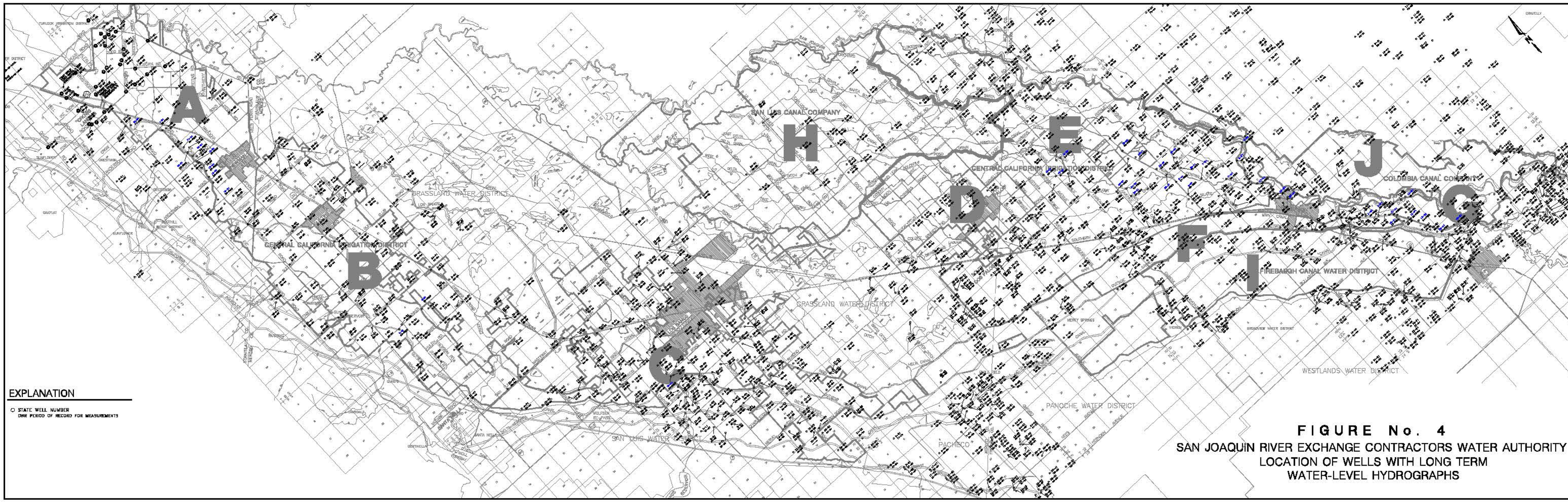


FIGURE No. 4
SAN JOAQUIN RIVER EXCHANGE CONTRACTORS WATER AUTHORITY
LOCATION OF WELLS WITH LONG TERM
WATER-LEVEL HYDROGRAPHS

tor's service area. Although the upper aquifer is apparently unconfined over much of the study area, there is some local confinement. One example is near Mendota, where fine-grained flood-basin deposits (the A-clay) are present at shallow depth. In this area, deposits between about 100 and 250 feet in depth are normally confined, whereas the top of the Corcoran Clay is about 450 feet deep, or well below these deposits. The confinement in the upper aquifer is indicated to be most pronounced near the trough of the valley, where shallow confining layers are present, and to the south, where the Corcoran Clay is generally deeper.

Exchange Contractor's Subareas A, B, C, E, F, G, and I are west of the San Joaquin River. The predominant trend in these subareas is a long-term constancy of water levels. No long-term groundwater overdraft is indicated for the upper or lower aquifer.

Aquifer Characteristics

Specific capacities and aquifer transmissivities were discussed in detail for the Exchange Contractors service area by KDSA (1997a). Figure 25 of KDSA (1997a) showed specific capacities for a number of wells, as of the mid-1990's. Figure 12 of the KDSA 2007 report was an updated map of specific capacities for CCID and other wells in the service area. In general, the same pattern is evident as from the previous map. In order to calculate groundwater flows, values for aquifer transmissivity were used. Those values were based primarily on aquifer tests conducted on several dozen wells in the mid-1990's, and supplemented with estimates from specific capacities. These values were used along with water-level gradients to determine groundwater flows.

Amounts of Lateral Groundwater Flow

The lateral groundwater flows at the boundaries of the Exchange Contractor's service area were determined by KDSA (1997) and updated in the 2007 report. Straight-line segments near the center of the actual irregular boundaries were developed, based largely on the directions of groundwater flow. Along the west and southwest boundaries near Sub-Areas A, B, C, and I, segments were used for groundwater inflow calculations. The direction of groundwater flow in the upper aquifer has generally been to the east or northeast in these areas. A segment along the east boundaries of Sub-Areas A and B was used for groundwater outflow calculations. The direction of groundwater flow in the upper aquifer in this area has also been normally to the east or northeast. Also, a segment was used for the east boundaries of Sub-Areas H, E, and J for calculating groundwater outflow. The direction of groundwater flow has been to the northeast in this area. In the area which is immediately south of the north part of the Grasslands Water District, groundwater in the upper aquifer moved primarily to the north. Thus an east-west segment was selected about three miles north of Highway 152, to calculate groundwater outflow from Sub-Areas C and H. Calculations of the amounts of groundwater flow were done for both normal and drought conditions. The lengths of some segments varied somewhat between the two conditions, because of changes in the direction of groundwater flow. Table 4 of KDSA (1997) summarized the estimated total lateral groundwater inflow into the upper aquifer. This inflow was 80,000 acre-feet per year for normal conditions and 50,000 acre-feet per year during droughts. The total lateral groundwater outflow was 115,000 acre-feet per year for normal conditions and 150,000 acre-feet per year for droughts.

