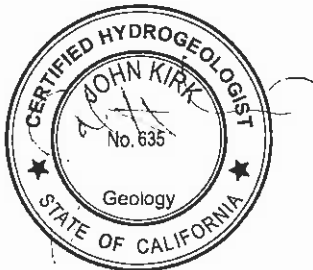


REVIEW OF GROUNDWATER CONDITIONS

FOR

NEW STONE WATER DISTRICT

MAY 2008



Date Signed: May 19, 2008



DATE SIGNED: 5-19-2008

PREPARED BY:

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New Stone Water District

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1 INTRODUCTION

The purpose of this study is to evaluate groundwater conditions in the New Stone Water District (NSWD or District) and identify alternatives for arresting the current groundwater overdraft.

1.1 Description of District

The New Stone Water District (District) is located along the Chowchilla Bypass in western Madera County. The District was formed by the Madera County Board of Supervisors in 1983 with the adoption of Resolution No. 8327. The District encompasses about 3,600 acres. Refer to **Attachment 1** for a location map of the District.

At some point prior to 1996, alfalfa was grown on most of the District lands. Between 1996 and 2003, the District was converted to grape vines. Currently, all water demands are met with pumped groundwater.

1.2 Problem Statement

Groundwater levels have been declining in the District at an estimated long-term rate of 2.0 to 2.5 feet per year. The rate of fall increases dramatically following wet years with strong recharge; in the post 1995 rain series, water levels rose approximately 80 feet, but then fell at the rate of 10 feet per year for the next six years. The long-term rate of decline is caused by a combination of increased reliance on groundwater as irrigated land areas increase, limited recharge capacity of the area due to low permeability surface soils, and the District's suspension of surface water diversions since grape vines and drip irrigation systems were installed between 1996 and 2003. In addition, no irrigation or water districts surround NSWD, so neighboring lands have no surface water contracts and pump groundwater to meet most of their water needs.

The declining groundwater levels have caused the following problems:

1. Increase in pumping costs
2. Decline in well yields
3. Modifications, such as pump lowering, are needed on several wells each year
4. Reduction in groundwater reserves and lower long-term water reliability

As a result of these problems, the District would like to stabilize their groundwater levels. This report evaluates alternatives to achieve this goal. The evaluation was performed at a pre-feasibility level and more detailed studies and design are recommended before any alternatives can be implemented.

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2 HYDROLOGY

2.1 Surface Water Features

The primary surface water feature in the area is the Chowchilla Bypass (Bypass), which runs along the eastern edge of the District. The Chowchilla Bypass is a designated floodway. Water is diverted into the Bypass from the San Joaquin River only in relatively wet years. The Bypass is the only existing conveyance facility that could deliver surface water to District lands.

The District owns gates and a diversion pipeline at the Bypass at Avenue 12. The pipeline can pass 30,000 gpm (estimated) according to the District. The District has a canal along the west side of the bypass up to the southern end of the District (see **Attachment 1**). The District formerly used Chowchilla Bypass water to irrigate crops. However, when a drip system was installed the water could no longer be used. As a result, a canal adjacent to the bypass in the District was backfilled to make more room for grape vines.

District landowners have observed that water flows in the Bypass when annual precipitation at the Fresno Air Terminal is 15 to 17 inches or more. Based on hydrologic records, water flows in the Chowchilla Bypass about once every three years. Monthly frequency is presented in **Table 1**.

Table 1 – Historical Chowchilla Bypass Flows (1967-1992)

Month	Frequency	Month	Frequency
Jan	19%	Jul	23%
Feb	35%	Aug	8%
Mar	27%	Sept	8%
Apr	38%	Oct	0%
May	35%	Nov	0%
June	31%	Dec	0%

However, future flows in the Bypass may be reduced due to the proposed San Joaquin River Restoration. The Bypass is managed by the Lower San Joaquin Levee District. The Levee District informs NSWd when they are free to divert surface water. The District is typically allowed to divert as much water as they want.

Attachment 1 shows several linear hydrologic features in the District. These could be old streambeds or canals. These have been backfilled for crop development, but areas surrounding old streambeds could be sandy and thus good for groundwater recharge. The two southern features may be canals based on their relatively straight alignment, but the northern feature has geometric characteristics of a streambed. District landowners believe that they have encountered sandy soils from this abandoned streambed in New Stone Ranch Blocks 35 and 36.

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3 HYDROGEOLOGIC CHARACTERIZATION

The area has been the subject of a number of regional geology and hydrogeology studies which describe the origin of the sediments, provide descriptions of the hydrostratigraphic units, present regional three-dimensional configurations of the aquifers and aquitards, and describe the water quality and geochemistry of the surface and groundwater supply. Soils have been described on a regional basis by the Natural Resources Conservation Service (formerly the Soil Conservation Service) of the U.S. Department of Agriculture.

3.1 Description of Geologic Units

For characterization purposes, the important geologic units will be described from the base of the basin upward. The units of interest are: basement rocks, marine rocks, unconsolidated sediments and soils.

Basement Rocks

The U.S. Geological Survey (Croft and Gordon, 1968) identified the basement rock materials beneath the District as metamorphic and igneous (granitic) rocks that can be observed in outcrop in the foothills of the Sierra Nevada. Depth to basement rock in the District area occurs at a depth in excess of 9,000 feet (interpolated from Plate 3 of Page, 1986). Contact between the basement rocks and the overlying sediments slope steeply westward from the Sierra Nevada beneath the marine rocks. The basement floor lies at great depth near the axis of the valley; at its deepest point, the basement rock is 32,000 feet deep. Because they are largely impermeable, the rocks of the basement complex are of little importance as a source of water supply (Davis and others, 1959).

Marine Rocks

Marine rocks, where present, overlie the crystalline basement rock. The rocks wedge out to the east where unconsolidated sediments lie directly upon the basement rocks (Croft and Gordon, 1968) and outcrop in the foothills west of Interstate 5. The marine rocks generally contain brackish and saline connate water and are unsuitable for most uses (Croft and Gordon, 1968). The base of the aquifer in the District area is the top of the marine rocks. The marine rocks occur at a depth of about 2,700 feet beneath the District (as interpolated from Plate 3 of Page, 1986).

Unconsolidated Sediments

Two kinds of sedimentary deposits are present in the region of the District area overlying the basement complex rocks. The first is deep, marine sediments deposited on the basement described above. The second consists of continental deposits primarily formed by very large alluvial fans bordering both sides of the valley and flood basin deposits formed primarily along the axis of the valley. The fans are coalescing with distinctive soil deposits in the fan and

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interfan areas. The fans are characterized by a mass of generally coarse, permeable deposits in the upper portions of the fan, and consist largely of tongues and lenses of sand and gravel that extend to near the topographic trough of the valley. Near the trough of the valley, the fan sediments are finer-grained with fewer thick and extensive permeable river bed sands present.

The alluvial sediments are typically silty sands with a moderate permeability. The soils formed in the axis of the valley near the toe of the interfan area were formed by the Fresno River and the San Joaquin River. A few miles west of the District are flood basin deposits (Overflow Lands described by Mitten and others, 1970). These formed fine-grained deposits and overflow lands, resulting in somewhat different soil characteristics.

Lake and marsh deposits formed in low areas that are isolated and discontinuous areas within the fan and are identified as clayey and silty sediments on driller's logs. The geologic environment in which these sediments formed is one of interfingering layers of silty sands, sands and clays/silts. Such an environment is not conducive to the development of areally extensive aquifers or aquicludes/aquitards. This is demonstrated by a review of the available well logs for the area. Although successions of silt, sand, clay and gravel are noted on the logs, they do not correlate well between logs, and construction of cross-sections displaying continuous sedimentary units with laterally continuous characteristics is difficult.

A sedimentary layer of both regional and local importance is the Corcoran Clay. The Corcoran Clay is essentially an impermeable barrier and creates a confined aquifer that is one of the primary sources of water in the area. Groundwater flow beneath the Corcoran Clay is both from the west towards the axis of the valley and from the east also towards the axis of the valley. The Sierran source groundwater is of higher quality than the Coast Range source groundwater. The Coast Range groundwater passes through sediments derived from marine source rocks and contains a higher quantity of salts and other mineral matter sometimes deleterious to crop growth. Wells drilled beneath the Corcoran Clay located in areas closer to the axis of the valley show a stronger influence from the Coast Ranges, with the water being of much lower quality. Although it is believed that the location of the District in relation to subsurface water flows and sources beneath the Corcoran Clay will obtain a higher portion of Sierran source groundwater, District wells completed beneath the Corcoran Clay should be sampled and tested for Electrical Conductivity. Seven District wells have been completed to depths ranging from 532 feet to 597 feet and would encounter sub-Corcoran water. Higher readings will indicate Coast Range source water which will be of limited usefulness as a water supply to the District. Lower readings will indicate acceptable water for irrigation purposes and will potentially add to the available water supplies.

The lake in which the clays formed was known as Lake Corcoran or Lake Clyde. It was widely extensive, ranging from 10 to 40 miles wide and more than 200 miles long, covering much of the valley floor.

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A study by Lettis (1982), shows that the Corcoran Clay is present in the area at an elevation of about -100 to -120 feet (top of clay). Ground surface at the District ranges from about 150 to 160 feet. Depth to the Corcoran Clay would therefore be about 250 to 280 feet. A regional geologic cross-section is shown as **Attachment 2**. The vertical scale of the figure is greatly exaggerated to emphasize the geologic structure. Distribution of the sedimentary source rocks is summarized as originating in the Coast Ranges, the Sierra Nevada, or from the Central Valley lake bed sediments forming the Corcoran Clay.

3.2 Local Geology

The local geology and soils have the following characteristics:

- Natural Resources Conservation Service soils maps show that surficial soils are not conducive to groundwater recharge, but the District has observed many sandy soils beneath surficial clay and hardpan.
- The District believes that blocks 19-22 and 25-28 could be good for groundwater recharge.
- The soils appear to have good infiltration. Water only stands in fields where there is hardpan or compacted furrows. In wet years with 20 inches of rain, no standing water is observed.
- Blocks 16 and 17 have gumbo clay.
- The District dug 9 test pits per 80 acre block. The east side of the ranch (Blocks 1-5 and 9-13) has surface sandy loam, everything else is clayey on the surface. Below about 2.5 feet, 80% to 85% of the soil was sandy. The northwest blocks are 40 to 50% sand.
- Most of the District was ripped to a depth of 5 feet to remove hardpan.

3.3 Aquifer Parameters

Short-term pump tests performed by PG&E in the San Joaquin Valley have been compiled by the U.S. Geological Survey (Davis, Lofgren and Mack, 1964). For the two townships the District falls within, they found that the well discharge rates and well specific capacities were high; the average discharge rate and specific capacity for T11S/R15E was 1,176 gpm and 81 gpm per foot respectively, and for T12S/R15E the discharge was 1,813 gpm with a specific capacity of 104 gpm per foot. Using the common conversion factor of 1,500 for unconfined aquifer conditions, the aquifer transmissivities would be 121,500 gpd per foot and 156,000 gpd per foot for T11S/R15E and T12S/R15E respectively. These are likely pump tests of wells screened above the Corcoran Clay. These are relatively high numbers commonly found in the better portions of the aquifers of the San Joaquin Valley.

3.4 Well Characteristics

The District's wells have the following characteristics:

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- Most wells in the District are only a few hundred feet deep and have a capacity of about 1,200 gpm. However, District landowners recently constructed a well with a depth of 600 feet and the well probably penetrates the Corcoran Clay. This well has a yield of about 2,000 gpm.
- The District has observed a decrease in well yields as groundwater levels have declined.
- The District has about 20 wells with pumps. They generally need to lower the pumps in 2 to 4 well per year. According to local growers, the bowls are only good for 4-5 years. If deeper wells are installed the bowls may last 5 to 10 years.

Table 2 – District Well Characteristics and Pump Test Results

Description	Units	Range	Average
Groundwater Depth	ft	51 - 110	76
Well Depth	ft	210-597	365
Well Diameter	in	14-16	16
Pump Depth	ft	120-242	181
Pump Power	hp	40-125	78
Specific Capacity	gpm/ft	15-123	41
Transmissivity	gpd/ft	22,500-184,400	44,000

Notes: Information based on 22 District wells

3.5 Water Quality (Chowchilla Bypass)

Although no data was found on the quality of the water in the Chowchilla Bypass, water quality in the San Joaquin River at various locations is available. In upstream areas below Friant Dam, the river water has an electrical conductivity (E.C.) of 120 ($\mu\text{mhos/cm}$); below Biola an E.C. of 197 $\mu\text{mhos/cm}$; and near Mendota an E.C. of 1,256 $\mu\text{mhos/cm}$. These water samples represent low flow conditions when groundwater enters the river (Mitten and others, 1970). Water during flood flow would likely be of a higher quality, more typical of San Joaquin River water below Friant Dam.

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4 EVALUATION OF GROUNDWATER OVERDRAFT

The California Department of Water Resources monitors water levels throughout the Central San Joaquin Valley and prepares summaries of findings in the form of groundwater hydrographs and groundwater elevation contour maps. The monitored wells in the vicinity of the District include more than 25 private wells which form part of the DWR network. Hydrographs from wells in and around the District are included in **Appendix C**. After reviewing the hydrograph data, they were compiled and summarized by area around the District, grouped as follows:

Attachment 3 - Wells in the District

Attachment 4 - Wells north of the District

Attachment 5 - Wells west and southwest of the District

Attachment 6 - Wells east and southeast of the District

All of the hydrographs have several characteristics in common: a period during 1940's in which water levels were relatively shallow (10 to 20 feet deep) and which show a mild decline over time; an overall declining water table after 1950 resulting from increasing agricultural development and the reliance on groundwater for nearly the entire water supply; two periods of sharp rises in water level due to large flood events followed by a very rapid decline in water levels and a possible return to the long-term rate of decline.

Attachment 3, Wells in the District Hydrographs, show a moderate to rapid decline of water levels with time; water levels fell 100 feet from 1960 to 2005, an average rate of 2.2 feet per year. January and February of 1969 produced near record rains which resulted in an increase in water levels of 20 or more feet. Heavy rains occurred again in 1983 and a succession of wet years in 1995, 1996 and 1998. Water table increases dissipated over time and a return to the long-term trend resumed within a few years of the rain events. Long-term data was available for only two wells in the District and neither of these was adjacent to the Chowchilla bypass. Water table rise in response to large storm events for wells adjacent to the Bypass are discussed below; it should be noted that the District wells not adjacent to the Bypass and those wells which are adjacent show a similar, though somewhat more subdued, increase in water levels in response to the large climatic events. The rate of water table drop increased after 1983 to 5.5 feet per year with single year fluctuations of nearly 30 feet. Water levels fell 65 feet from 1999 to 2005, a rate of fall of more than 10 feet per year. *Although the graph appears to show a return to the long-term average trendline, there is insufficient data to make this case and it is possible that the rapid declines that occurred post 1983 and 1999 may continue into the foreseeable future unless additional large storm events intervene to restore water levels.*

Attachment 4, Wells North of the District Hydrographs, show a moderate to rapid decline with time; water levels fell 80 feet from 1940 to 1983, a rate of 1.8 feet per year. Although January

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and February of 1969 produced near record rains, this only produced a minor spike-up in water levels in comparison to the 1983 rainfall season which resulted in a 50 to 60 foot rise in the water table. This feat was repeated in 1995 (and following) with another 50 to 60 foot spike in water levels. These storm seasons were variously termed the 100, 200 and 500 year flood event; the 1969 flood was also termed a 100 year flood event. In both 1983 and 1995 cases, after the initial sharp rise, water levels fell at more than twice the average rate of the long-term trend. The 1983 event dissipated rapidly and the long-term declining trend appears to have been resumed. However, the rate of fall from 1983 to 1995 was more than 10 feet per year. Three of the four wells included in this group are adjacent to the Chowchilla Bypass and may explain the strong increases in water level in response to the major flood events.

Attachment 5, Wells West and Southwest of the District Hydrographs, show a much more subdued response to storm events; a water table rise of no more than about 20 feet was observed in 1983 and only 1 or 2 feet in 1969. The rate of decline is also more subdued, with an average rate of decline of about 0.8 feet per year. Although generally more subdued, a water level decline of 40 feet from 1999 to 2005 was observed in one well. This is equivalent to an annual rate of decline of 6 to 7 feet per year.

Attachment 6, Wells East and Southeast of the District Hydrographs, show a moderate to rapid decline of water levels with time; water levels fell 65 feet from 1950 to 1980, a rate of 2.2 feet per year. Single year fluctuations in water level were generally small prior to about 1975. After 1975, swings became more pronounced with single year fluctuations in water level of 60 feet observed in one well. After the year 1999, the rate of water level fall increased, with some 60 feet of fall observed from 1999 to 2005, a rate of decline of 10 feet per year. The flood of 1969 produced only a 10 foot or so rise in the water table, while the larger events of 1983 and 1995 (and succeeding years) produced a more substantial water table rise of approximately 40 to 50 feet. Although a return to the long-term trend occurred within a few years after the floods, there is some indication that the water table rise had a longer-lasting effect in these areas; there is insufficient information to draw a further conclusion.

A fifth group of wells is located along the overflow lands. These wells suggest a persistent shallow water table and perhaps perched groundwater conditions. The wells are located two or more miles west of the District. This condition does not appear to impact groundwater at the District but may be worthy of further consideration to verify that such conditions would not be replicated in anticipated recharge areas.

A representative water table map prepared from the DWR mapping program is shown as **Attachment 7**. It can be seen from the figure that the District lies adjacent to a series of pumping centers which have created a series of pumping depressions parallel to the axis of the valley. The pumping centers have resulted from increasing irrigated lands with permanent crops in areas with no or limited surface water supply available. This has created a persistent

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overdraft of the water supply and resulted in the long-term falling water levels observed in and around the District. It can also be seen from the figure that there are four recharge zones supplying subsurface water to the area. These include: a recharge zone along the San Joaquin River south and southeast of the District (between the District and Kerman); subsurface flow from the regional aquifer flowing from east to west; recharge from a water table high located northeast of the District, providing subsurface recharge from this area; and recharge from the San Joaquin River in the Firebaugh area providing subsurface flow from the west and southwest. The location and magnitude of these recharge sources will mitigate to some extent the long-term overdraft condition and provide subsurface flow towards the District as water levels continue to fall. In fact it is feasible, though not possible to verify, that groundwater flows to the District could increase as groundwater levels decline and the local pumping depression gets larger.

Groundwater level declines are attributed to three major causes:

1. Increased development in the area. Some surrounding lands that were formerly fallow are planted with permanent crops or developed as dairies. Groundwater pumping on these lands has increased substantially.
2. Suspension in Use of Surface Water The District formerly used surface water from the Chowchilla Bypass to meet some of their crop water demands, but suspended use of the surface water when drip irrigation systems were installed between 1996 and 2003.
3. No irrigation or water districts surround the district borders, so neighboring lands have no surface water contracts and pump groundwater to meet most of their water needs.

In summary, the NSWDC has faced some significant historical declines in groundwater levels. After periods of above normal precipitation the groundwater levels rise, but soon return to the long-term rate of decline. The NSWDC can expect groundwater levels to continue declining into the foreseeable future.

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5 ALTERNATIVES FOR REDUCING GROUNDWATER OVERDRAFT

Five alternatives have been identified for reducing groundwater overdraft. These include:

1. Direct groundwater recharge
2. Vineyard flooding
3. Direct use of surface water for irrigation
4. Construct deeper wells
5. Water conservation

A discussion on each of these alternatives is provided below. Vineyard flooding and constructing deeper wells were identified as the best alternatives. Direct groundwater recharge is also recommended in facilities (canals and reservoirs) constructed for vineyard flooding operations.

5.1 Direct Groundwater Recharge

Construction of large recharge basins is not recommended because it would require that large quantities of land be fallowed. This would require the removal of grape vines for basins and subsequent loss of revenue. This would probably not be an economical use of land since the basins would only be used in about one of every three years.

Direct groundwater recharge could be performed in canals and reservoirs that are constructed to achieve vineyard flooding. Vineyard flooding, described below, should only be performed when the vines are dormant (December to February). In other months, floodwater can be ponded and recharged in the recommended canal system and terminal reservoirs.