As part of the 2007 evaluation, the water-level map for Spring 2006 (Figure 2) was used to provide more up-to-date estimates of groundwater lateral flows in the upper aquifer. The segments used for this evaluation are shown on Figure 2. On the west side, one segment extended from Mendota to near the Fresno County-Merced County line. The width of groundwater flow perpendicular to the direction of groundwater flow along this segment was 21 miles, and the average water-level slope was six feet per mile in Spring 2006. An average transmissivity of 190,000 gpd per foot was used for this segment, based on the 1997 evaluation.

Using Darcy's Law, the calculated lateral inflow of groundwater through this segment was about 27,000 acre-feet per year.

Another segment on the west side extended from near the Fresno County-Merced County line to near the San Luis Wasteway. The width of flow along this section was 22 miles, and the average water-level slop was ten feet per mile. The average transmissivity used was 100,000 gpd per foot, from the 1977 evaluation. The calculated lateral groundwater inflow through this segment was about 25,000 acre-feet per year in Spring 2006. Another segment on the west side was between the San Luis Wasteway and a point west of Newman. The width of flow was 15 miles and the average water-level slope was nine feet per mile. An average transmissivity of 100,000 gpd per foot was also used for this segment. The calculated lateral groundwater inflow through this segment in Spring 2006 was about 15,000 acre-feet per year. Another segment extended from a point west of Newman to the north end of Sub-Area A. The width of flow for this segment was ten miles, and the average water-level slope was seven feet per mile. An average transmissivity of 100,000 gpd per foot was also used in this area. The calculated lateral groundwater inflow along this segment was about 8,000 acre-feet per year. The total lateral groundwater inflow into the upper aquifer along the west side of the combined service areas was thus estimated to be about

75,000 acre-feet per year in Spring 2006. This was slightly less than the value (80,000 acre-feet per year) estimated in 1997 for normal conditions.

For groundwater outflow to the east, one segment was used from near the east edge of the CCC to a point to the west along the San Joaquin River about three miles downstream of the Mendota Dam. The width of flow was six miles, and the average water-level slope was seven feet per mile. An average transmissivity of 160,000 gpd per foot was used for this segment, from the 1997 evaluation. The calculated lateral groundwater outflow for this segment was about 8,000 acre-feet per year as of Spring 2006.

Another segment used was between the northwest end of the previous segment and a point along the San Joaquin River about four miles north of Firebaugh. The width of flow was seven miles and the average water-level slope was 28 feet per mile. An average transmissivity of 160,000 gpd per foot was also used for this segment. The amount of lateral groundwater outflow along this segment was 35,000 acre-feet per year, as of Spring 2006.

A third segment along the east side of the service area extended from the north end of the previous segment to a point near the San Joaquin River and the easterly extension of Eucalyptus Road. The width of flow was six miles and the average water-level slope was 11 feet per mile. The amount of groundwater outflow along this segment was 12,000 acre-feet per year as of Spring 2006.

Another segment was used from the north end of the previous segment to a point along the San Joaquin River at a point about two miles north of the easterly extension of Henry Miller Road. The width of flow was ten miles and the average water-level slope was ten feet per mile. A transmissivity of 140,000 gpd per foot was used, based on the previous evaluation. The groundwater outflow along this segment was about 17,000 acre-feet per year as of Spring 2006.

The next segment used was near the north edge of Sub-Area H, and primarily east of the San Joaquin River, where the direction of groundwater flow was general to the northwest. This segment was four miles wide, and the average water-level slope was six feet per mile. An average transmissivity of 140,000 gpd per foot was used for this segment. The groundwater outflow was 4,000 acre-feet per year along this segment as of Spring 2006.

The next segment used was along the west part of the north boundary of Sub-Area H, where the direction of groundwater flow was generally north, toward the San Joaquin River. The width of flow was three miles and the average water-level slope was two feet per mile. An average transmissivity of 140,000 gpd per foot was used for this segment. The lateral groundwater outflow along this segment was 1,000 acre-feet per year as of Spring 2006.

The next segment used extended from a point about three miles north of Los Banos to the northwest, to a point about one mile northeast of Ingomar Grade and one and a half miles northwest of the San Luis Wasteway. The direction of groundwater flow in this area was to the northeast. The width of flow was six miles and the average water-level slope was five feet per mile. A transmissivity of 140,000 gpd per foot was used, from the previous evaluation. The groundwater outflow along this segment was 5,000 acre-feet per year as of Spring 2006.

The next segment extended to the northwest from the north end of the previous segment to a point about one mile northeast of Gustine. The width of flow was nine miles and the average water-level slope was about eight feet per mile. A transmissivity of 100,000 gpd per foot was used, from the previous evaluation. The groundwater outflow through this segment was 8,000 acre-feet per year as of Spring 2006.

The next segment extended from a point about one mile northeast of Gustine to the northwest, to a point about three miles southeast of Crows Landing. The width of flow was nine miles, and the average water-level slope was two feet per mile. A transmissivity of 100,000 gpd per foot was used for this segment. The amount of groundwater outflow to the northeast was 1,000 acre-feet per year as of Spring 2006.

The last segment used on the east side of the service area extended north to the north boundary of Sub-Area A. The direction of groundwater flow was to the northeast, toward the San Joaquin River. The width of flow was four miles and the average water-level slope was ten feet per mile. A transmissivity of 100,000 gpd per foot was used for this segment. The groundwater outflow was 5,000 acre-feet per year as of Spring 2006.

The total lateral groundwater outflow from the upper aquifer in the service area was 96,000 acre-feet per year as of Spring 2006. This value was 19,000 acre-feet per year less than the value (115,000 acre-feet per year) previously calculated for normal conditions. The lateral outflow exceeded the lateral inflow by 21,000 acre-feet per year. This was 15,000 acre-feet per year less than that estimated previously for normal conditions.

Land Subsidence

The land surface can subside when water levels in confined aquifers decline and interbedded fine-grained confining beds are compacted. Subsidence begins when the water surface in the aquifer falls below a certain threshold level. The rate of subsidence depends on how far water levels fall below that level, how long they remain there, and the characteristics of the sediments. Grain size, sorting, and the clay mineral type are the most important sediment characteristics. Observations in the San Joaquin Valley indicate that subsidence began when water levels dropped more than about 100 feet below the earliest measured levels. Water-level declines in excess of 100 feet began in the 1940's, when and pumpage increased significantly from deep wells tapping the lower aquifer.

Subsidence was measured in the part of the service areas south of Los Banos by the U.S. Geological Survey. The total land subsidence between 1926 and 1972 (taken from U.S. Geological Survey Professional Paper 437-F) is shown in Figure 5. Subsidence ranged from one to 12 feet in the part of the study area south of Los Banos.

Since 1972, much less information is available on land subsidence than for the previous decades. Some information is available for the settling of some canals and other features. The Delta-Mendota and Outside Canals have required extensive repairs due to subsidence, and the repair or replacement of Mendota Dam is being considered. Up to 12 feet of subsidence were recorded by 1972 along some parts of the Outside Canal, and there was an additional two feet by 1994. Figure 6 shows subsidence along the Delta-Mendota Canal. Subsidence was the greatest near Russell