5.2 Vineyard Flooding

Vineyard flooding would involve the spreading of shallow depths of water over most or all of the District lands. The primary goal would be to recharge groundwater, but this would have the incidental benefits of pre-irrigation, satisfying evapotranspiration demands, and leaching salts from the soils.

5.2.1 Facilities and Operations

The District has been experiencing problems with increasing salinity in their soils. This is likely a byproduct of a relatively new drip irrigation system that fails to leach salts through the soil. As a result, the District has purchased a gated pipe system to spread water over District lands to leach the salts. In 2007, the District purchased 2 miles of gated pipe and 1 mile of transfer pipe. Additional pipe might be purchased in the future, if funds permit. The District applied 1.5 acre-feet/acre of pumped groundwater over the soils to leach the salts. With this quantity of water, the soil salinity should match the groundwater salinity.

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This gated pipe could also be used for flooding (groundwater recharge) with few modifications. Some canals and regulation reservoirs would need to be constructed. In addition, some additional soil moisture sensors may be needed, depending on how many are currently in place within the District. See Section 6 for more discussions on proposed facilities.

Vineyard flooding should be acceptable when the vines are dormant, which is typically during the months of December to February. Surface water could be applied during different periods, but it would have to be in smaller quantities to prevent damage to the vines.

Some general information is known about local soils and infiltration rates, and overall the infiltration rates appear to be good. Nevertheless, the ability of the land to accommodate flooding will have to be determined by trial and error. Soils are known to be variable in the area, and some areas may take much more water than other areas. It is recommended that infiltration rates and flooding potential be closely observed while water is spread for leaching salts using the new piping system.

5.2.2 Research Article

Research has been performed on artificial groundwater recharge by flooding vineyards. Refer to **Appendix A** for a technical article from the Water Resources Bulletin on this topic. The article concludes that flooding during grapevine dormancy is a viable recharge method.

The study was performed over four years in Fresno, California. The recharge test plot was 0.27 hectares (0.67 acres). The vineyards were planted with the cultivar Thompson seedless. No other grape varieties were included in the study, but the results are probably applicable to similar varieties. Flooding was only performed during the dormant season (December to February). No efforts were made to flood vineyards during the rest of the year.

A set of piezometers was installed to a depth of 5.5 meters in the recharge area. The soils consisted of sand and loam to a depth of 5.5 meters, and a clay loam layer at a depth of 5.5 meters. An average daily rate of 80 mm (3.1 inches) was recharged over a 32-day period each year. The recharge plot was maintained with approximately 150 mm of water above the soil at all times.

The authors also noted that recharging water by continuous flooding will have two effects on water quality. First, it will speed up the movement of some contaminants to the groundwater. Second, it will also dilute these chemicals as it leaches them.

There were no observed adverse effects on the grapevines and yields in the flooded plots in any of the growing seasons following recharge periods. The authors concluded that artificial groundwater recharge by continuous flooding during grapevine dormancy is a viable recharge method.

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5.2.3 Possible Agronomic Problems

Several agronomic problems are possible from vineyard flooding, especially if the fields are flooded outside of the dormant season. Water delivered prior to bud break would have less of a potential to cause damage than when the vines are experiencing new growth. A brief discussion on some of these issues follows:

1. **Root rot.** Extended periods of standing water and anaerobic conditions will definitely favor the onset of root rots. However, vines were flood irrigated long before they were drip irrigated, so flooding events with well drained soils should be tolerable in moderation.
2. **Waterlogging.** Waterlogging leads to an oxygen deficiency which can be tolerated for a long time in winter when the oxygen requirement is low. In summertime, waterlogging rapidly produces symptoms of water deficiency in the leaves, the leaves become a pale yellow color due to nitrogen deficiency and in some cases the leaves turn red.
3. **Erosion.** Soil erosion could occur if the water flows at high velocities. This will depend on the current field slopes and degree of existing land leveling. Lands in the District have been leveled but they were not laser leveled to a high accuracy.
4. **Nematodes.** Nematodes are probably already present in the wetted area of the drip emitter, so vineyard flooding will probably not exacerbate the problem.

If the vineyards are flooded during the dormant season (Dec. to Feb.) then they should probably not be flooded in March or April when growth begins. If floodwaters are first available in March, then possibly some water could be recharged, but may cause excessive early growth or could stunt growth.

5.3 Direct Use of Surface Water for Irrigation

Direct use of floodwater for irrigation may be feasible. Floodwater would need to be filtered before being sent through the District's drip irrigation systems. This would probably only be practical if the filtration systems are located near the proposed conveyance systems. It may also require additional labor and challenges controlling flowrates and water levels in the canals; certainly it would be more challenging than using well water. Nevertheless, it is recommended that District landowners explore this option due to the direct impact it would have on reducing groundwater pumping.

5.4 Construct Deeper Wells

Additional water supplies can be achieved by drilling deeper wells that penetrate the Corcoran Clay. By pumping water beneath the Corcoran Clay the unconfined aquifer will be less stressed and this could have a positive impact on local groundwater levels. The Corcoran Clay is

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believed to be about 250 to 280 feet below ground surface in the District, but this should be confirmed during well drilling. It is recommended that future wells be constructed into the Corcoran Clay. These wells should also have higher yields than shallower wells. In areas south and west of the District, groundwater below the Corcoran Clay has elevated dissolved solids (salts) making use of the water marginal. If deeper wells are anticipated, then a pilot boring with specific conductivity testing should be performed prior to final well design and construction.

5.5 Water Conservation

Water conservation is probably not an option for reducing water demands and groundwater overdraft. The entire District is irrigated with an efficient drip irrigation system and there is little to no room for increasing irrigation efficiency. In addition, since installing the drip irrigation system, salts have accumulated in the soils and the District is now spreading additional water over all the lands to leach the salts. Increasing the irrigation efficiency could exacerbate the current salinity problem.

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6 DESCRIPTION OF PROPOSED FACILITIES

Proposed new facilities include earth canals and two small reservoirs. These will permit floodwater from the Chowchilla Bypass to be diverted onto District lands and spread to achieve groundwater recharge. Refer to **Attachment 8** for a map showing the locations of the proposed facilities. Drawings of the facilities are not provided, but preliminary dimensions are provided below.

6.1 Gated Pipe

The District has a gated pipe system that they use to spread water and leach salts from the soil. The existing gated pipes have a diameter of 10 inches and have been used to deliver about 2.2 cfs, but they may be able to deliver up to 5.5 cfs (personal communication with Mike Logoluso). They were used to deliver 1.5 acre-feet/acre to district lands to leach salts. The current system includes 2 miles of gated pipe and 1 mile of transfer pipe. This can deliver water to ½ section (320 acres). The gated pipe allows water to be delivered in furrows and thus prevent erosion and damage to the trellis system. This system could also be used, with few modifications, for spreading floodwater for groundwater recharge.

6.2 Diversion Pipeline

The District owns a concrete pipeline that diverts water from the Chowchilla Bypass to a canal parallel to the Bypass. The District reported that the pipeline has a capacity of 30,000 gallons/minute (67 cfs). This pipeline has a diameter of 42 inches and an outlet diameter of 41 inches. With a flowrate of 67 cfs, the flow velocity would be 7.3 feet/second, which is relatively high. The capacity of this pipeline should be verified with field measurements or detailed calculations, which would require surveying the elevation of the pipeline with respect to Bypass water levels. If the pipeline has a capacity of 67 cfs then no pipeline expansion is required.

6.3 Canal

An existing canal is present from the diversion pipeline, extending north along the Chowchilla Bypass to the southern border of NSWD. The existing canal is roughly triangular with a width of about 15 feet and depth of about 5 feet. The canal flows by gravity and is assumed to be able to convey 30,000 gallons/minute (67 cfs), the same as the assumed capacity of the diversion pipeline. This will need to be confirmed after detailed topographic data on the canal is collected. At this flowrate the velocity would be about 1.8 feet/second, near the threshold of erosion for an earth canal. This canal should be extended as shown on **Attachment 8** with two lateral canals travelling in a westerly direction to terminal reservoirs. Pipelines could be constructed instead of canals but they offer the disadvantages of being more expensive. In addition, incidental and intentional recharge will be possible in the canals, as discussed later.

6.4 Terminal Reservoirs

Two terminal reservoirs are proposed, as shown on **Attachment 8**. The reservoirs would regulate flows, capture sediment, and capture spillwater. They would also provide some

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incidental recharge while being used for vineyard flooding, and at other times could be used, with the earth canals, for direct recharge. The reservoirs would be excavated below ground and have a storage capacity of 0.6 acre-feet each assuming the following dimensions:

Length = 100 feet
Width = 100 feet
Depth = 5 feet
Freeboard = 1 foot
Side Slopes = 3H:1V

Assuming a maximum flowrate of 5.5 cfs, the reservoirs would fill in 1.4 hours. This is a fairly short response time, but a small reservoir is suggested because a large area would have to be taken out of production if a 12 hour response time is desired. The District landowners should ultimately determine the size of the reservoir based on the amount of risk they are willing to assume.

6.4 Groundwater Recharge Capacity

Using the proposed facilities, groundwater recharge can be achieved through a combination of: 1) vineyard flooding, 2) incidental recharge in canals and reservoirs during vineyard flooding, 3) intentional recharge in canals and reservoirs, 4) intentional recharge in basins, 5) irrigation with floodwater, and 6) constructing deeper wells. Following is a summary of estimated average annual recharge using these different methods:

Vineyard flooding (December to February)

Existing gated pipe system (5.5 cfs) = 176 AF/year
Expanded gated pipe system (11 cfs) = 353 AF/year
Uncontrolled flooding (67 cfs) = 2,150 AF/year

Incidental recharge in canals and reservoirs

During vineyard flooding (Dec to Feb) = 37 AF/year

Intentional recharge in canals and reservoirs (Mar to Nov)

Canals and terminal reservoirs = 115 AF

Intentional recharge in basins

Recharge basins = 15 AF/acre of basin

Irrigation with floodwater

Irrigation with floodwater (Mar to Nov) = up to 1,490 AF/year

New Stone Water District Review of Groundwater Conditions

Construct Deeper Wells

Stress on the unconfined aquifer can also be relieved by constructing wells that reach into the Corcoran Clay. The amount of water saved would be based on the ratio of the perforated interval above and below the Corcoran Clay. It will likely take the District many years to replace all their wells so that they all extract water from below the Corcoran Clay. It should be noted that some jurisdictions do not allow well perforations in the same well to extend above and below the Corcoran Clay.

The intentional and incidental recharge values above are based on assumed infiltration rates of 0.3 feet/day. This assumption will need to be confirmed. Based on Chowchilla Bypass hydrology, water was assumed to be available an average of 16.2 days per year from December to February, and 51 days per year from March to November.

Using the existing gated pipe system, with the recommended canals and terminal reservoirs groundwater recharge from vineyard flooding, incidental and intentional recharge in the new canals and reservoirs would only be 330 AF/year. For comparison purposes, the District is estimated to have an evapotranspiration demand of about 9,000 AF/year. However, accomplishing this small amount of groundwater recharge may be sufficient to maintain the District's active status. To achieve significant recharge, either uncontrolled flooding (2,150 AF/year) or irrigation with floodwater (1,490 AF/year) is needed. Uncontrolled flooding may cause erosion and damage the existing trellis system, but it is practiced by other growers in the area. Recharge could also be performed in dedicated recharge basins. The District will need to determine if an average annual recharge of 15 AF/acre is worth taking land out of production.

New Stone Water District Review of Groundwater Conditions

7 OPINION OF PROBABLE COST

The groundwater recharge system can include a variety of facilities. The District will need to determine what is best for them. Preparation of detailed designs and cost estimates was beyond the scope of this study, but the following unit prices are provided for planning purposes

Excavation	\$2/cubic yard
Canal extension	\$3/lineal foot
Gated Pipe System	\$65,000 for 5.5 cfs system serving 320 acres
Low lift pumps	\$10/hp capacity
Water pumping	\$0.20 acre-foot/acre
PVC Pipe – 18"	\$24/lineal foot
PVC Pipe – 24"	\$43/lineal foot
PVC Pipe – 30"	\$70/lineal foot
Vine removal	\$1,500/acre

The unit prices do not account for lost agricultural production resulting from the removal of grape vines to construct the facilities. The annual profit from the vines is not known and the landowners will need to estimate this cost themselves.

Maintenance costs for these facilities are estimated to be 1-2% of the capital costs per year.

Labor costs will depend on the available staff in the District. The time to operate the recharge facilities will not be large, so staff may be able to operate the facilities as part of their regular duties.

The unit prices are for comparison purposes only. They are estimated to have an accuracy of +/-25%. The development of more detailed unit prices and a more detailed design is required to more reliably assess the costs.

Land spreading will serve the dual purpose of groundwater recharge and salt leaching. Without the land spreading the salt leaching would still be needed. The savings from not having to pump groundwater to perform salt leaching is estimated to be \$19,800/year (based on 1.5 acre-feet/acre percolation once every five years, 3,000 acres of land, \$0.20/AF-ft pumping cost, and 110 foot average groundwater depth). This is a net savings resulting from the construction and operation of a groundwater recharge system.

New Stone Water District Review of Groundwater Conditions

8 LEGAL STATUS OF DISTRICT

In the past few years, the Local Agency Formation Commission (LAFCO) has been investigating the status of the District. A report summarizing their investigation is included as **Appendix B**. The District was viewed as being inactive by LAFCO, primarily because the District stopped using surface water after the conversion of row crops to permanent crops that rely exclusively on pumped groundwater.

The landowners are encouraged to keep the District active because it can offer them numerous benefits. These benefits include the following:

1. The District can apply for certain grants and low interests loans from State and Federal Agencies.
2. Being within a Water District could potentially increase the value of the land if it is sold, especially if District lands have the ability to receive surface water.
3. Landowner property taxes could possibly be reduced if land or facilities are deeded to the District. The laws concerning this are complex and legal counsel should be consulted before any decisions are made.
4. The District would have the ability to tax the land to fund capital improvements.
5. From a practical matter it is much easier to secure a contract for water purchases, or anything else, using a public agency, i.e. District, because a District is viewed as having taxing power to pay all bills incurred.
6. If the District adopts a Groundwater Management Plan and cooperative agreements with other local agencies, they could show local control and thus avert State required regulations intended to prevent groundwater overdraft.

Based on their report, LAFCO will consider the District active if they pursue a groundwater recharge program. This can be achieved by following the recommendations described in Section 8 – Conclusions and Recommendations. In addition, it is also recommended that the District implement the following tasks to help maintain their active status:

1. Prepare and adopt a Groundwater Management Plan in compliance with California State Senate Bill No. 1938.
2. Sign a cooperation agreement with other nearby agencies, such as Madera Irrigation District, to jointly manage groundwater resources.
3. Prepare annual groundwater contour maps.
4. Consider deeding a portion of the facilities, such as the Chowchilla Bypass diversion pipeline and canal, to the District. This will give the District tangible assets (and could result in lower property taxes for the landowners). The District would need to write an agreement permitting the landowners to operate the facilities.
5. According to the LAFCO document, Section 30, just north of the New Stone Ranch is also a part of the District. The owners of New Stone Ranch and this landowner should meet to

New Stone Water District Review of Groundwater Conditions

discuss their roles in managing the District, or possibly de-annexing this section from the District.

6. Hold board meetings at least once a year.
7. Follow all rules and regulations for public meetings according to California's Brown Act. These include, but are not limited to, publicly posting meeting agendas and preparing meeting minutes.
8. Follow all rules and regulations for Water Districts described in the California Water Code.
9. Follow the District Bylaws, or amend them if needed.
10. Send a copy of the District Bylaws to the Madera County Board of Supervisors (In December 2007 the County was not aware that the District had bylaws).

New Stone Water District Review of Groundwater Conditions

9 CONCLUSIONS AND RECOMMENDATIONS

The District is experiencing a falling water table and considerable groundwater overdraft that is expected to continue. Besides periodic flood flows in the Chowchilla Bypass, the only water supply available to the District is groundwater. If groundwater levels and well yields decline substantially, then land values could depreciate.

It is recommended that the District attempt to reduce the rate of groundwater level decline. This can at least be partially accomplished with periodic vineyard flooding with Chowchilla Bypass water, intentional groundwater recharge in proposed canals and terminal reservoirs, and constructing new wells below the Corcoran Clay.

It is recommended that the District take the following steps in their initial efforts towards stabilizing groundwater levels:

1. Closely observe and record percolation rates during operation of the salt leaching system. These should include detailed records on percolation rates, standing water, etc. in each Block of the District. This information can be used to estimate the volume of surface water that can be recharged while operating a recharge program.
2. Have a qualified hydrogeologist prepare general guidelines for the design of wells in the District.
3. Determine the capacity of existing facilities (diversion pipeline and canal).
4. Perform a preliminary design of the proposed facilities to better determine the cost and feasibility of a land spreading system.
5. Implement the recommendations listed in Section 8 – Legal Status of District, to help the District maintain an active status.
6. Drill all new wells below the Corcoran Clay to enhance pumping rates, increase well efficiencies, decrease the upper zone falling water table rate, get better quality water, and have less interference with neighboring shallow wells.
7. Attempt at least a small effort to perform groundwater recharge. This will help with long-term water reliability, but is probably also needed to maintain the District's active status. The District should consider uncontrolled flooding and/or irrigation with floodwater if they want to make a significant impact on the declining groundwater levels.

New Stone Water District

Review of Groundwater Conditions

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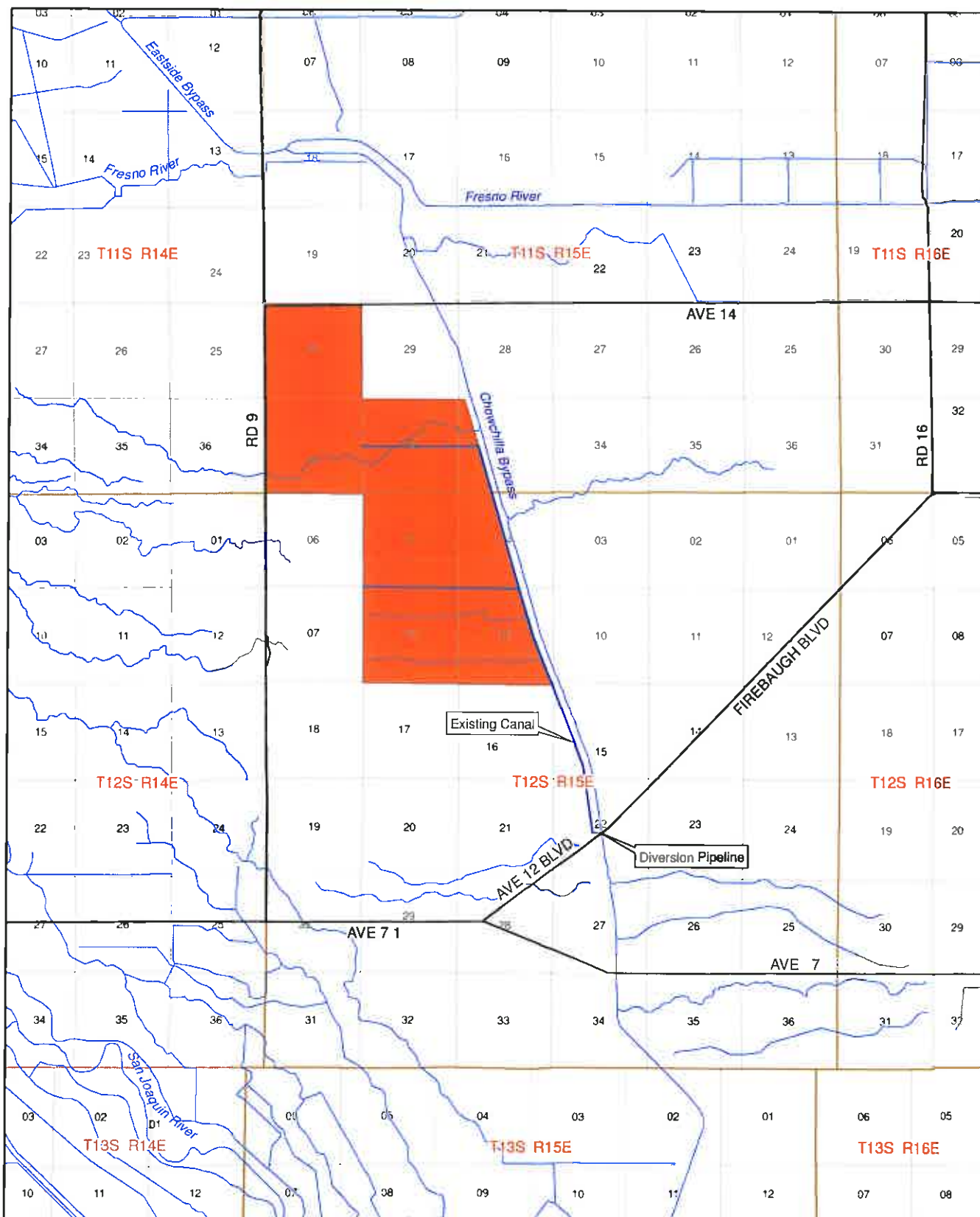
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NEW STONE WATER DISTRICT

REVIEW OF GROUNDWATER CONDITIONS

ATTACHMENTS



0 1 2
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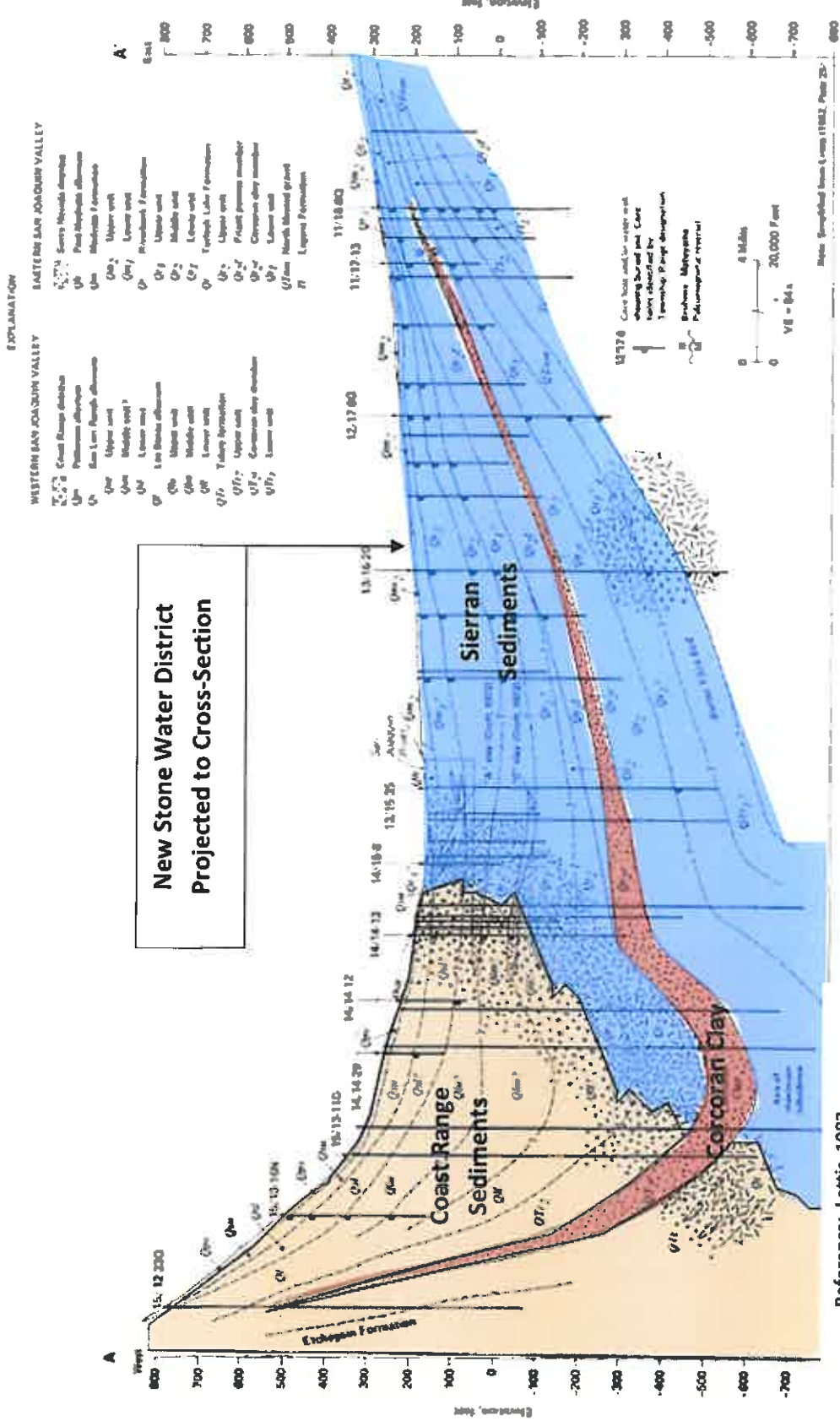
Legend

- Major Road
- Section
- USGS 1:24000 Hydro Feature
- Township / Range
- New Stone W.D.
- LAFCO 2007

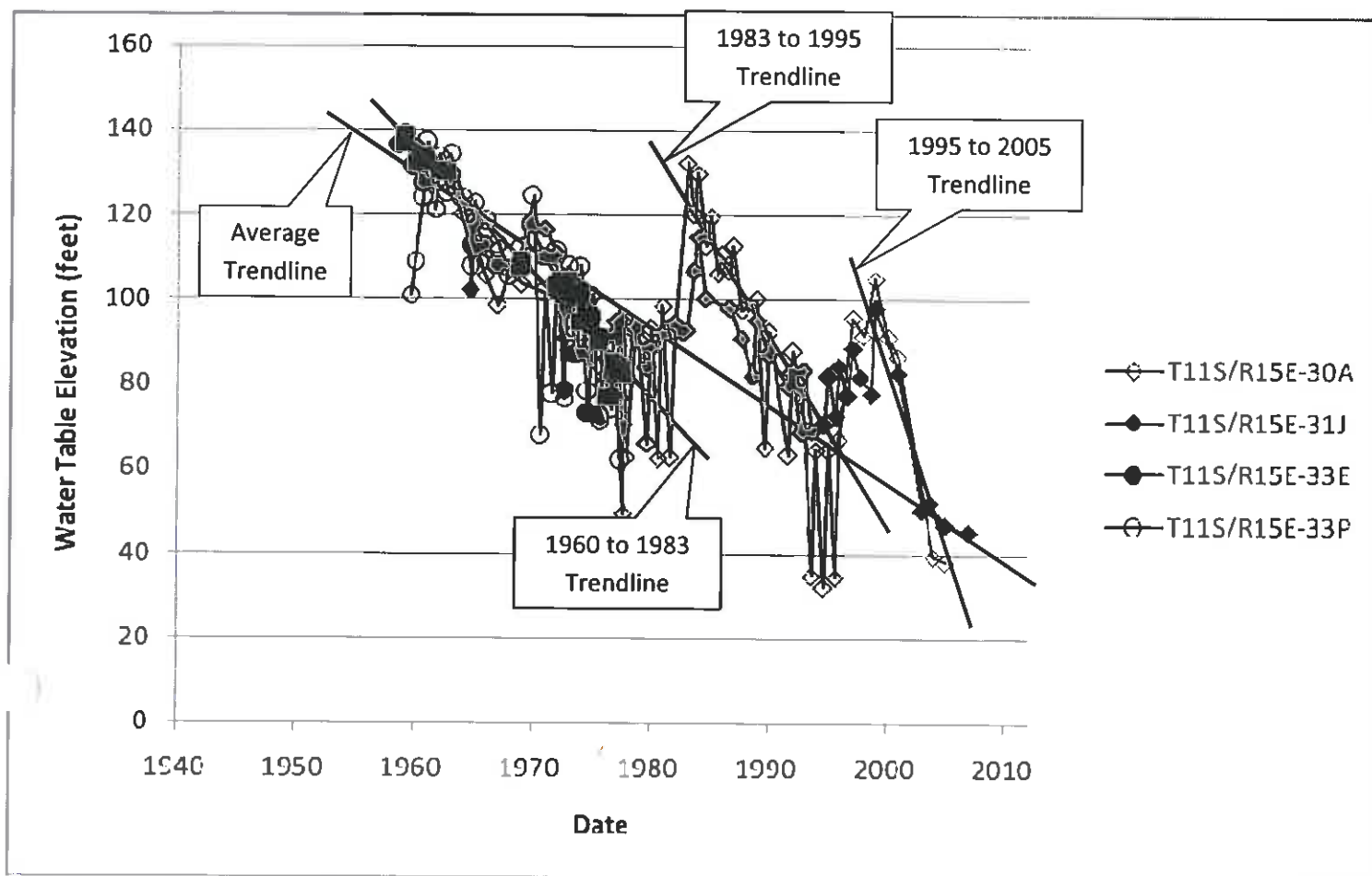
New Stone Water District

Attachment 1

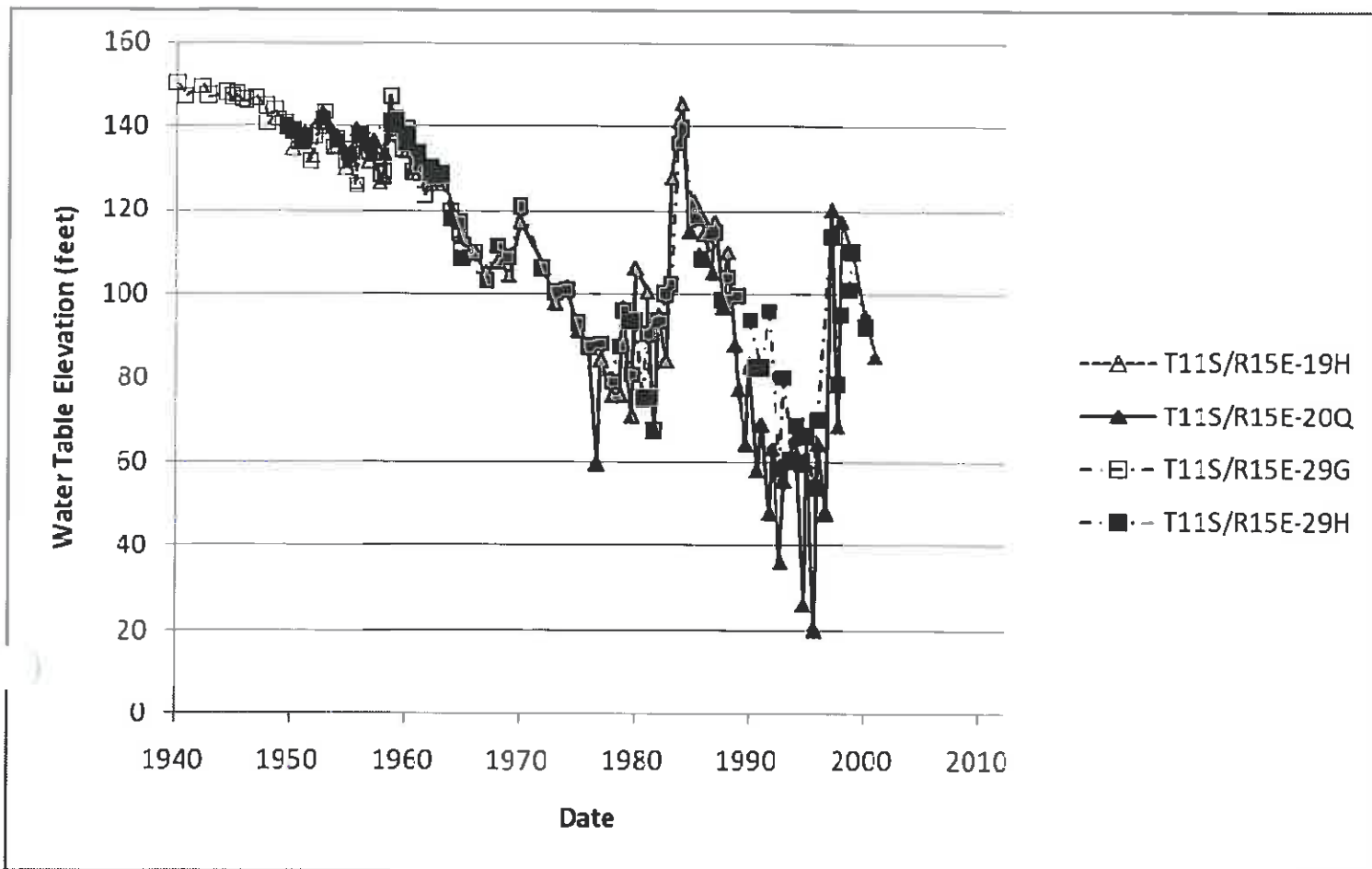
Location Map



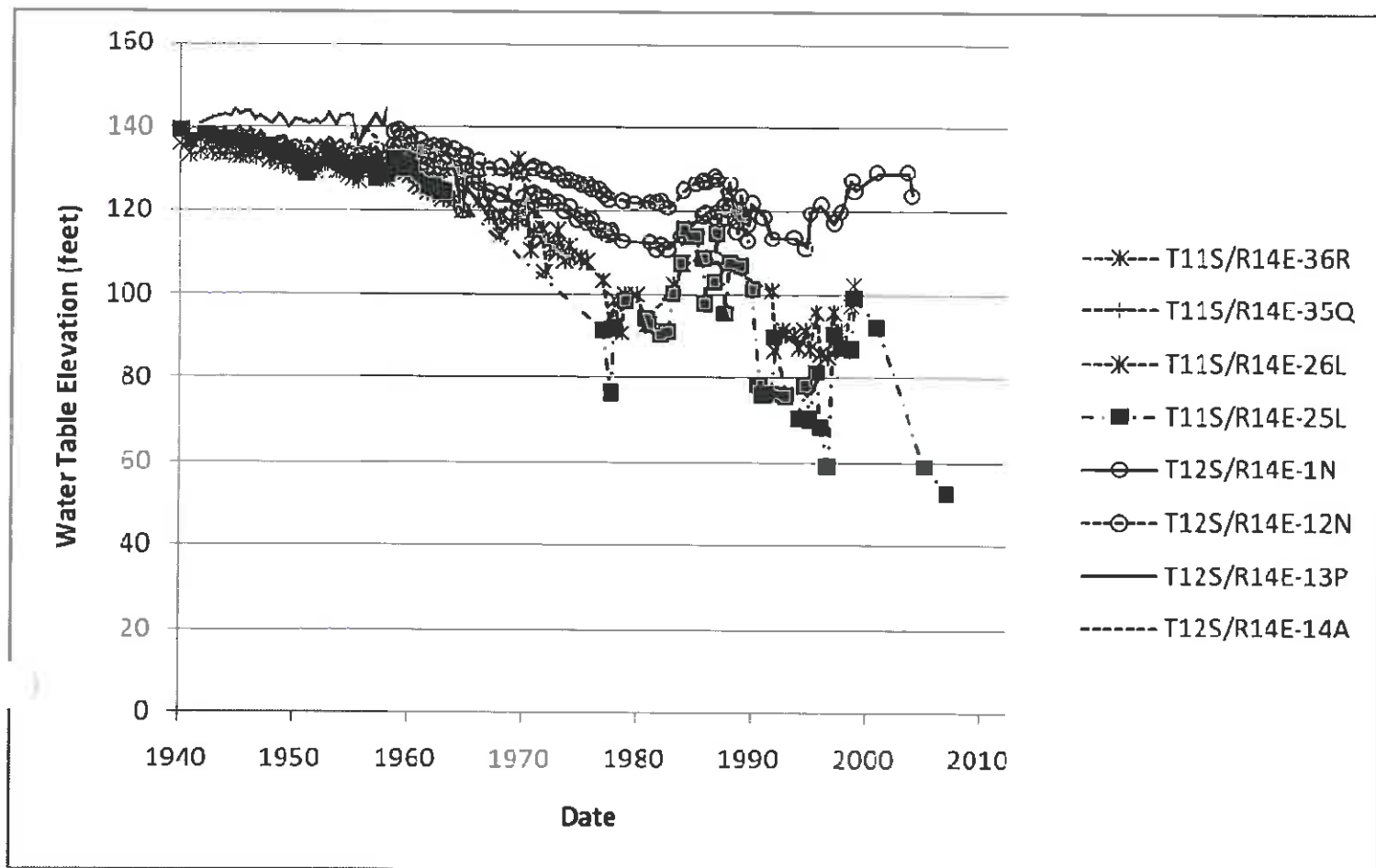
Attachment 2 - Regional Geologic Cross-Section
Southwest to Northeast



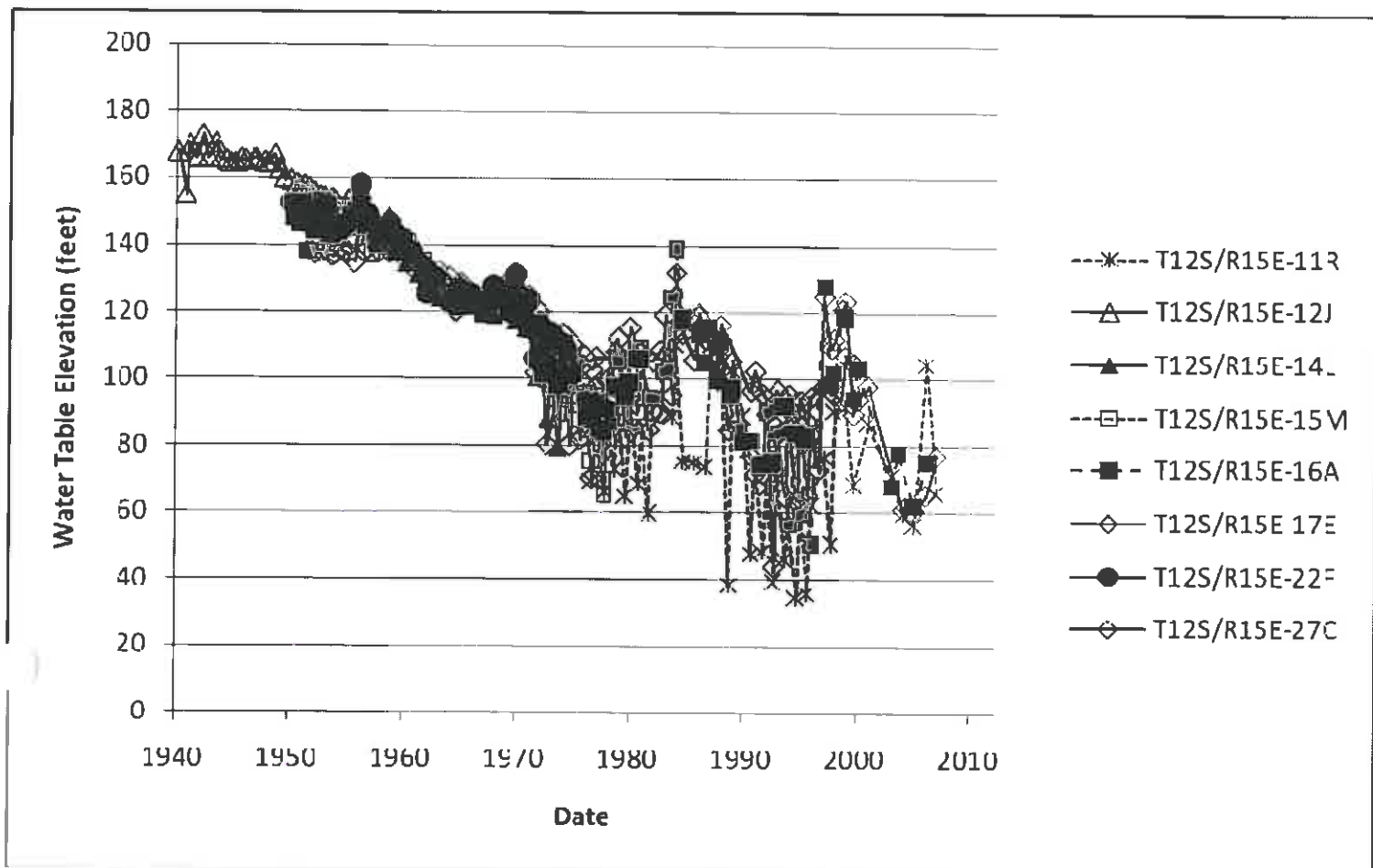
Attachment 3
Groundwater Hydrographs of Wells
Within District Boundaries