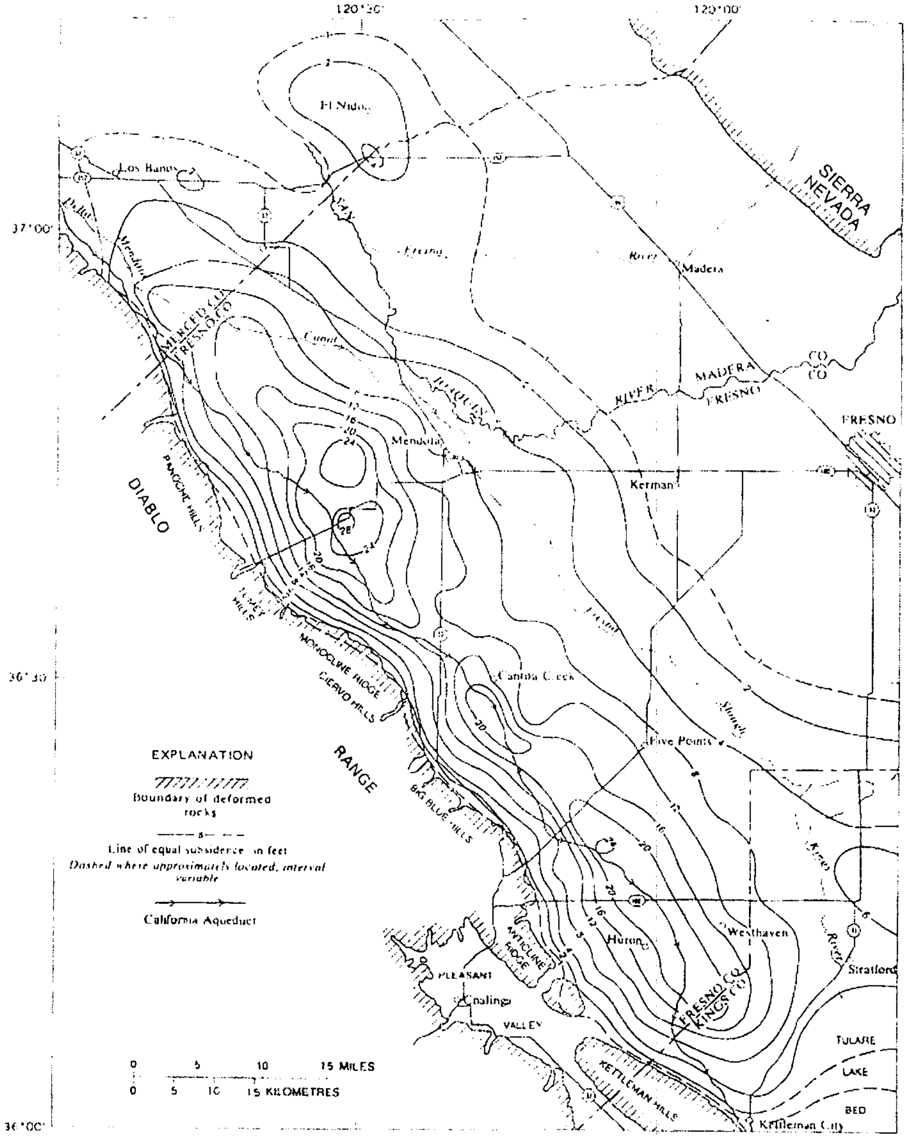
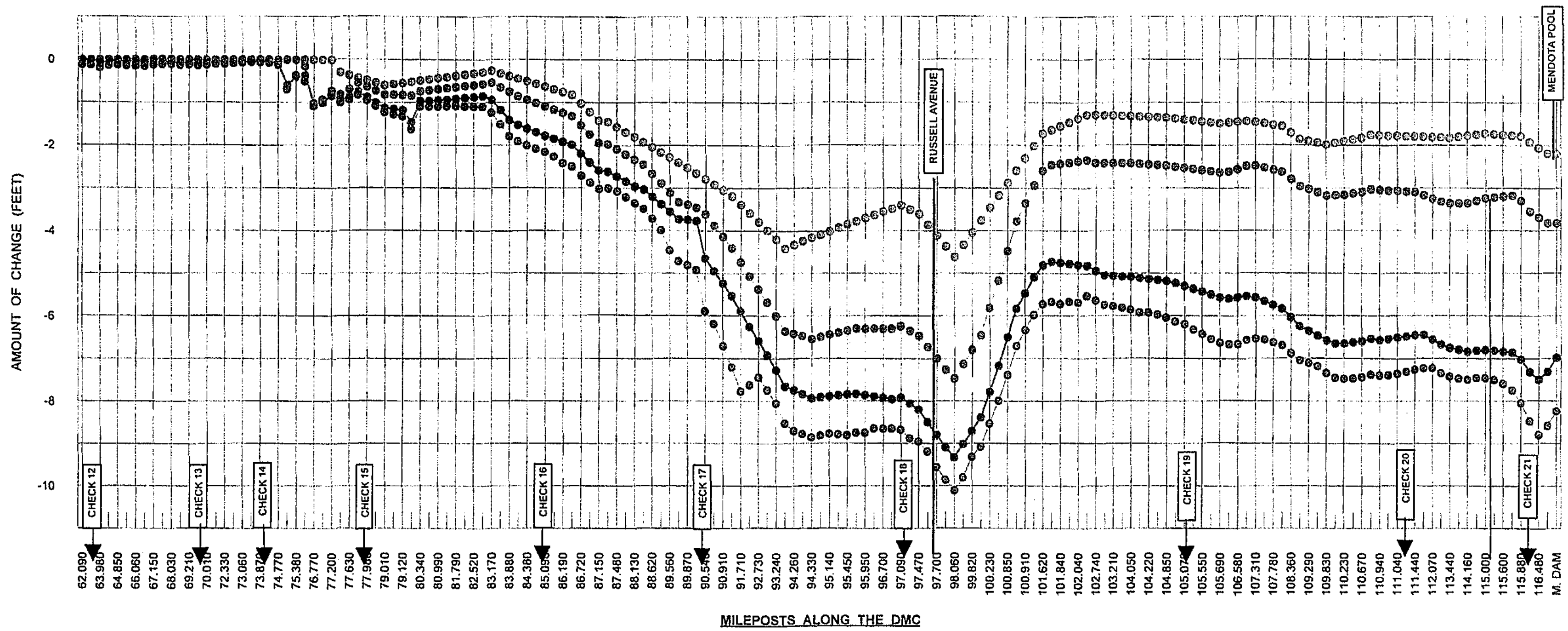


FIGURE 5- LAND SURFACE SUBSIDENCE FROM 1926 TO 1972

SUBSIDENCE DATA ALONG THE DELTA-MENDOTA CANAL, COTTONWOOD ROAD TO MENDOTA POOL



1935-1953 Subsidence · 1935-1957 Subsidence · 1935-1984 Subsidence · 1935-1998 Subsidence

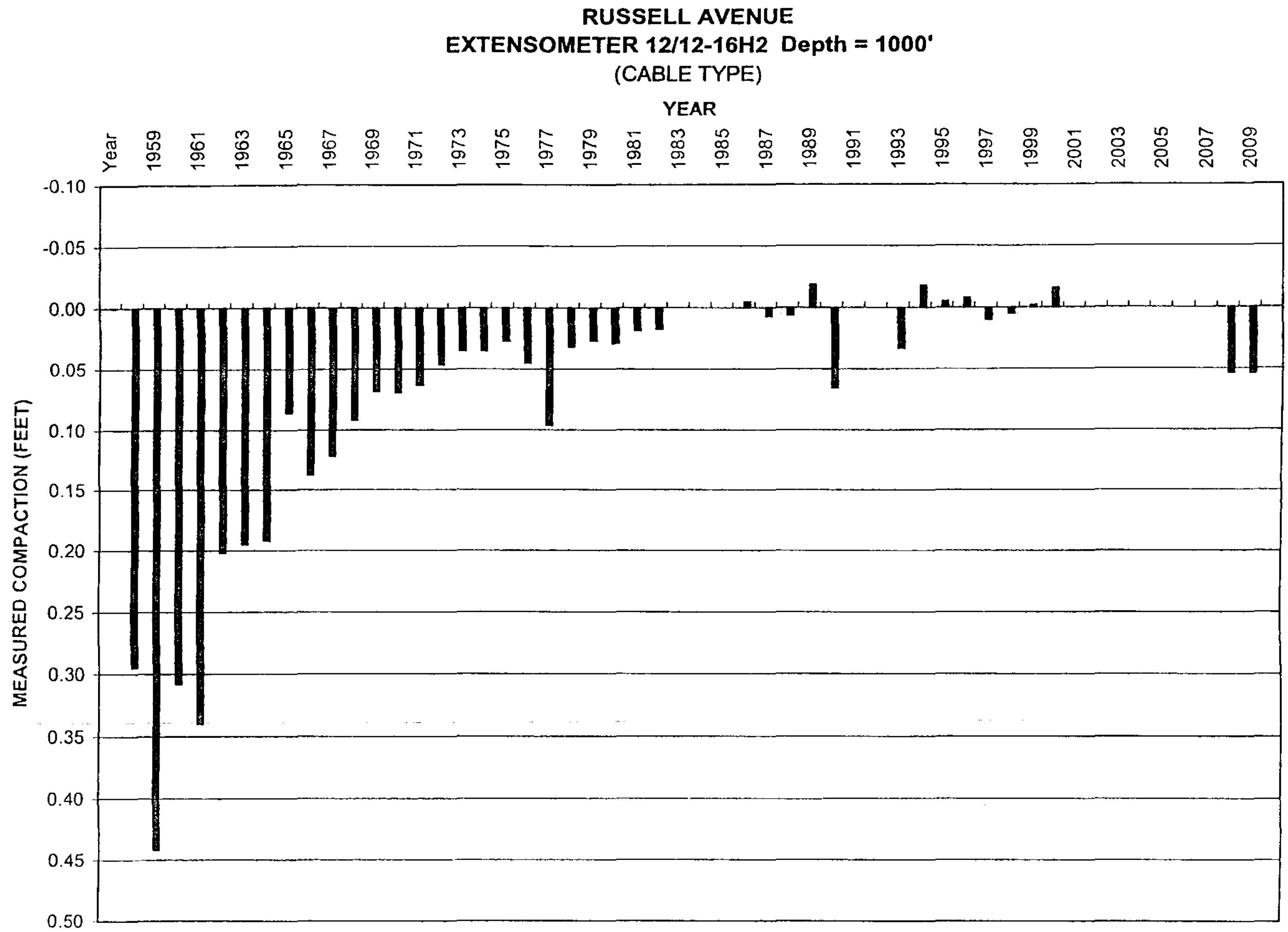
MP 62.090@COTTONWOOD RD; MP 75.84@HWY 152; MP 86.19@COTTON GIN RD; MP 90.54@ CHECK NO. 17; MP 97.68@RUSSELL AVE. ;MP102.93@FAIRFAX AVE.; MP111.51@SIERRA AVE; MP116.48@BASS AVE.

Figure 6 - SUBSIDENCE ALONG THE DELTA-MENDOTA CANAL

Avenue, where a number of lower aquifer wells are present.

There have been adequate water-level declines for causing subsidence in the Crows Landing-Newman area, but no specific subsidence monitoring programs have been in effect in this area, except for canal surveys. The partial submergence of Anderson Road Bridge over the Main Canal indicates that there has been at least a foot of subsidence just south of Orestimba Creek.

A number of recorders were installed in the San Joaquin Valley several decades ago, to allow the rates and amounts of compaction of strata at different depth intervals to be evaluated. One of these recorders was near Russell Avenue and the DMC (Figure 7). Since 1975, compaction and subsidence rates have been relatively small except during drought periods. Compaction rates decreased after deliveries from the San Luis Canal/California Aqueduct began in 1968 and pumpage was subsequently reduced. Compaction rates increased during the 1976-77 drought, the 1987-92 drought, and the recent drought. Near Russell Avenue, 93% of the measured compaction during 1958-82 was in strata below the top of the Corcoran Clay. Two compaction recorders are being monitored near the Mendota Pool, as part of monitoring for the Mendota Pool Group transfer program. It is clear that water levels do not need to be drawn below historic lows, for compaction to resume. The U. S. Geological