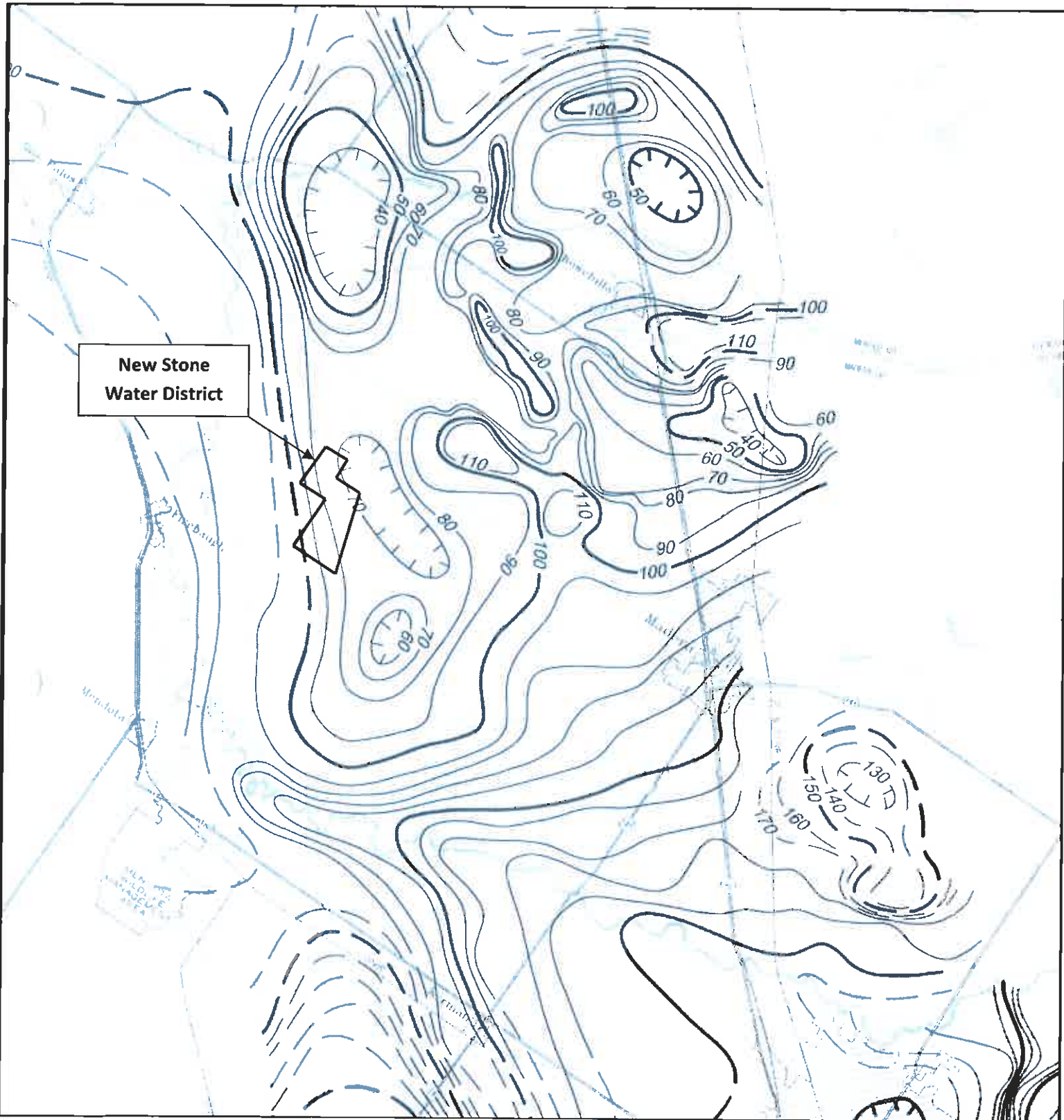
Attachment 4
Groundwater Hydrographs of Wells
North of District



Attachment 5
Groundwater Hydrographs of Wells
West and Southwest of District



Attachment 6
Groundwater Hydrographs of Wells
East and Southeast of District



Reference: California Department of Water Resources

Attachment 7
Water Table Elevation Map
2002



NEW STONE WATER DISTRICT

REVIEW OF GROUNDWATER CONDITIONS

APPENDIX A

**ARTIFICIAL GROUND WATER RECHARGE BY FLOODING DURING GRAPEVINE
DORMANCY**

ARTIFICIAL GROUND WATER RECHARGE BY FLOODING DURING GRAPEVINE DORMANCY¹

N. K. Dokoozlian, Jr., V. E. Petrucci, J. E. Ayars, C. D. Clary, and R. A. Schoneman²

ABSTRACT: The potential for artificial ground water recharge by continuous flooding of dormant grapevines was evaluated in the San Joaquin Valley of California using the cultivar Thompson Seedless. The study was started in 1982 and was completed in 1985 after three complete flooding cycles during dormancy. An average daily rate of recharge of 80 mm/day for a 32-day period each year was achieved through a clay loam soil. There were no adverse effects on the grapevines and yields in the flooded plots in any of the growing seasons following recharge periods. Yields were higher in the recharge plots than in the control plots in the last year of the study. We conclude that artificial ground water recharge by continuous flooding during grapevine dormancy is a viable recharge method.

(KEY TERMS: ground water recharge; grapevines; water management; flooding.)

INTRODUCTION

In the San Joaquin Valley south of the San Joaquin River, an average annual overdraft of $1.85 \times 10^9 \text{ m}^3$ occurs in spite of the current efforts of many water agencies to provide artificial ground water recharge. Approximately 12 percent of the normal surface runoff or $1.05 \times 10^9 \text{ m}^3$ is intentionally recharged in 261 facilities. An additional $0.16 \times 10^9 \text{ m}^3/\text{yr}$ is recharged due to overirrigation (Cotton and Brown, 1977; Nightingale, 1972). Recharge activities involve flooding in 4,492 ha of basins and 931 ha of stream channels. Recharging enough water to balance the current overdraft of $1.6 \times 10^9 \text{ m}^3/\text{yr}$ in the Southern San Joaquin Valley (Tulare Sub-basin) would require the identification and development of 5,261 ha of additional basin ponding areas capable of recharging an amount equivalent to that of Leaky Acres, which is approximately $305 \times 10^6 \text{ m}^3/\text{yr}$. While sites of this potential capacity exist along the east side of the Valley, less expensive methods are desirable.

The need to develop new recharge technologies which can directly integrate into irrigated agriculture and utilize excess irrigation water during crop dormancy or short duration flood flows is becoming increasingly important as the finite limits of our surface water supply are approached. Studies

by Nightingale (1972) in Eastern Fresno County, pertaining to soil type and salt movement beneath different irrigated crops, indicated that the grapevine is a crop commonly grown on soils sandy enough to percolate significant quantities of water (Ford, 1978). Recharge by flooding of dormant grapevines in Eastern Fresno County has considerable hydrologic and economic merit. By recharging vineyards with access to existing surface irrigation water supplies, land use intensity would be increased, and the need for expensive basin-type recharge facilities would be reduced. The tolerance of grapevines to extended flooding during dormancy must be determined before this recharge method could be recommended.

METHODS

The experiment to evaluate the effect of irrigation during grapevine dormancy was started at the California State University (CSUF), Campus in 1982 by the Viticulture Dept. of CSUF and the Water Management Research Laboratory, USDA-ARS. Two treatments, ground water recharge and an untreated control, were used in the study. Each treatment consisted of a four-row plot, containing 84 vines per row and oriented in an east to west direction (Figure 1). Within each treatment, six three-vine replications were randomly selected. The center two vine spaces in each replication were used for data collection and experimental analysis (Figure 2).

Application of water to the recharge treatment was during vine dormancy from December through February of each year (1982-1985). Plow built levees from the soil located between vine rows were used to control the area in which water application occurred. The recharge plot was maintained with approximately 150 mm of water above the soil surface at all times.

The cultivar used in this study was Thompson Seedless, specifically grown for table grape production. The vines were spaced $2.44 \times 3.6 \text{ m}$, head trained to a height of 1 m, and

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cane pruned. The vines were planted in 1958 in a Greenfield Series, clay loam soil.

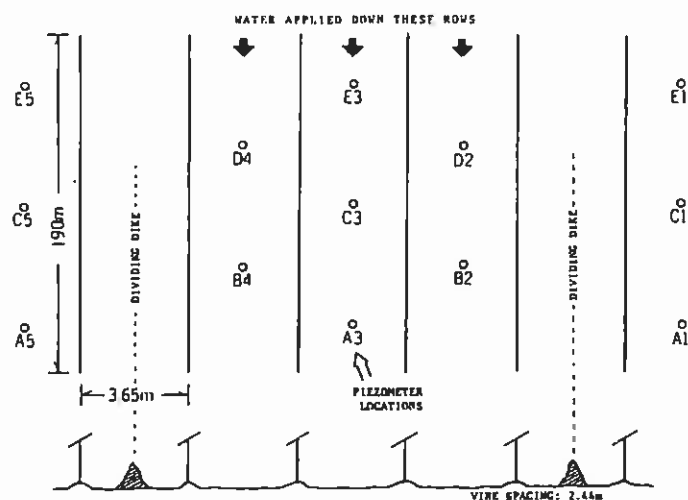


Figure 1. Plot Plan Showing Recharge Areas and Piezometer Locations.

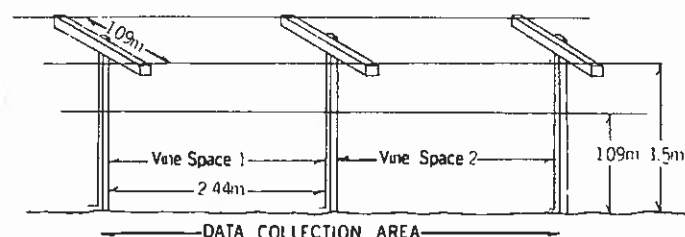


Figure 2. Diagram of Data Collection Area for Plant Analysis.

Vines were pruned in December of each year to approximately four canes, consisting of 15 nodes each. Chemical berry thinning with gibberellin was done during bloom (mid-May) to reduce the number of berries which set per cluster. Immediately following berry set (late May), cluster thinning, trunk girdling and size enhancement applications of gibberellin were performed to improve the size and quality of remaining fruit on the vine. Normal cultural operations such as cultivation, irrigation, weed, pest, and disease control were identical within each of the treatments.

Plots were harvested in August. The fruit from each replication was removed from the vine and weighed and the number of clusters per plot recorded. Fruit set analysis was done by removing the two proximal (upper) laterals of six randomly selected clusters per replication. Each of these laterals was measured and the number of berries per lateral recorded. This data was used to calculate the number of berries per centimeter of lateral for each plot.

A randomly selected sample of 50 berries per replication was chosen for fruit quality analysis. Each sample was weighed and then crushed to obtain juice. The juice from each sample was then used to determine the Brix (percent soluble solids), titratable acidity, and pH of the fruit by standard laboratory procedures. The percent of USDA grade packable fruit was estimated by visual inspection of the clusters from each treatment.

Vegetative growth was determined by taking the weight of shoots removed during pruning at dormancy. The rate of vine growth was measured by performing bi-monthly shoot lengths from a single pre-selected node position per replication. Composite petiole samples for each treatment were taken during bloom to determine vine nutritional status. Any visual abnormalities were recorded bi-monthly during shoot growth measurements.

The growth parameters (nodes retained per vine, percent of node emergence, number of shoots per vine, shoot growth, and pruning weight) were statistically analyzed to determine the effect of irrigation during dormancy on plant vigor. Yield and cluster per vine, berry set, and berry weight were analyzed as were percent soluble solids and acidity to determine the effect on yield and quality.

The statistical procedure used was a one-way analysis of variance with the 5 percent confidence level being the minimum acceptable level of significance. Exceptions to the confidence levels are noted.

A set of piezometers was installed to a depth of 5.5 m in the recharge area to monitor the build-up of a perched shallow ground water on a clay loam layer under the recharge area (Figure 1). Soil samples taken during the installation of the piezometers were analyzed for soil type determinations. The piezometers were monitored in the winter of 1983 and 1984. The soil profile in the research area consists of a sandy loam to a depth of 2.4 m followed by a 0.3 m layer of loamy sand. From 2.7 m to 4 m there is a sand layer overlying a loamy sand layer which extends to a depth of 5.5 m. There is a clay loam layer at a depth of 5.5 m.

Evaporation from a Class A evaporation pan and rainfall were measured at a weather station located 2 km from the site. Rainfall contributing to recharge was computed as the depth of rainfall in excess of measured evaporation from a Class A evaporation pan.

RESULTS

The effects of artificial ground water recharge on fruit set, yield, cluster number, and percent packable clusters, percent soluble solids, and acidity are summarized for all years in Table 1. The treatment had no effect on fruit set as expressed by the number of berries per centimeter of lateral. It should be noted that the accurate measurement of this parameter is subject to question due to the influence of gibberellin applications made during bloom. Gibberellin applications made at this time cause berry abortion, thus reducing the number of

TABLE 1. Summary of Growth and Yield Parameters for Thompson Seedless Table Grapes With and Without Recharge During the Dormant Season.

	1982			1983			1984			1985		
	C*	R	S	C	R	S	C	R	S	C	R	S
Number of Nodes Retained Per Vine	—	—	—	60	53	NS**	58	60	NS	70	83	NS
Percent of Node Emergence	—	—	—	71	66	NS	83	86	NS	84	87	NS
Number of Shoots Per Vine	—	—	—	50	40	NS	66	61	NS	59	72	NS
Fruit Set, Berries/cm of Lateral	2.2	2.2	NS	3.9	3.8	NS	3.0	2.9	NS	2.5	2.8	NS
Yield Per Vine (kg)	39.1	29.4	NS	13.6	11.7	NS	10.8	12.4	NS	10.1	16.5	1%
Clusters Per Vine	55.8	53.5	NS	20.7	23.1	NS	23.8	26.7	NS	—	—	—
Percent Packable Clusters	86.0	86.0	NS	72.0	74.0	NS	61.0	67.0	NS	89.0	85.0	NS
Percent Soluble Solids °Brix	17.7	18.1	NS	19.5	20.5	NS	19.3	18.7	NS	18.9	17.2	10%
Titrateable Acidity, g/L	0.82	0.83	NS	0.77	0.83	NS	0.74	0.75	NS	0.70	0.76	NS
pH	3.5	3.7	NS	3.6	3.6	NS	3.4	3.4	NS	3.2	3.2	NS
Berry Weight, g	5.4	5.6	NS	4.6	4.8	NS	3.9	4.0	NS	3.2	3.2	NS
Pruning Wt (kg)	3.7	4.5	NS	2.9	3.0	NS	3.2	3.2	NS	2.4	2.5	NS

*C = Control treatment.

R = Recharge treatment.

S = Statistical significance, 1 percent, 10 percent.

**NS = No significant difference at 5 percent.

berries set per cluster. While both treatments yielded nearly identical berry set values each year, it is difficult to determine the actual treatment effect for this parameter.

The treatment means for the yields were not significantly different between the recharge and control until 1985 when the recharge plot had significantly higher yields. As expected, differences in the number of clusters per vine space were not significant (Table 1). Since fruit bud differentiation of grape occurs during the early summer of the prior crop year, the recharge treatment would not have influenced cluster numbers in 1982. Effects of the 1982 recharge treatment on the number of clusters per vine will be revealed by cluster counts made during harvest in 1983 and subsequent years. The percentage of USDA grade packable fruit, for the treated and for the control, was not significantly different in any year (Table 1).

No differences in the rate of vine growth or amount of pruning weight were found between the treatments (Table 2). Monthly shoot measurements show no significant difference in length for any of the dates presented. The amount of vegetative growth per vine removed during dormancy was also not significantly different between the recharge and control for each year.

The treatment means for the effect of artificial ground water recharge on fruit quality are presented in Table 1. No difference in Brix, titrateable acidity, pH, or 50 berry weight were found except in 1985 when the sugar was significantly lower in the recharge treatment. Crop load is one of the primary factors influencing fruit quality. Differences in fruit quality levels (Brix) occurred when significant differences in vine yield were obtained, as in 1985.

Ground water recharge for this experiment was calculated as the sum of the water applied during continuous flooding and rainfall occurring in excess of Class A pan evaporation from October to May. Generally, no irrigation occurs on grapevines during the period from October to May. The results of this calculation are given in Table 3. The sum of annual water recharge and excess rainfall ranged from 1167 to 3711 mm over the duration of the experiment. A total of 10,067 mm of water were recharged in addition to 436 mm of excess rainfall. The excess rainfall in each year indicates that evaporative demands during this period were met by rainfall and that water in excess of this demand was available for recharge.

The data in Table 4 give the average daily recharge rate for the four years of the study. The average time of recharge was 32 days per year at an average daily rate of 80 mm. The water table data taken under the vineyard indicated that no perched water table developed so the root system was not in a saturated zone at any time during the recharge.

DISCUSSION

Several questions must be answered before recharge by continuous flooding can be recommended. The most important is whether there are any adverse effects on the grapevines resulting from this practice. All the data collected during this experiment indicate that flooding of vines during dormancy is not a problem. Within a single year there were no significant differences between any parameters except in 1985. In that year, the yields were higher in the recharge plots compared to the control, and the sugar content of the recharge plots was significantly lower than in control plots.

TABLE 2. Effect of Artificial Ground Water Recharge Applied During Dormancy on Shoot Growth and Pruning Weight of Thompson Seedless Table Grapes.

	Shoot Growth (cm)*						Pruning Weight (kg)
	April 1	May 1	June 1	July 1	August 1	September 1	
1982							
Recharge Treated	8	33	67	114	145	170	4.53
Control	9	36	74	112	146	166	3.67
Significance of F**	NS	NS	NS	NS	NS	NS	NS
1983							
Recharge Treated	4	28	59	118	151	183	3.05
Control	6	26	61	117	158	178	2.86
Significance of F**	NS	NS	NS	NS	NS	NS	NS
1984							
Recharge Treated	12	37	69	125	172	197	3.15
Control	10	30	71	131	165	183	3.21
Significance of F**	NS	NS	NS	NS	NS	NS	NS
	April 8	May 2	June 5	July 2	September 11		
1985							
Recharge Treated	24	96	154	182	160		2.5
Control	24	85	139	145	125		2.4
Significance of F**	NS	NS	NS	NS	NS		NS

*Shoot measurements have been rounded to the nearest centimeter.

**Treatment means not significantly (NS) different at the 5 percent level.

TABLE 3. Ground Water Recharge Summary During Grapevine Dormancy from October to May.

Year	Applied Water (mm)	Rain (mm)	Excess Rainfall* (mm)	Ground Water Recharge** (mm)
1981-82	3,635	337	76	3,711
1982-83	2,595	640	297	2,889
1983-84	1,135	234	32	1,167
1984-85	2,702	209	34	2,736
Totals	10,067	1,420	436	10,503

*Excess Rainfall – Rainfall in excess of an evaporation from open Class A pan calculated on a month-by-month basis from October to May.

**Ground water recharge is equal to the sum of the applied water and excess rainfall.

From a strict management viewpoint it is possible to recharge water during grapevine dormancy. However, pollution of shallow ground water by fertilizers and other agricultural chemicals is a major concern. In work done by Nightingale (1972), the nitrate concentrations in the soil and water were lower under grapes than under fallow land, orchards, and row and truck crops. His data suggest that continuous flooding of conventionally managed grapes will not cause nitrate levels in ground water to exceed minimum health standards.

There are management alternatives that can be adopted and would reduce the pollution potential from recharge during dormancy. A shift from surface flooding to trickle irrigation during the growing season is one method. Use of trickle irrigation to apply fertilizer will permit timely application of fertilizer and water in amounts needed for plant growth and thus minimize loss. Precise placement of water and fertilizers can also be accomplished with trickle irrigation systems.