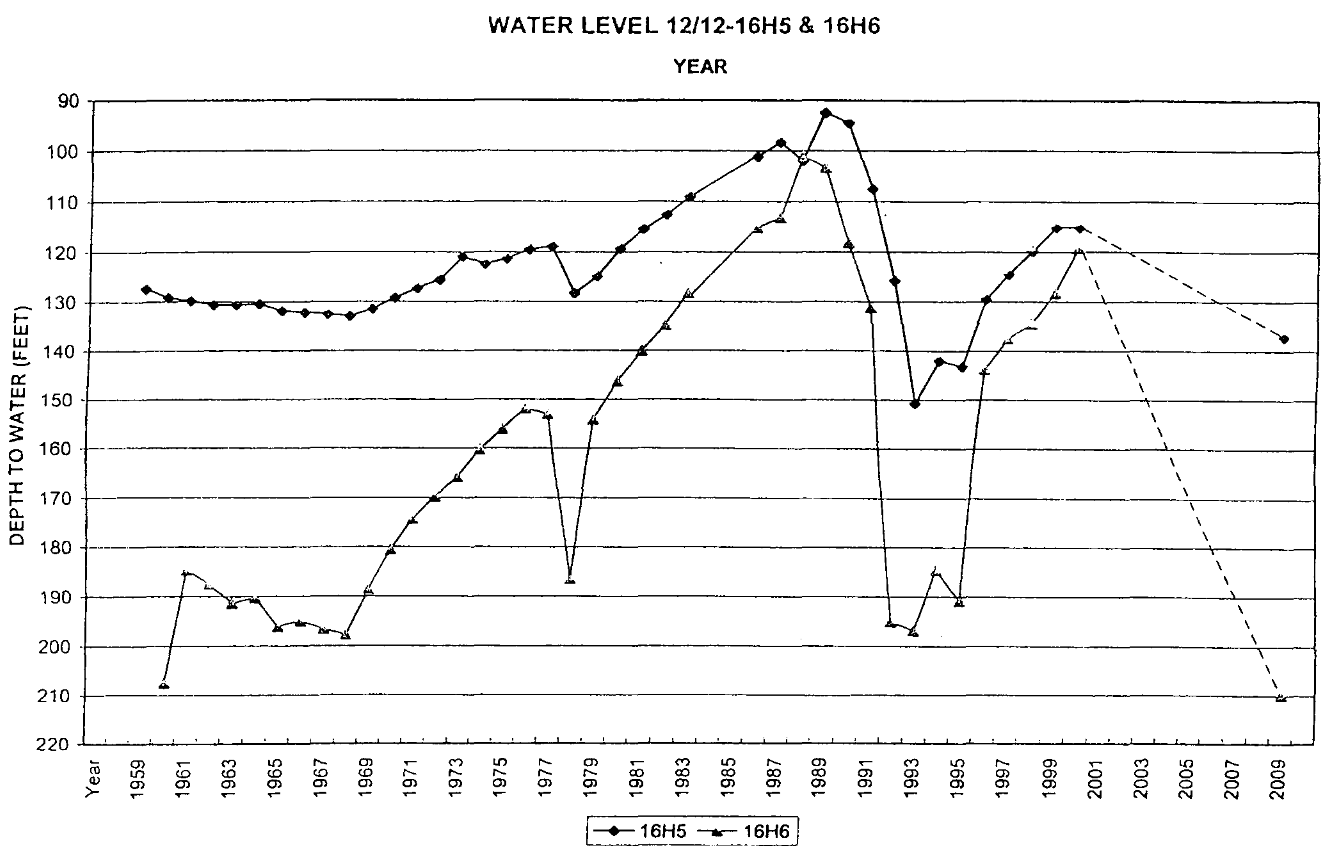


Figure 7 - COMPACTION AND WATER-LEVEL CHANGES AT RUSSELL AVENUE RECORDER

Survey is now conducting un updated subsidence study in part of the San Joaquin Valley. The focus has been on the California Aqueduct in Fresno and Kings Counties.

Groundwater Quality

KDSA (1997b), as part of studies for the CCID, mapped electrical conductivities and boron concentrations in the upper aquifer, based on analyses for the 1990's. Figure 13 of KDSA (1997b) showed electrical conductivities for the upper aquifer. Groundwater with electrical conductivities of less than 1,200 micromhos per centimeter at 25°C was present in areas recharged by the larger westside streams, from Los Banos Creek to near Crows Landing. Relatively low electrical conductivities were also found along the east side of the area near the San Joaquin River, from south of Highway 152 to near Mendota.

An exception to the pattern of low groundwater salinity to the east was an area of high electrical conductivity in the center of T10S/R13E. A zone of relatively shallow brackish water was observed on many electric logs in this area. The area of brackish water appears to underlie a large part of the San Luis Canal. Co. area. Virtually all water supply wells are completed at depths (above a depth of about 250 feet) above the brackish water zone.

Electrical conductivities greater than 1,800 micromhos were in 1) areas recharged by creeks south of Los Banos Creek, 2) an area of poor quality groundwater southwest of Mendota, 3) at the down slope ends of westside alluvial fans in T8S/R9E and T9S/R9E, and 4) in an area northeast of Los Banos. These higher conductivities were probably caused by historical evaporation of shallow groundwater in those areas. Electrical conductivities exceeding 3,000 micromhos severely restrict irrigation of most crops. Conductivities ranging from 700 to 3,000 micromhos cause a slight to moderate restriction (Ayers and Westcot, 1985).

Intermediate electrical conductivities (1,200 to 1,800 micromhos) were associated with the smaller westside drainages and in an area adjacent to the area of low electrical conductivity groundwater near the San Joaquin River.

As part of the 2007 evaluation, an updated map was prepared to show the distribution of electrical conductivity in the upper aquifer for the mid-2000's, in parts of the Exchange Contractors service area where recent data are available (Figure 8). In the 1997 report, electrical conductivity contours for 1,200, 1,800, and 2,400 micromhos were shown for the 1990's. These same contours are shown in Figure 8 for the mid-2000's. These contours were selected for grouping purposes and do not represent specific water quality criteria. Substantial data were available for the area between dos Palos and Mendota, in the Crows Landing and Newman areas, and in the Los Banos area. Overall, these contours

This Page Intentioanlly Left Blank

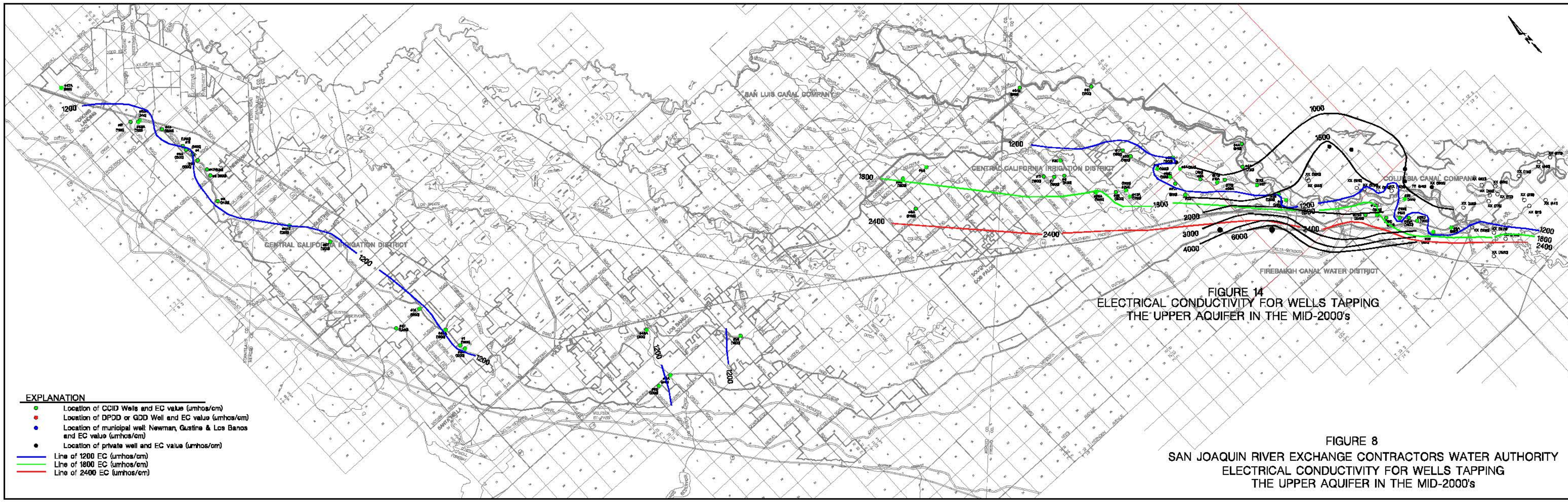


FIGURE 8
SAN JOAQUIN RIVER EXCHANGE CONTRACTORS WATER AUTHORITY
ELECTRICAL CONDUCTIVITY FOR WELLS TAPPING
THE UPPER AQUIFER IN THE MID-2000's

are generally similar to those for the 1990's.

The electrical conductivity map for the area south of the San Luis Canal Co. service area is generally consistent with that for the mid-1990's (Figure 29 of KDSA, 1997). However, a noticeable trend is for a number of the mid-2000's contours to be slightly northeast of downgradient of the contours for the mid-1990's. In the Mendota-Firebaugh area the mid-2000's contours for 1,200, 1,800, and 2,400 micromhos per centimeter at 25°C were an average of about a half mile east of those for the mid-1990's. This is consistent with observations from groundwater monitoring near Mendota, and with observations in the western part of the Columbia Canal Co. service area, where TDS concentrations and electrical conductivities have increased during the past decade. The northeasterly migration of high salinity groundwater in the upper aquifer is due to the increased northeasterly water-level slope, which has been partly caused by water-level declines in western Madera Co., particularly in irrigated areas without surface water supplies.

In summary, the electrical conductivities of groundwater in most of the CCID and San Luis Canal Co. service areas are suitable for irrigation of the crops that have been grown. Water from CCID district-owned wells is pumped into canals and mixed with surface water before use. In addition, district-owned wells have generally been located in areas of lower salinity groundwater. These factors tend to mitigate potential problems associated with higher electrical conductivities in the groundwater.

Time Changes. CCID has prepared hydrographs for District pumpage and electrical conductivity for four parts of the District (KDSA, 2007, Appendix B). Electrical conductivities in water from CCID wells in the Mendota-Firebaugh area, have generally increased since 1959. Rates of increase in electrical conductivity have generally been greater during periods of heavy pumping, compared to periods of little pumpage. More groundwater from west of the wells (upgradient) appears to be pumped in drought periods, and there is more downward leakage of shallow high TDS groundwater. For the area between Firebaugh and Dos Palos, a similar pattern is evident since 1959.