A system can also be used where chemicals and fertilizers are placed in alternate land strips between vines and the

remaining land used for flooding. This would also reduce the potential for leaching chemicals into the ground water.

TABLE 4. Average Daily Recharge Rate (mm) for Artificial Ground Water Recharge During Grapevine Dormancy.

Year	Applied Water (mm)	Days	Daily Recharge Rate (mm)
1981-82	3,635	14	145
1982-83	2,595	30	86
1983-84	1,135	25	45
1984-85	2,702	48	56
Totals	10,067	128	83

There is still the problem of chemicals previously used for crop production. Several of these chemicals, i.e., DBCP's, are present and are now reaching wells located adjacent to vineyards. Recharging ground water by continuous flooding will have two effects. First, it will speed up the movement of these compounds to the ground water. Second, it will also dilute these chemicals as it leaches them.

Nightingale and Bianchi (1977) reported on ground water quality changes resulting from artificial ground water recharge at the Leaky Acres facility. They found that the chloride concentration, specific electrical conductivity (EC), and nitrate levels were all reduced as a result of recharge. Their water quality data show seasonal changes in volume and quality of water being recharged. As the volume of water recharged was increased there were proportional reductions in the concentrations of chlorides, nitrates, and EC. Better quality of recharge water resulted in proportional reductions in the concentrations of chlorides, nitrates, and EC. The effects were observed both below the recharge facility and down gradient from the recharge facility.

The average daily recharge rate is 120 mm per day for the Leaky Acres facility (Nightingale, *et al.*, 1983). Results from previous recharge studies have shown that the recharge rates decrease as the recharge area increases (Bianchi, *et al.*, 1978). A field scale trial of flooding during grapevine dormancy would be required to establish an expected recharge rate.

While the Leaky Acres facility is limited to 83 ha, the gross available mapped area having soils suitable for recharge in Eastern Fresno County is 66,000 ha. Grower and district cooperation, crops, and site location of all would affect the potential for using a given site. However, there should still be a substantial acreage available for recharge after all the problems have been taken into account.

SUMMARY AND CONCLUSIONS

A four-year study of the potential for artificial ground water recharge during grapevine dormancy was conducted in Fresno, California. There were no negative effects on Thompson Seedless grapevine being grown for table grape production. In the final year of the study, the yield of the grapes grown in the recharge area increased when compared to the control.

During the four-year period, a total of 10 m of water was recharged through a 0.27 ha area. The average daily rate of recharge was 80 mm, which is approximately 66 percent of the rate achieved in a facility designed for artificial ground water recharge.

Pollution of shallow ground water is a potential problem using this technique. There are alternatives to minimize this potential such as trickle irrigation and alternating fertilized and flooded areas. Water quality data collected at and around the Leaky Acres ground water recharge facility suggest a potential to improve the ground water quality by recharge.

We conclude that artificial ground water recharge by flooding during grapevine dormancy is a viable recharge method.

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NEW STONE WATER DISTRICT

REVIEW OF GROUNDWATER CONDITIONS

APPENDIX B

LAFCO REPORT ON NEW STONE WATER DISTRICT

5.7 NEW STONE WATER DISTRICT

P.O. Box 1350, Selma, CA 93662

Contact: Jeffrey Lion

The New Stone Water District was formed by the Madera County Board of Supervisors in 1983 with the adoption of Resolution No. 8327. The District comprises approximately 3,600 acres of existing agricultural land in the county, adjacent to the Chowchilla Bypass, in western Madera County. The District is a landowner-voter district that was formed to:

- Provide water to the landowner(s) in the District.
- Facilitate contracting with the United States Bureau of Reclamation for delivery of water from the Mid-Valley Canal, Division of the Central Valley Project.
- Obtain surplus waters, if any, from the Madera Irrigation District, for use on District lands.
- Appropriate surplus flows out of the San Joaquin By-Pass.

The District provides well and surface water for agricultural uses and distributes it to its landowners on District lands. The District also seeks to obtain Section 215 or uncontrolled season waters from the San Joaquin River, to obtain storm water runoff available in the Chowchilla By-Pass and to provide quality groundwater (from wells) to the landowners in the District. Territory within the District is currently served primarily by groundwater for irrigation purposes. In recent years, the District delivered surface water from its turnout in the Chowchilla By-Pass to row crops growing on farms in the District.

Recently, territory in the District has been chiefly developed to permanent crops. This change in cropping pattern has focused the District's attention to providing reliable, clean, groundwater (using groundwater extraction wells) while also seeking to replenish the aquifer beneath the district using groundwater recharge with surface waters that may be available to the District from the Chowchilla By-Pass.

With questionable groundwater supplies, lowering groundwater tables in the western part of the District and the uncertainty regarding reliable future surface water supplies as a result of the recent San Joaquin River settlement (2007 Court case now before Congress for funding) it has become increasingly important for the District to develop ways to maintain the quality and quantity of its water supplies for District lands.

With the likelihood that groundwater recharge will benefit District lands; the District is enthusiastic about initiating a short-term engineering study followed by a long-term implementation of a groundwater recharge program, pending the results of that study. Until recently the District has been inactive, primarily because of the conversion from row crops that utilized occasional surface water availability to permanent crops that relied exclusively on pumped ground water. The prospect of groundwater recharge and the ongoing availability of surface waters at the District's turnout on the Chowchilla By-Pass have allowed the District to become active once again.

1. Infrastructure Needs or Deficiencies

Purpose: *To evaluate infrastructure needs and deficiencies in terms of supply, capacity, condition of facilities, and service quality.*

The District Board meets regularly to discuss the groundwater and surface water needs of the lands serviced by the District. As a result of: (a) the San Joaquin River settlement, (b) the availability of quality storm water, flood release or Section 215 waters in the Chowchilla By-Pass; and, (c) groundwater levels/quality/availability; the District is now exploring the feasibility of doing on-site, in-District groundwater recharge of the aquifer underlying the District's lands. This will be accomplished by using such storm, surface, flood release and Section 215 waters as may become available to the District via the Chowchilla By-Pass. The District is contacting the engineering firm of Provost and Prichard to explore the feasibility and design of a series of ditches and on-site groundwater recharge basins or sites in the eastern portion of the service boundary to help maintain and augment the availability of groundwater and the District's water table.

Determination: *The short-term plans for the District involve a groundwater recharge study. The long-term plans for the District involve the development of a series of ditches and basins designed to transport surface waters available to the District, to be used in groundwater recharge uses, to improve the performance of the aquifer underlying District lands. Until recently the District has been inactive, primarily because of the conversion from row crops that utilized occasional surface water availability to permanent crops that relied exclusively on pumped ground water. The prospect of groundwater recharge and the ongoing availability of surface waters at the District's turnout on the Chowchilla By-Pass have allowed the District to become active once again.*

2. Growth and Population Projections for the Affected Area

Purpose: *To evaluate service needs based on existing and anticipated growth patterns and population projections.*

The District is not going to expand due to growth in population. The landowners within its service boundary are committed, long term, to permanent crops-not population growth.

Determination: *The District boundaries prevent the need to expand services since growth in population in District territory is unlikely and/or unfeasible*

3. Financing Constraints and Opportunities

Purpose: *To evaluate factors that affect the financing of needed improvements.*

The District is considering funding the previously mentioned Provost and Prichard Engineering study and then, if feasible, implementing construction of a series of ditches and basins using the District's turnout at the Chowchilla By-Pass to capture surface waters available to the District and to use those waters consistent with the groundwater recharge plan under study. All funds to operate the District are contributed, pro-rata, by its landowners.

Determination: *New Stone Water District does not receive from revenue from property tax, donation or revenues from water services. All funds to operate the District are contributed, pro-rata, by its landowners.*

4. Cost Avoidance Opportunities

Purpose: *To identify practice or opportunities that may help eliminate unnecessary costs.*

All of the landowners in the District donate their time to operating the District. There are no employees and no administrative or other expenses. The only "out of pocket" expenses anticipated by the District will be the short-term groundwater recharge study (to be paid for, pro-rata, by District landowners), followed by the possible long-term construction of a series of ditches and basins to augment the current condition of groundwater in the District. The implementation phase could take several years in order to achieve the desired results based on surface water availability and construction dollars approved by the District's landowners and Board.

Determination: *Cost avoidance opportunities have already been taken and the District operates, currently, with no overhead. All of the landowners in the District donate their time to the operating the District. The District anticipates expending no funding other than those essential to the groundwater recharge study and its implementation, if feasible. The cost of the study will be shared by all landowners in the District and manpower to implement the plan will be donated on an "as needed and volunteer" basis.*

5. Opportunities for Rate Restructuring

Purpose: *To identify opportunities to positively impact rates without decreasing service levels.*

The District currently neither sets nor collects any rate for its water services. Its customers, in the future, would be those within the service boundaries that benefit from the recharge plan now being studied. Until that plan is deemed feasible and then implemented, there are no opportunities for rate restructuring. The District's landowners will contribute to the plan for recharging groundwater, pro-rata, if implemented.

Determination: *The District charges no rates and currently there are no opportunities for rate restructuring. However, if the plan for recharging groundwater is implemented, the District's landowners will contribute to it, pro-rata.*

6. Opportunities for Shared Facilities

Purpose: *To identify the opportunities for jurisdictions to share facilities and resources creating a more efficient service delivery system.*

The District does not need and would not benefit from the services of other Districts. All of the equipment, turn-out facilities and water conveyance facilities enjoyed by or used by the District in terms of having water delivered to its boundaries are already in place. The District currently is set up to take spill, storm, excess, flood release or other waters available in the Chowchilla By-Pass by way of flood attenuation and flood relief for downstream areas.

Determination: *The District has the equipment, turn-out facilities and water conveyance facilities enjoyed by or used by the District in terms of having water delivered to its boundaries are already in place. The District is able to take spill, storm, excess, flood release or other waters available in the Chowchilla By-Pass by way of flood attenuation and flood relief for downstream areas. At this time sharing facilities or infrastructure is not necessary.*

7. Government Structure Options, Including Advantages and Disadvantages of Consolidation or Reorganization of Service Providers

Purpose: *To consider the advantages and disadvantages of various government structures that could provide public services.*

Consolidation or reorganization of the District is not necessary at this time. The District maintains a small, finite service area that can and will be efficiently served by the current and planned delivery program. The District can utilize all of the water available to it if it can implement the groundwater recharge plan currently under consideration, with no opportunity to share such waters with adjoining lands, due to the limited amount of water available and the water rights and diversion rights already identified with such water.

Determination: *There is no duplication of services in the District. There are no costs or expense currently for the District and so expanding the District or combining with another district would achieve no cost savings and would only result in cost increases and inefficiencies connected with travel, size, labor, etc. Consolidation or reorganization of the District is not necessary at this time.*

8. Evaluation of Management Efficiencies

Purpose: *To evaluate the quality of public services and the agency's ability to provide services.*

The District is currently has no costs for its current operations or management. It has no paid employees. Board Members volunteer their time to study and carry out the objectives of the District, at no cost. All of the equipment, turn-out facilities and water conveyance facilities enjoyed by or used by the District in terms of having water delivered to its boundaries are already in place. The District currently is set up to take spill, storm, excess, flood release or other waters available in the Chowchilla By-Pass by way of flood attenuation and flood relief for downstream areas.

Determination: *All activities by the Board and actions taken by the District are completed on a volunteer basis. All of the equipment, turn-out facilities and water conveyance facilities enjoyed by or used by the District in terms of having water delivered to its boundaries are already in place. The District currently is set up to take spill, storm, excess, flood release or other waters available in the Chowchilla By-Pass by way of flood attenuation and flood relief for downstream areas.*

9. Local Accountability and Governance

Purpose: *To evaluate the accessibility and levels of public participation associated with the agency's decision-making and management processes.*

All District landowners are involved on the Board of the District and it has 100% participation in all decisions affecting the District. Actions are generally by unanimous written consent with signed waivers. The District does not conduct regular board meetings, but meets on an as-needed basis.

Determination: *The District complies with statutory requirements for conducting public hearings. No incidences of Brown Act violations have been reported.*

Review of Agency Sphere of Influence

Madera LAFCO has the statutory authority and obligation to establish and adopt a sphere of influence for each city and special district within the county (Government Code Section 56425). A sphere of influence is a planning boundary outside of an agency's legal or "service" boundary that designates the agency's probable future boundary and service area. State law also requires LAFCO to review and update, as necessary, the adopted spheres of influence of agencies once every five years (Government Code Section 56425 (f)). Pursuant to state law, the New Stone Water District sphere of influence was reviewed in conjunction with the service review presented in this report.

The primary purpose in reviewing the District's sphere of influence (SOI) was to evaluate if this ultimate boundary is appropriate and necessary, determine if the District can feasibly provide well planned efficient services in this territory, and if the current location of the SOI (or another location) will be a benefit to residents, those that receive services and property owners within the area.

Review of the District's SOI involved detailed research, involving the following resources:

- Madera County LAFCO - official agency records.
- Madera County Recorder/ Assessor records.
- Correspondence from the District's legal counsel.
- SOI maps from the District, Assessor's office, Water Resources Board.
- Personal communications with District staff.

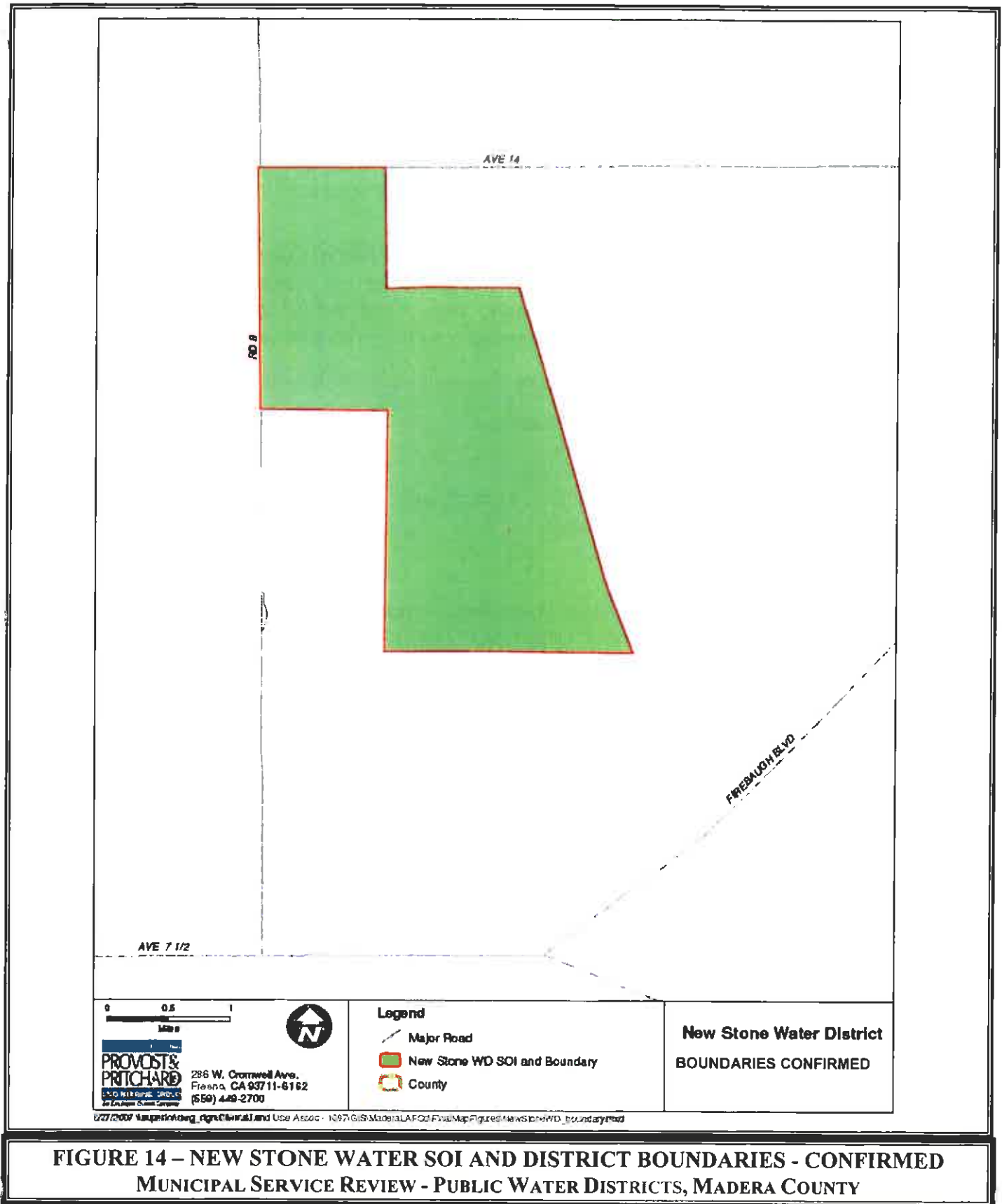
Discussion and Findings

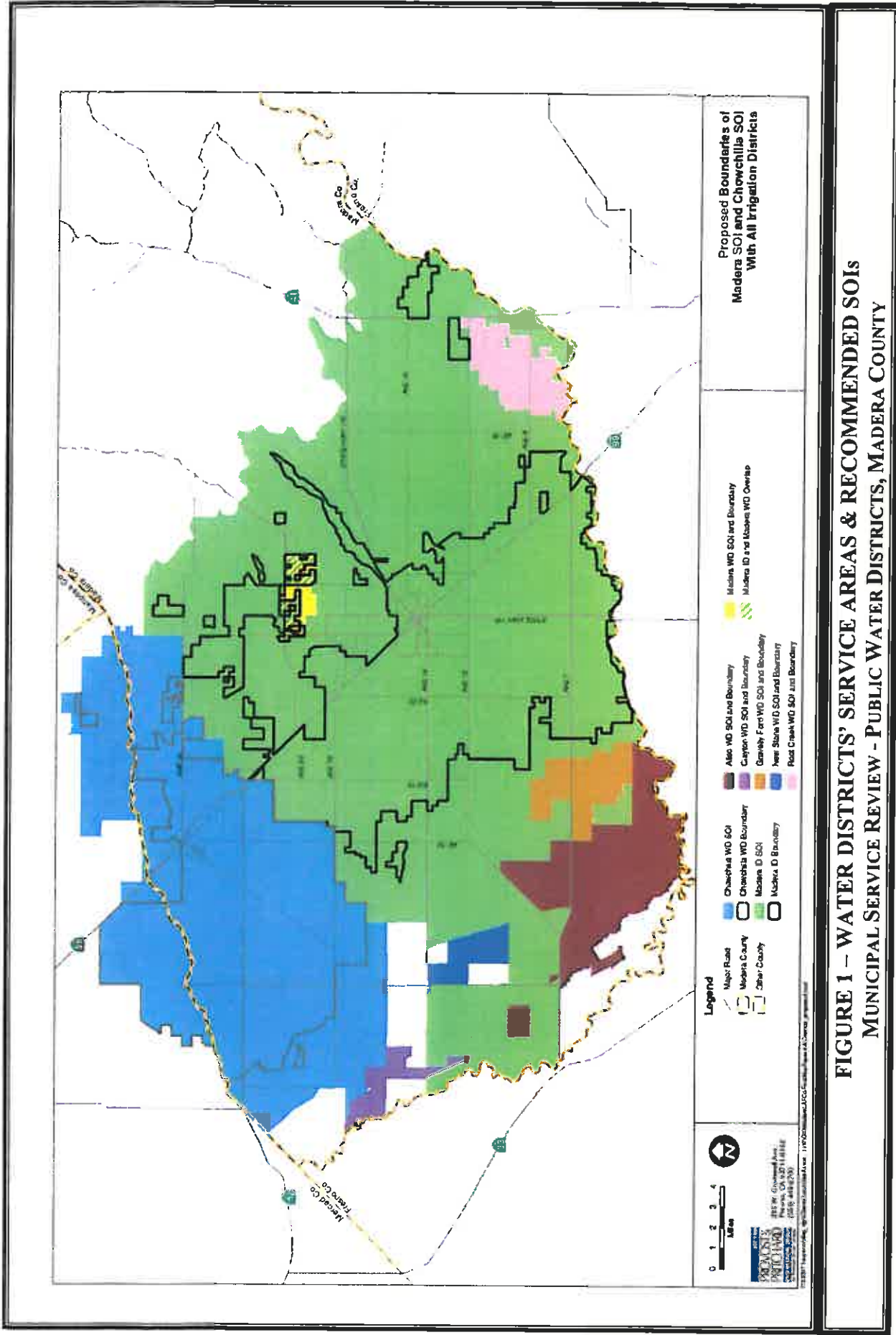
The precise SOI boundaries for the New Stone Water District were verified during the review. The actual sphere of influence boundaries were verified using LAFCO records, with confirmation by the District (see Figure 14). The District's SOI and service boundaries (i.e., boundary of the District) are coterminous.

A remaining issue relates to the District's assertion that it is at this time and will continue to work toward becoming an "active" district and is now and will continue to take the necessary steps to provide services to property owners located inside its service boundaries. Giving the District the benefit of the doubt, this review concluded that the New Stone Water District boundary is appropriate and necessary, the District is at this time and will continue to work toward becoming an active district that will provide planned efficient services in this territory, and the current location of the SOI is a benefit to those that will receive services within the area (see Figure 14). It is recommended that LAFCO reevaluate the New Stone Water District in five years to confirm productive activity, and if such activity is not verified consider dissolution of the district.

Recommendations

1. Adopt the "Written Determinations" for the New Stone Water District presented in this service review pursuant to California Government Code Section 56430.
2. Find that the District's current sphere of influence is appropriate and necessary, the District can provide well -planned efficient services in this territory, and the current location of the SOI is a benefit to those that receive services and/or property owners within the area. Make no change to the New Stone Water District boundaries or the adopted sphere of influence at this time.
3. Reevaluate in five years to confirm productive activity or consider dissolution.





NEW STONE WATER DISTRICT

REVIEW OF GROUNDWATER CONDITIONS

APPENDIX C

CATALOG OF GROUNDWATER HYDROGRAPHS

(Department of Water Resources Graphs and Data)
For Townships:

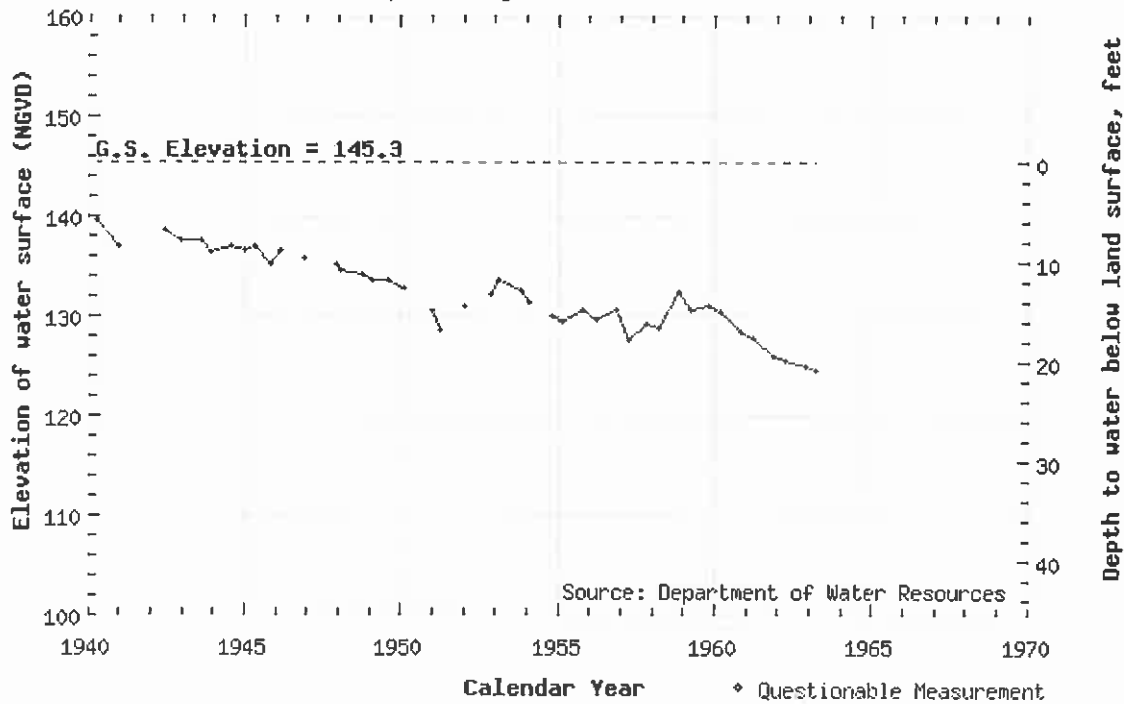
T11S/R14E
T11S/R15E
T12S/R14E
T12S/R15E

Appendix C (Cont'd)

T11S/R14E

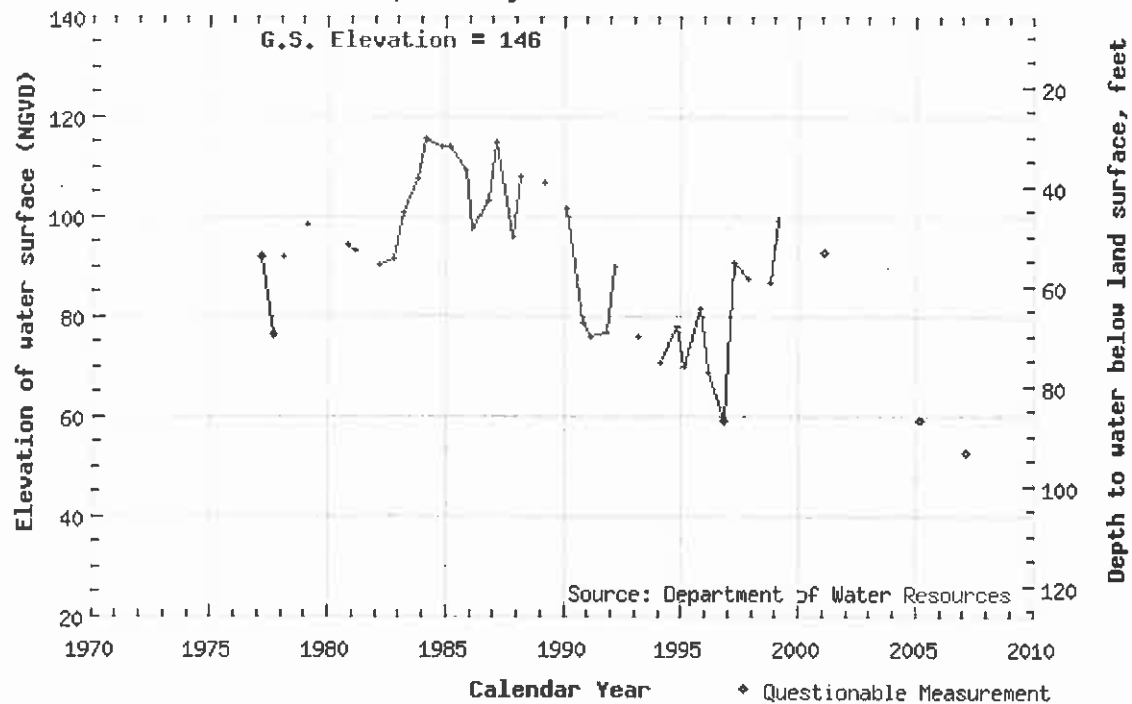
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San Joaquin Valley (Chowchilla Basin)



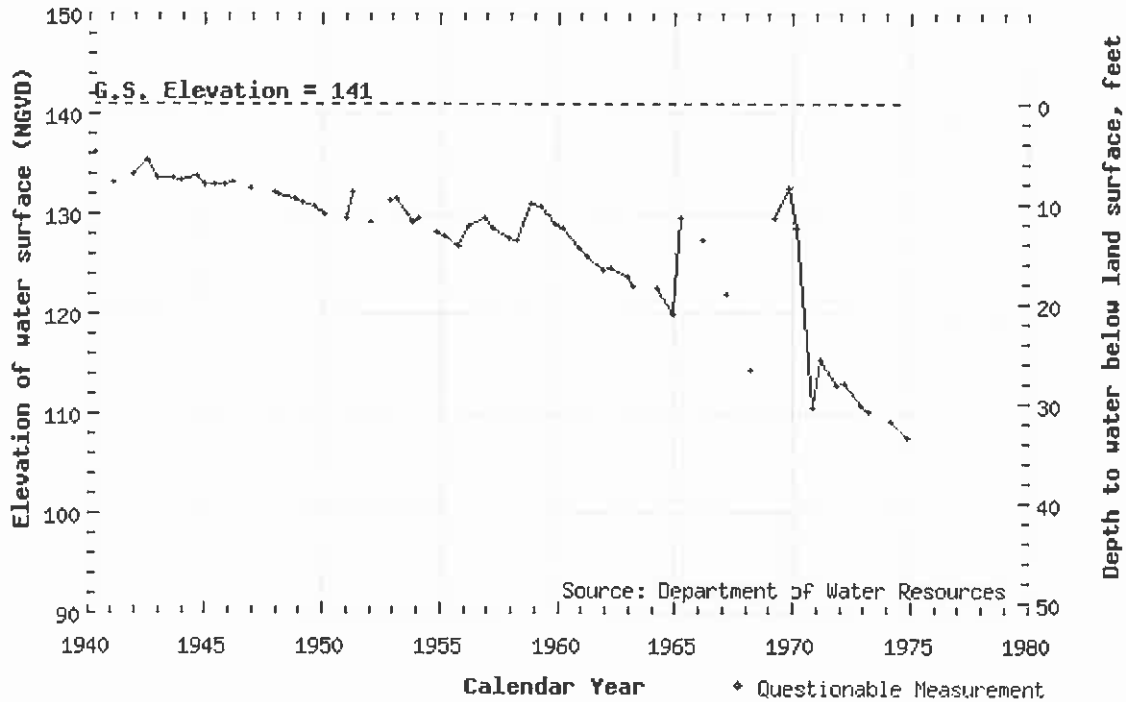
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San Joaquin Valley (Chowchilla Basin)



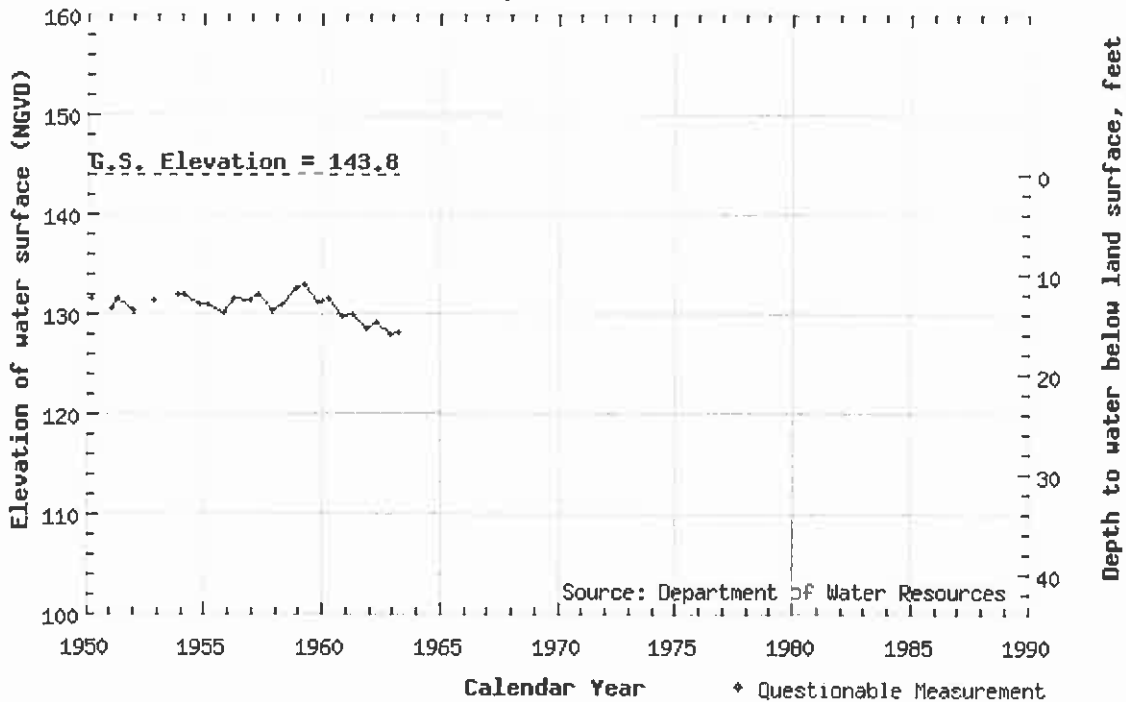
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San Joaquin Valley (Chowchilla Basin)



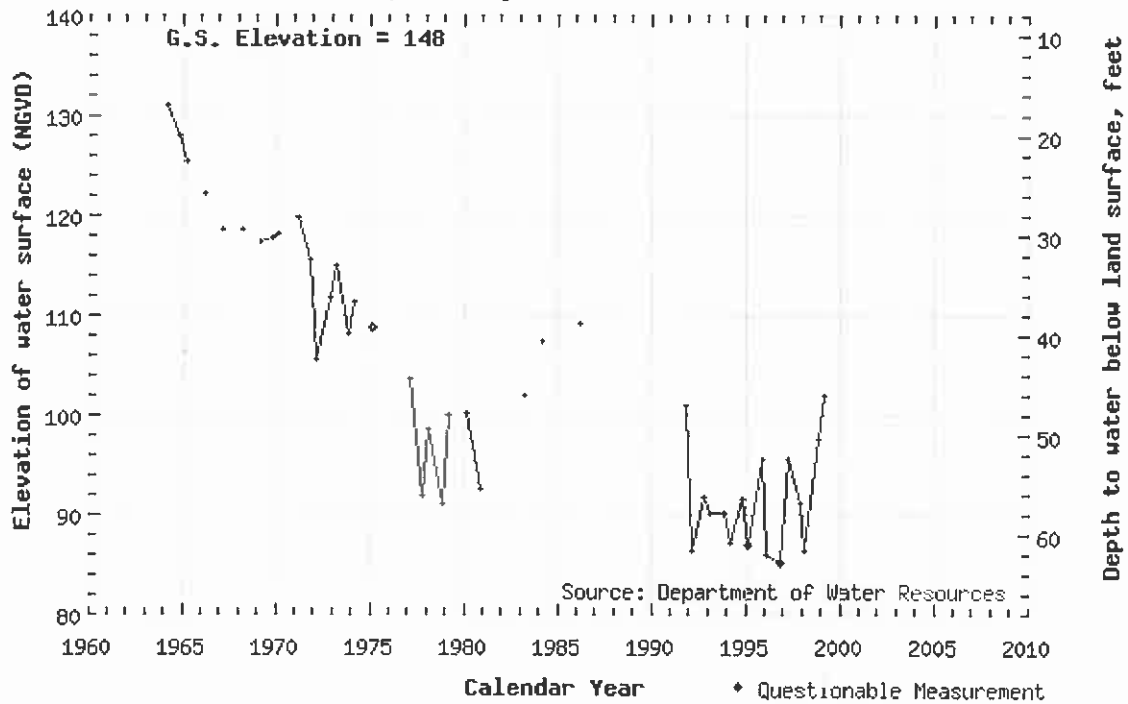
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San Joaquin Valley (Chowchilla Basin)



Groundwater Levels, 11S14E36R001M

San Joaquin Valley (Chowchilla Basin)

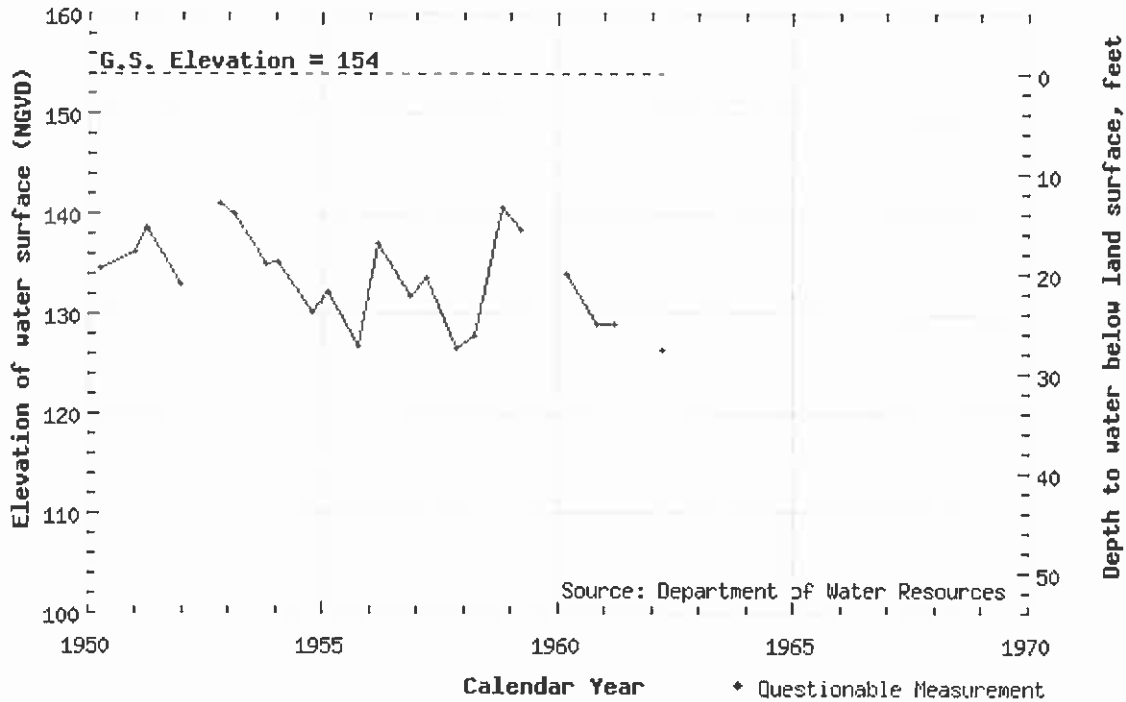


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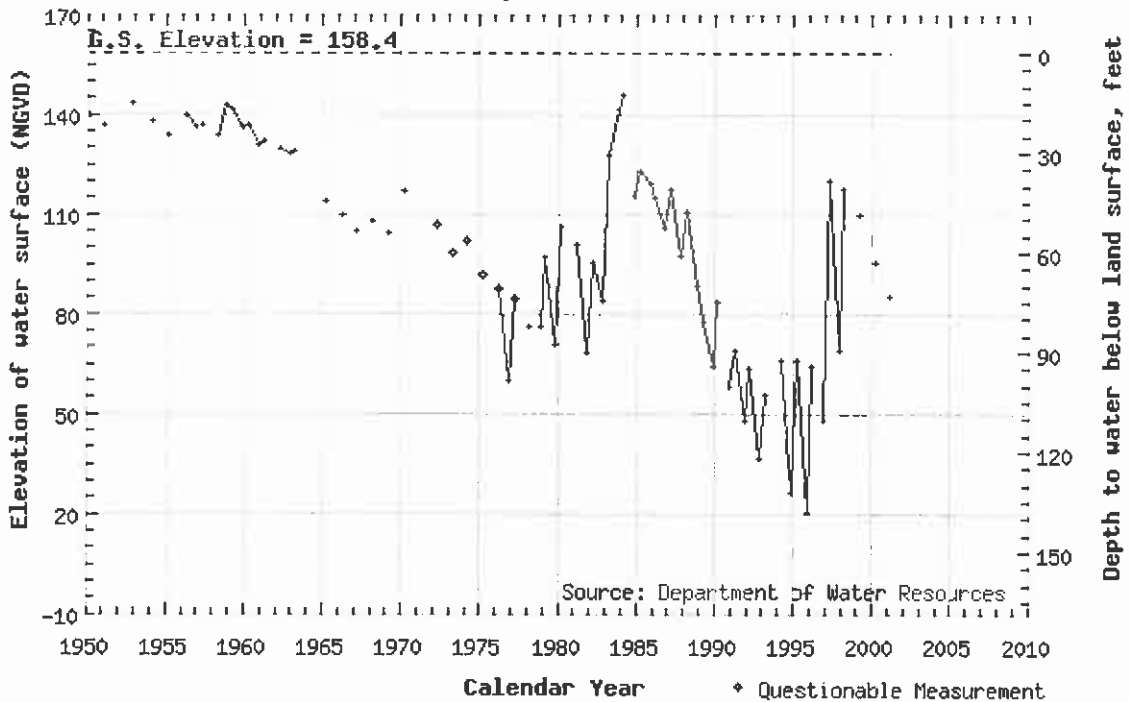
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San Joaquin Valley (Chowchilla Basin)