For the Los Banos area, historical data for the CCID wells are limited, but no large changes in electrical conductivity are indicated. For the Gustine-Newman areas, electrical conductivities of water from several wells have increased since 1968, but the increases appears to be less that in the Firebaugh-Mendota area. Part of these increases is likely due to downward flow of poor quality shallow groundwater, particularly when water levels are significantly lowered in the underlying strata.

IMPACTS ON GROUNDWATER

No Project

Water development by the District from conservation and tail water recapture programs is less expensive than well pumping. It is assumed that the Exchange Contractor's would continue to up-date their facilities to the extent previously used when water transfers were occurring. Reused tail water be integrated into the Exchange Contractor's water supply and well pumping would be reduced. Groundwater levels and groundwater inflows and outflows would remain the same.

Alternative A

Up to 50,000 acre-feet per year of water would be developed due entirely to temporary land fallowing. The existing condi-tions includes 8,000 acre-feet per year due to temporary land fallowing. 5,000 acre-feet per year is associated with lands not affecting San Joaquin River hydrology. This area is essentially upstream of the Lander Avenue Bridge river crossing (east of Gustine). An additional 42,000 acre-feet per year of water would be developed by fallowing 16,800 acres of land. Half of this acreage would be in the upstream area. The reduction in deep percolation would be 0.5 acre-feet per acre per year, or 4,200 acre-feet per year, in the upstream area. In effect, this alter-native would decrease groundwater outflow from the Exchange Contractor's service area to the northeast by about 4,200 acre-feet per year. Because of the poor quality (high total dissolved solids concentrations) of this groundwater, this is not considered an adverse impact.

Alternative B

Up to 88,000 acre-feet per year of water would be developed through a combination of conservation and temporary land fallowing. This would also involve 50,000 acre-feet per year of temporary land fallowing. The remaining water would be from tail water recycling and recapture that would not influence groundwater. In terms of the impacts of groundwater, this alternative would be no different that for Alternative A.

Alternative C

Up to 130,000 acre-feet per year of water would be developed. 50,000 acre-feet per year would be from temporary land fallowing, and 80,000 acre-feet per year from conservation, including tail water recapture. In terms of impacts to groundwater, the alternative would be the same as for Alternative A.

Alternative D

Up to 130,000 acre-feet per year of water would be developed. 20,000 acre-feet per year of this water would be conserved by reductions in irrigation applications and a subsequently decrease in deep percolation of 20,000 acre-feet per year. Half of this would be in the upstream area. This alternative would result in a reduction in groundwater outflow to the northeast of up to 10,000 acre-feet per year, primarily in the area upstream of Highway 152.

KDSA (1997a) calculated the amount of groundwater moving to the northeast out of the Exchange Contractor's service area under normal conditions. For the area south of Highway 152, this was about 72,000 acre-feet per year. Thus this alternative would reduce the normal groundwater outflow to the northeast by up to about 14 percent. Because of the poor quality of much of this water, the impact is considered beneficial.

REFERENCES

Ayers, R. S., and D. W. Westcot, 1985, "Water Quality for Agriculture", FAO Irrigation and Drainage Paper 29, Revision 1, Rome, Italy, 174p.

Croft, M.G. 1969, "Subsurface Geology of the Late Tertiary and Quaternary Water-Bearing Deposits of the Southern Part of the San Joaquin Valley, California", U.S. Geological Survey Open-File Report, Menlo Park, Calif, 63 p.

Davis, G.H., and J.F. Poland, 1957, "Ground-Water Conditions in the Mendota-Huron Area, Fresno and Kings Counties, California", U.S. Geological Survey Water-Supply Paper 1360-G, pp 409-588.

Hotchkiss, W.R., and G.O. Balding, 1971, "Geology, Hydrology, and Water Quality of the Tracy-Dos Palos Area," U.S. Geological Survey Open File Report, Menlo Park, Calif., 107 p.

Kenneth D. Schmidt and Associates, 1997a, "Groundwater Flows in the San Joaquin River Exchange Contractor's Service Areas", report prepared for the San Joaquin River Exchange Contractor's Water Authority, Los Banos, California.

Kenneth D. Schmidt and Associates, 1997b, "Groundwater Conditions in and near the Central California Irrigation District", report prepared for Central California Irrigation District, 131 p.

Kenneth D. Schmidt and Associates, 2007, "Update on Groundwater Conditions in the San Joaquin River Exchange Contractor's Service Area", report prepared for San Joaquin River Exchange Contractor's, Los Banos, California, 44 p.

Kenneth D. Schmidt and Associates, 2011, "Report on Results of Groundwater Monitoring for CCID 2010 Pumpage Program", report prepared for Central California Irrigation District, Los Banos, California, 40 p.

Meade, R.H., 1968, "Compaction of Sediments Underlying Areas of Land Subsidence in Central California", U.S. Geological Survey Professional Paper 497-D, 39 p.

Miller, R.E., Green, J.H., and G.H. Davis, 1971, "Geology of the Compacting Deposits in the Los Banos-Kettleman City Subsidence Area, California", U.S. Geological Survey Professional Paper 497-E, 46 p.

Page, R.W., 1986, "Geology of the Fresh Ground Water Basin, Central Valley, California", U.S. Geological Survey Professional Paper 1401-C, 54 p.