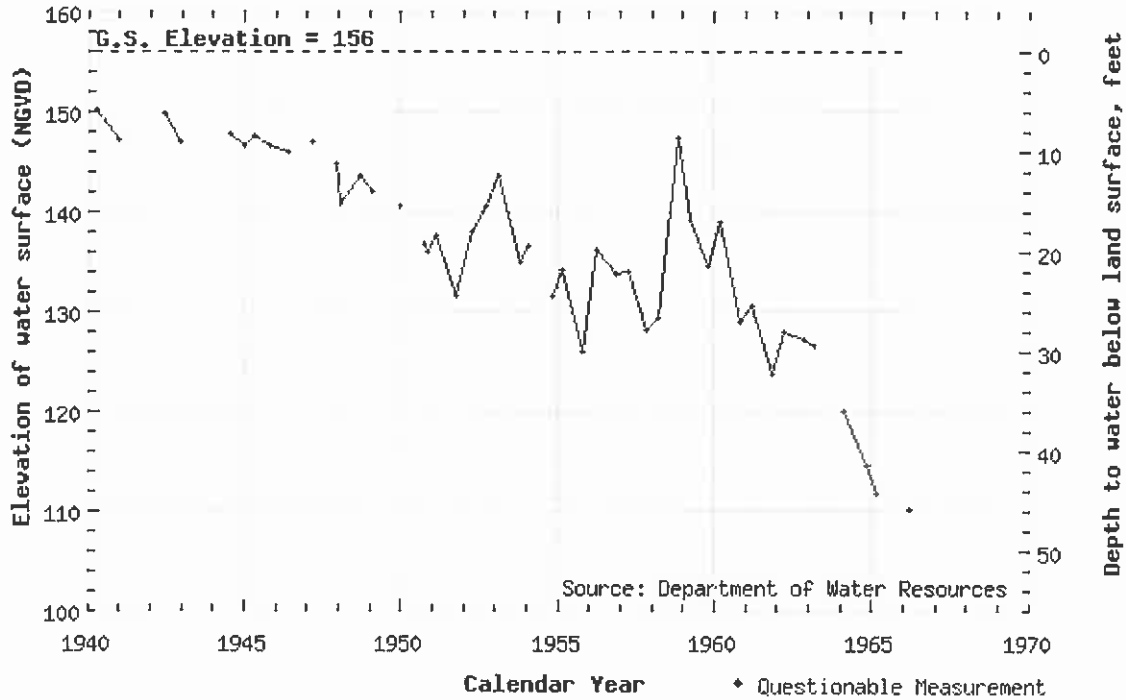
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San Joaquin Valley (Chowchilla Basin)



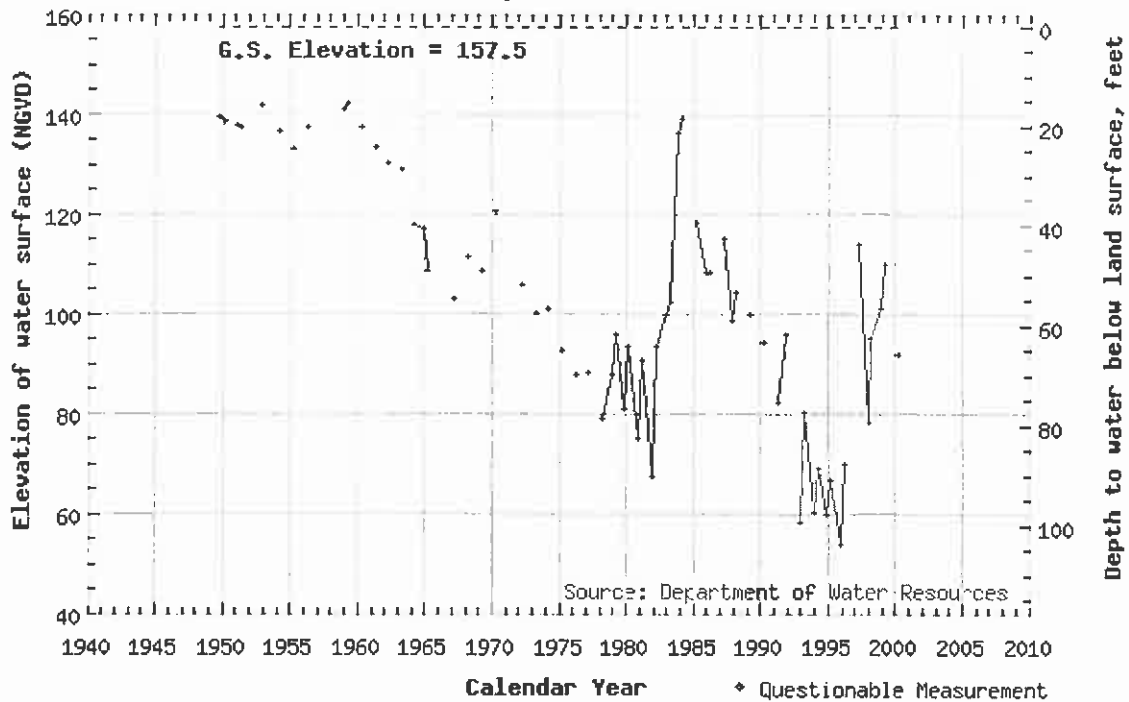
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San Joaquin Valley (Chowchilla Basin)



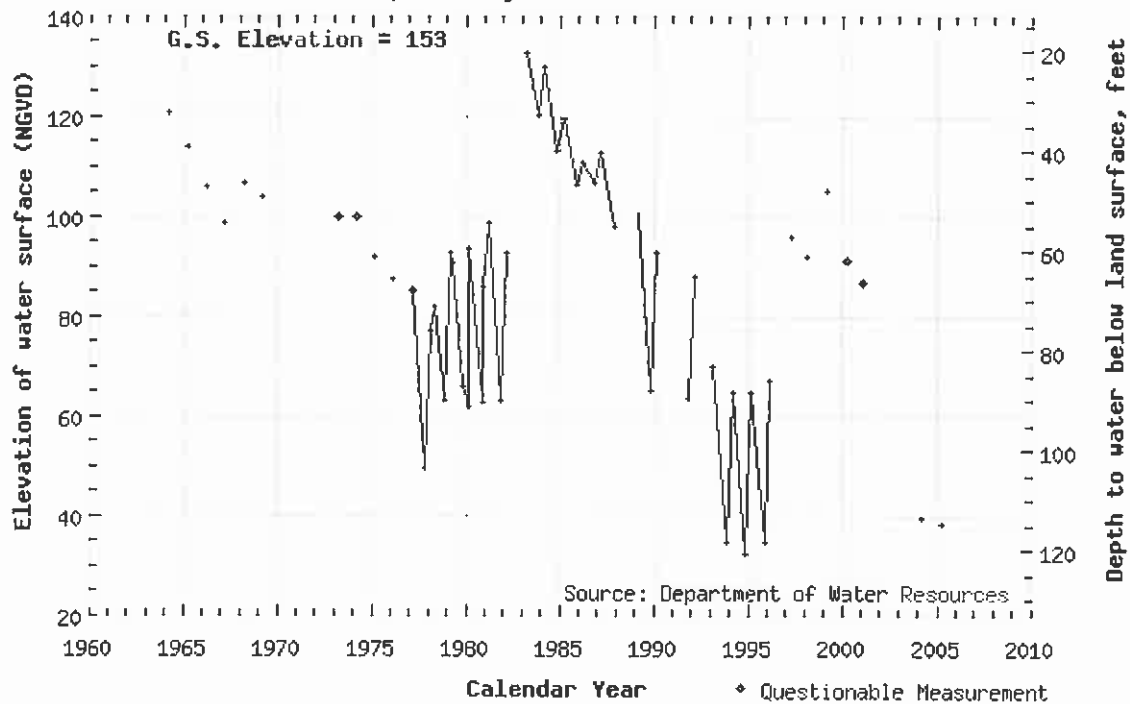
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San Joaquin Valley (Chowchilla Basin)



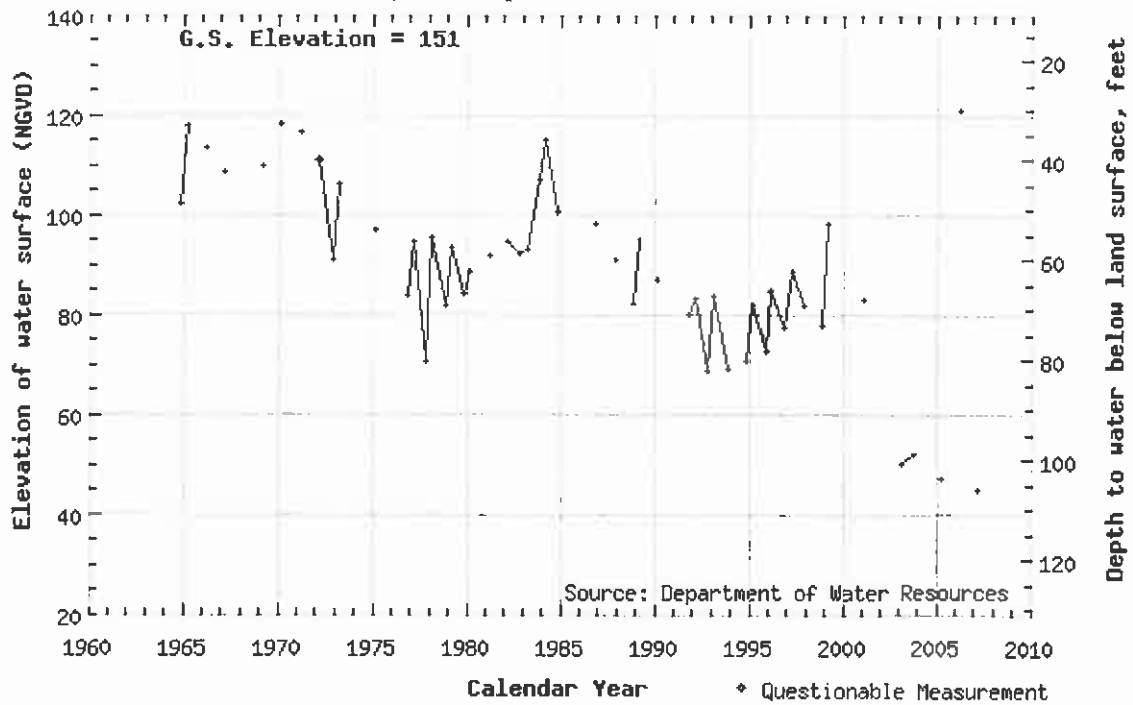
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San Joaquin Valley (Chowchilla Basin)



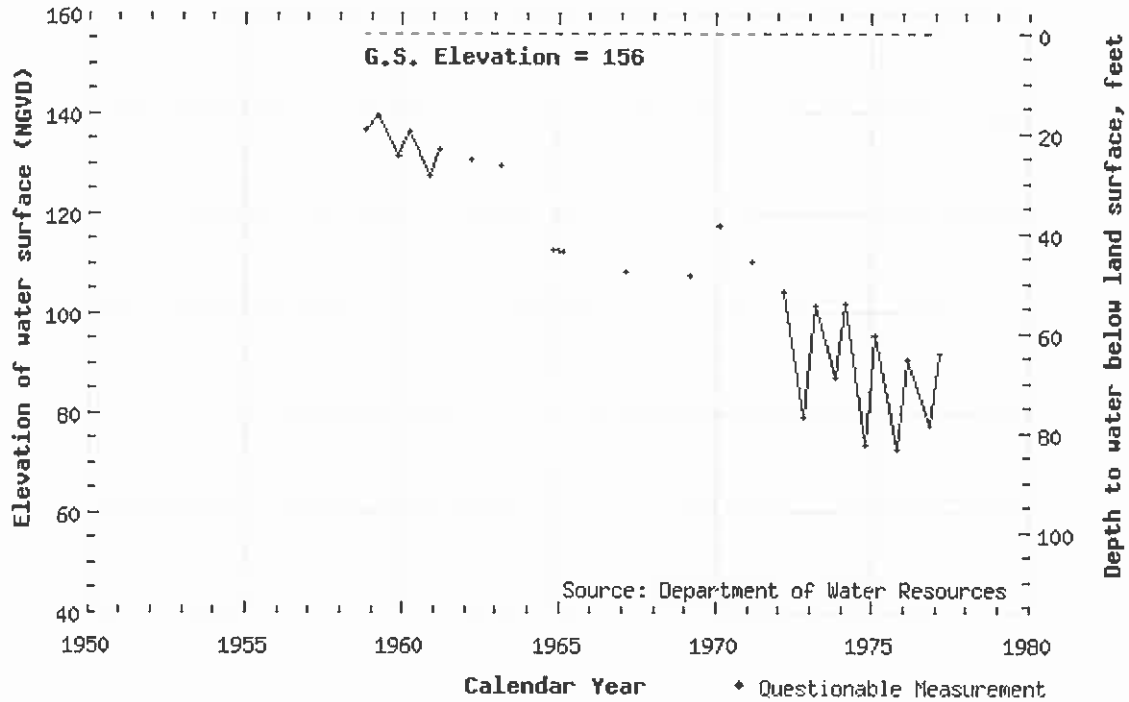
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San Joaquin Valley (Chowchilla Basin)



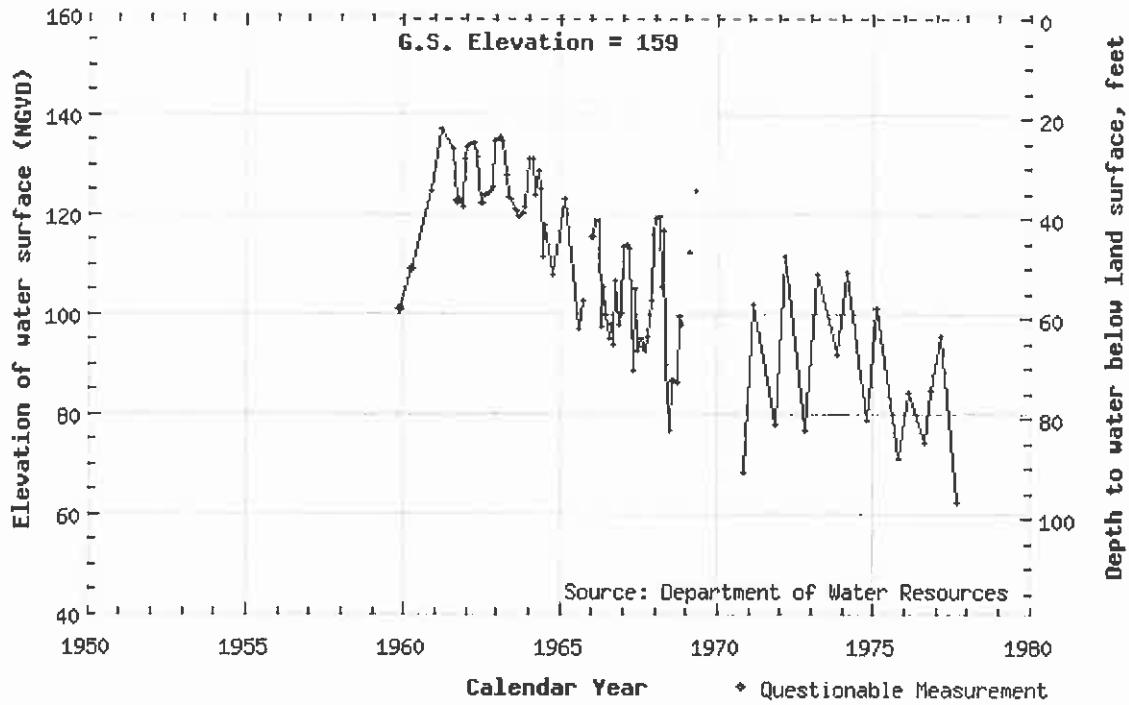
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San Joaquin Valley (Chowchilla Basin)



Groundwater Levels, 11S15E33P001M

San Joaquin Valley (Chowchilla Basin)

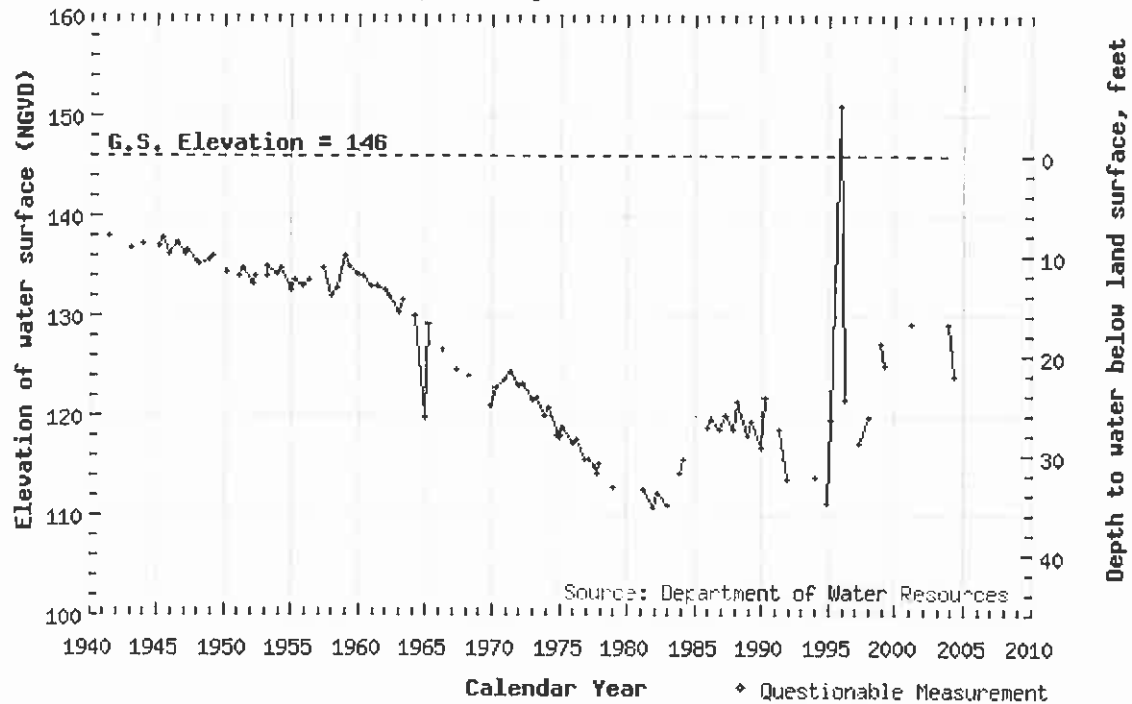


Appendix C (Cont'd)

T12S/R14E

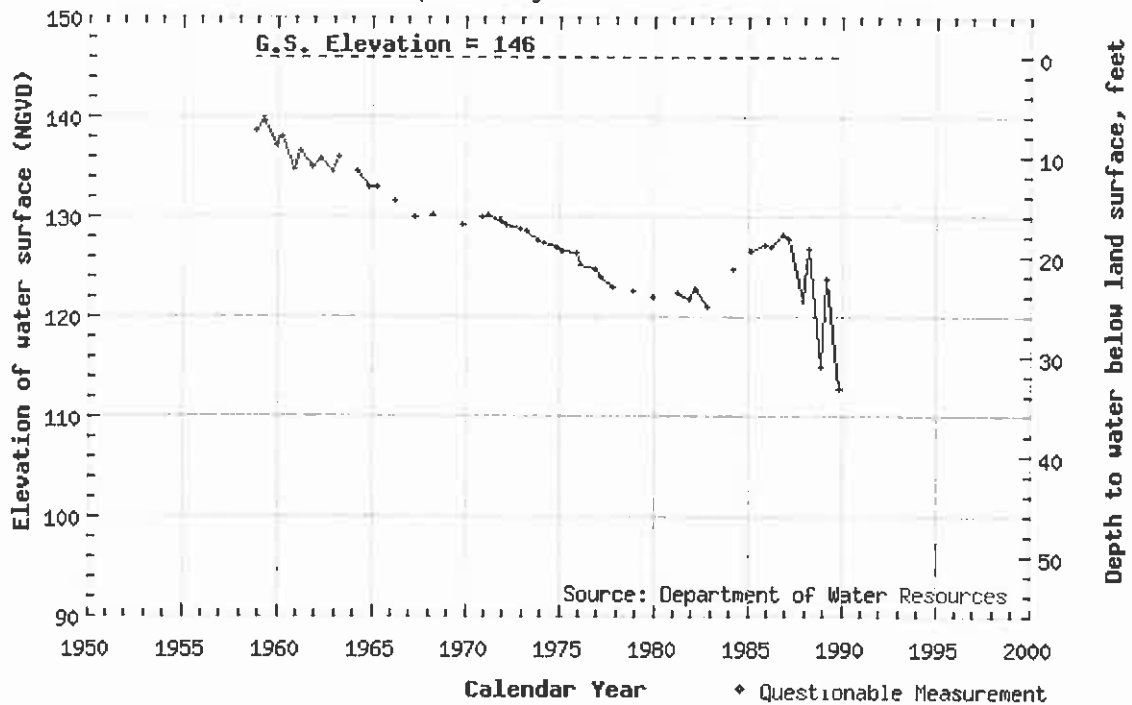
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San Joaquin Valley (Madera Basin)



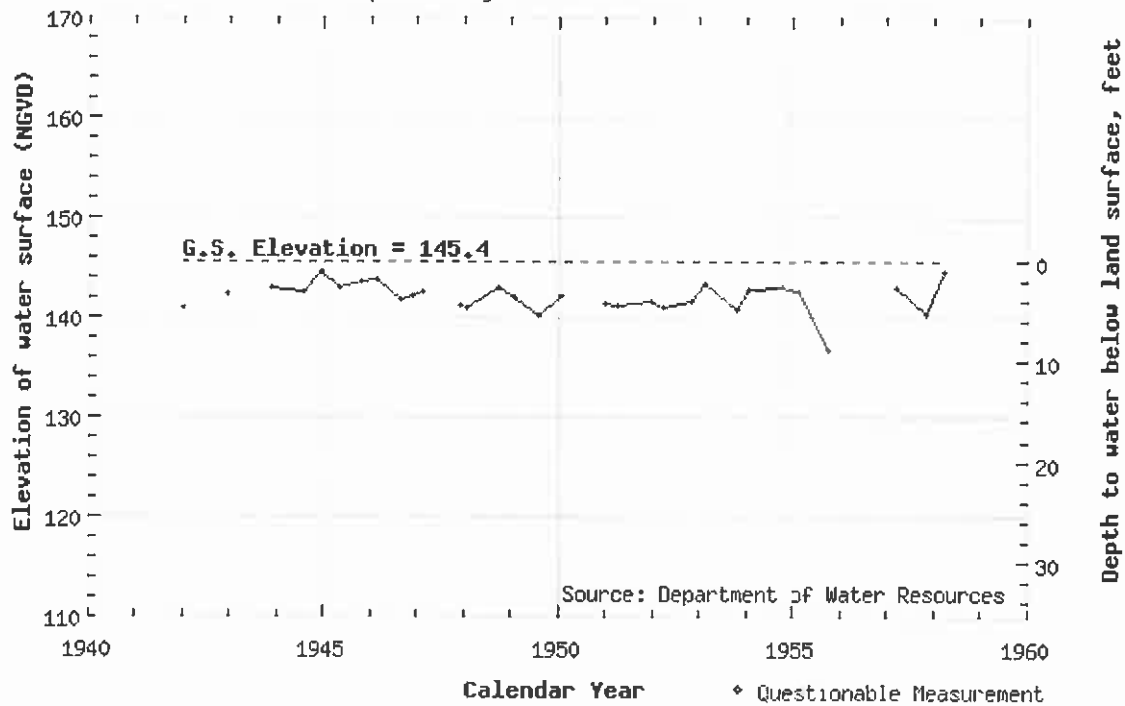
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San Joaquin Valley (Madera Basin)



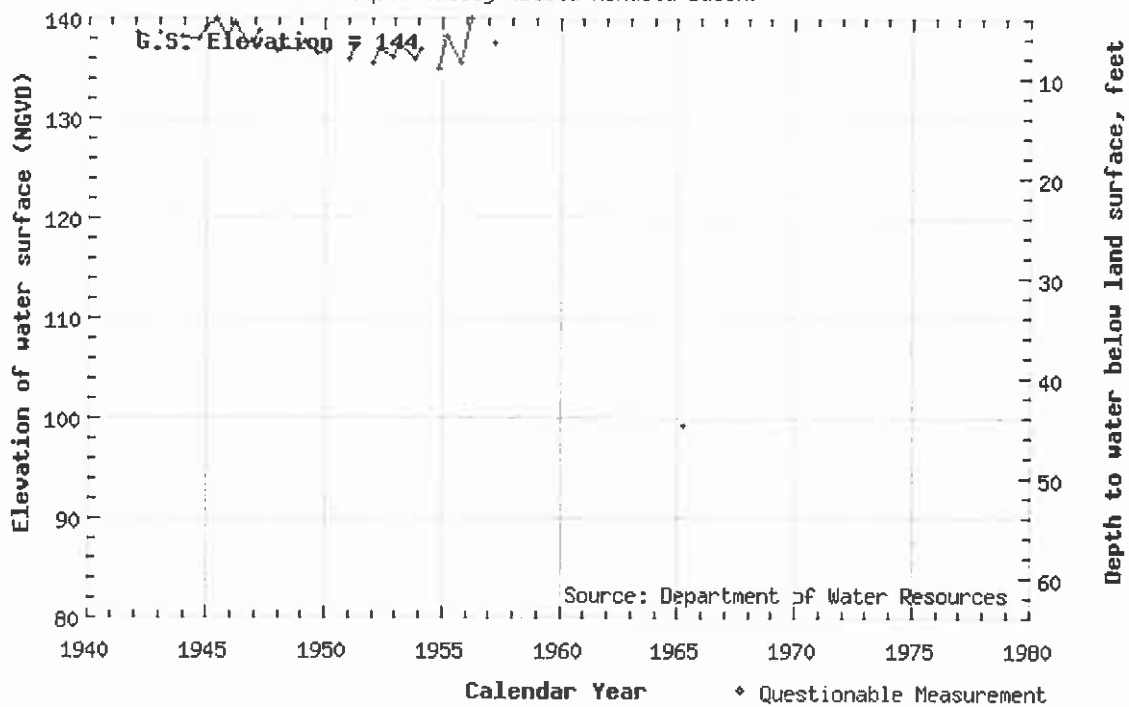
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San Joaquin Valley (Delta-Mendota Basin)



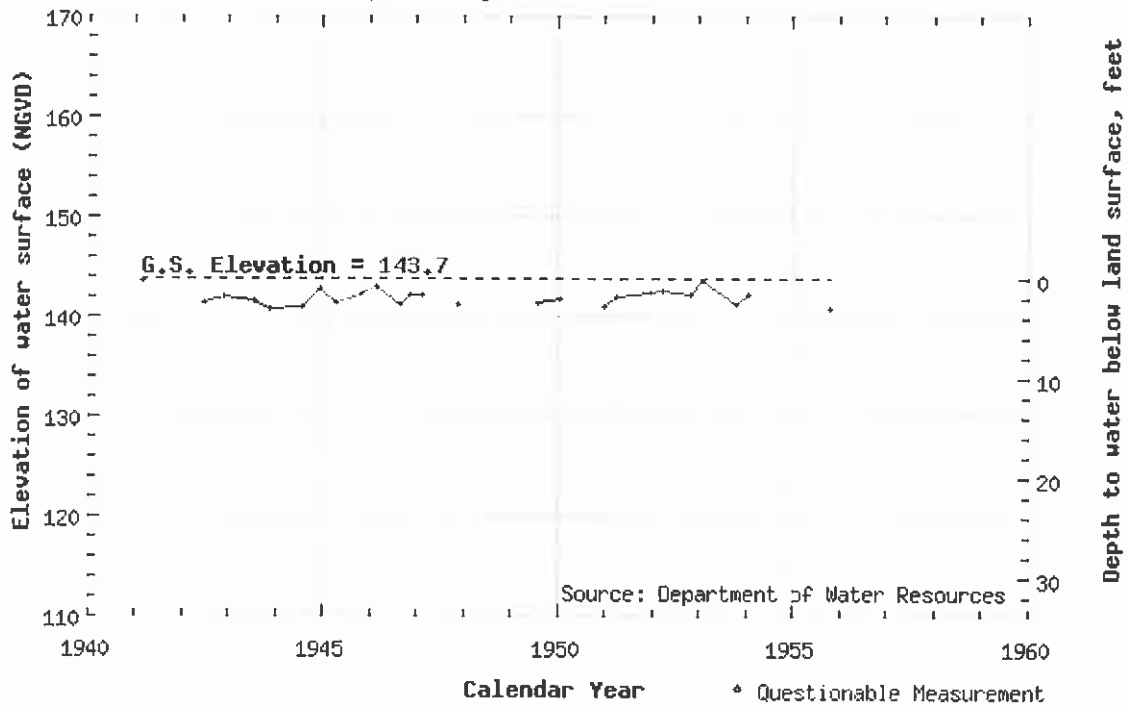
Groundwater Levels, 12S14E14A001M

San Joaquin Valley (Delta-Mendota Basin)



Groundwater Levels, 12514E23Q001M

San Joaquin Valley (Delta-Mendota Basin)

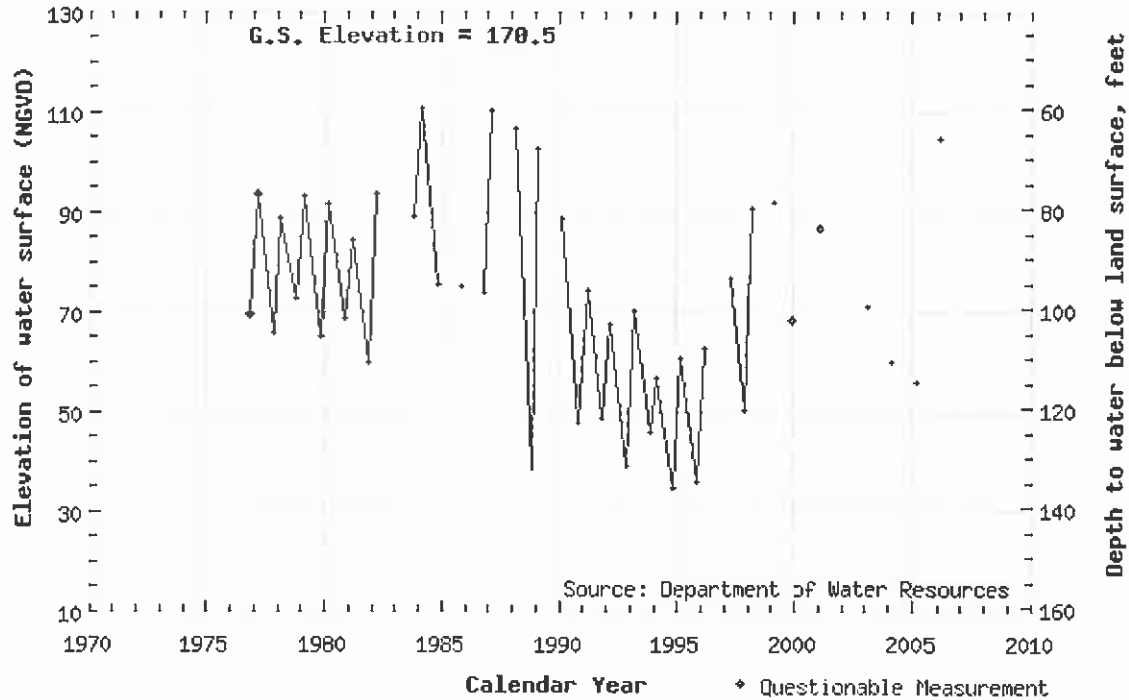


Appendix C (Cont'd)

T12S/R15E

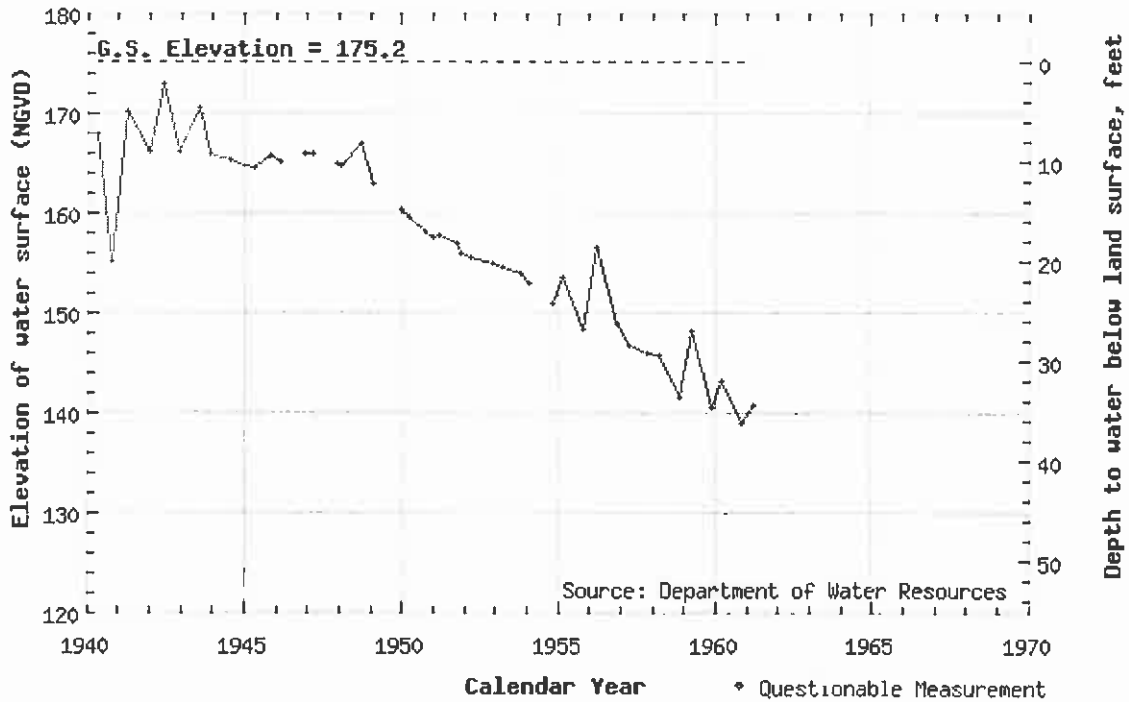
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San Joaquin Valley (Madera Basin)



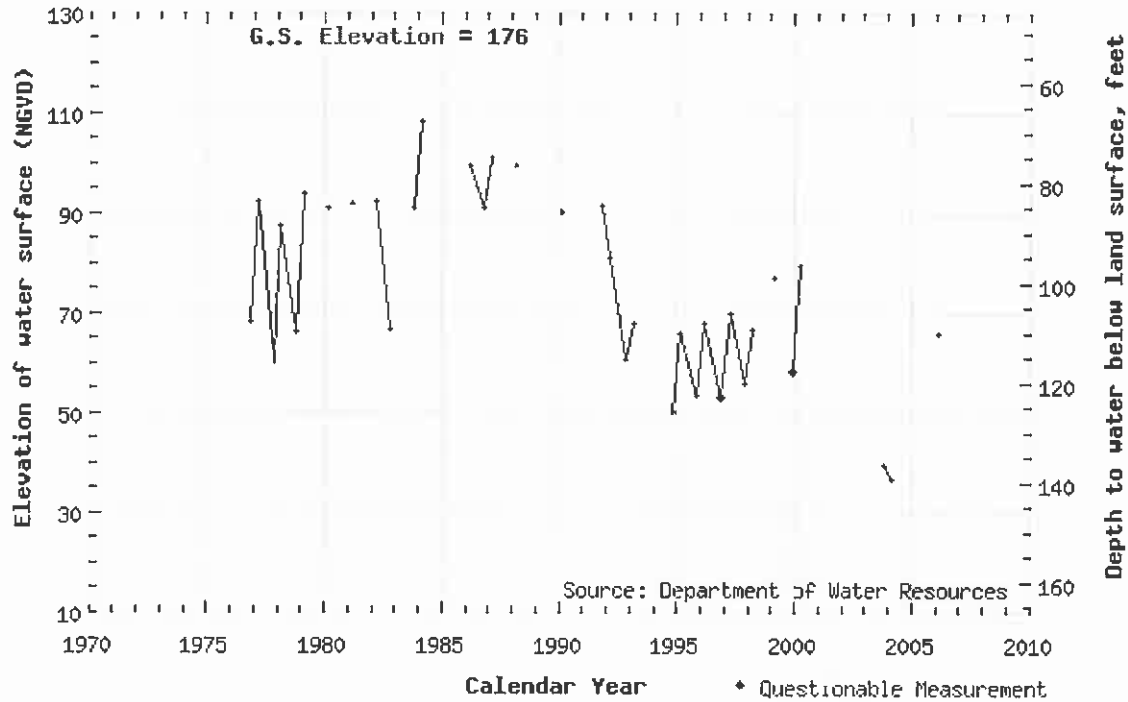
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San Joaquin Valley (Madera Basin)



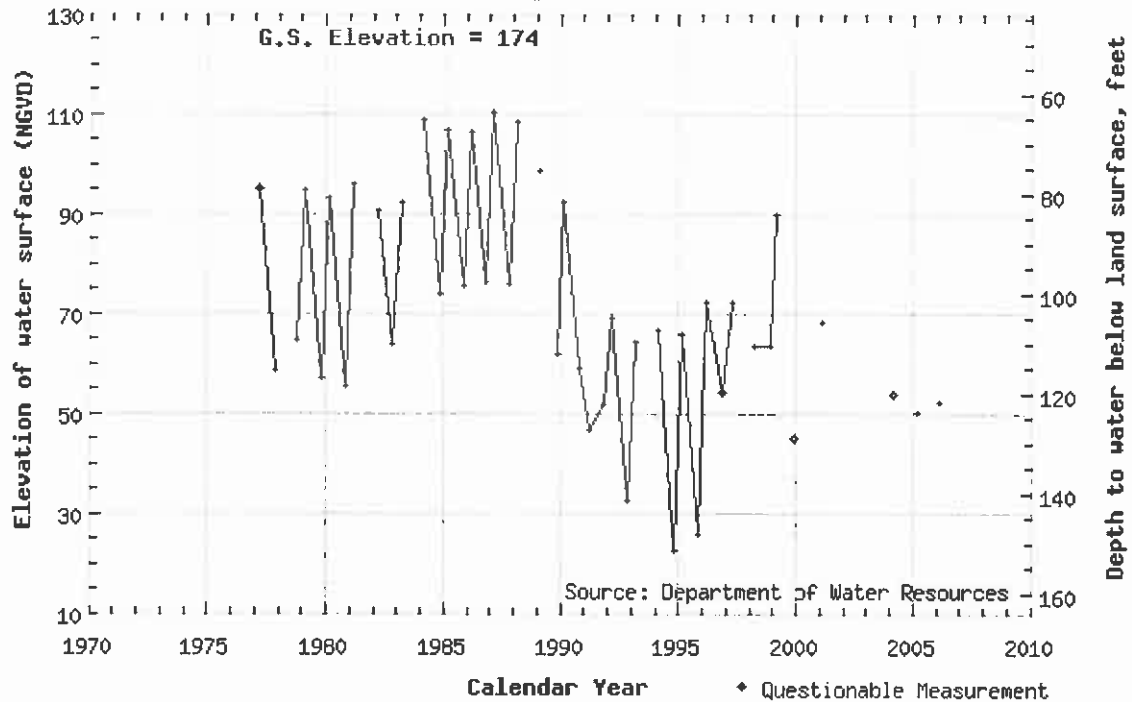
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San Joaquin Valley (Madera Basin)



Groundwater Levels, 12S15E13R001M

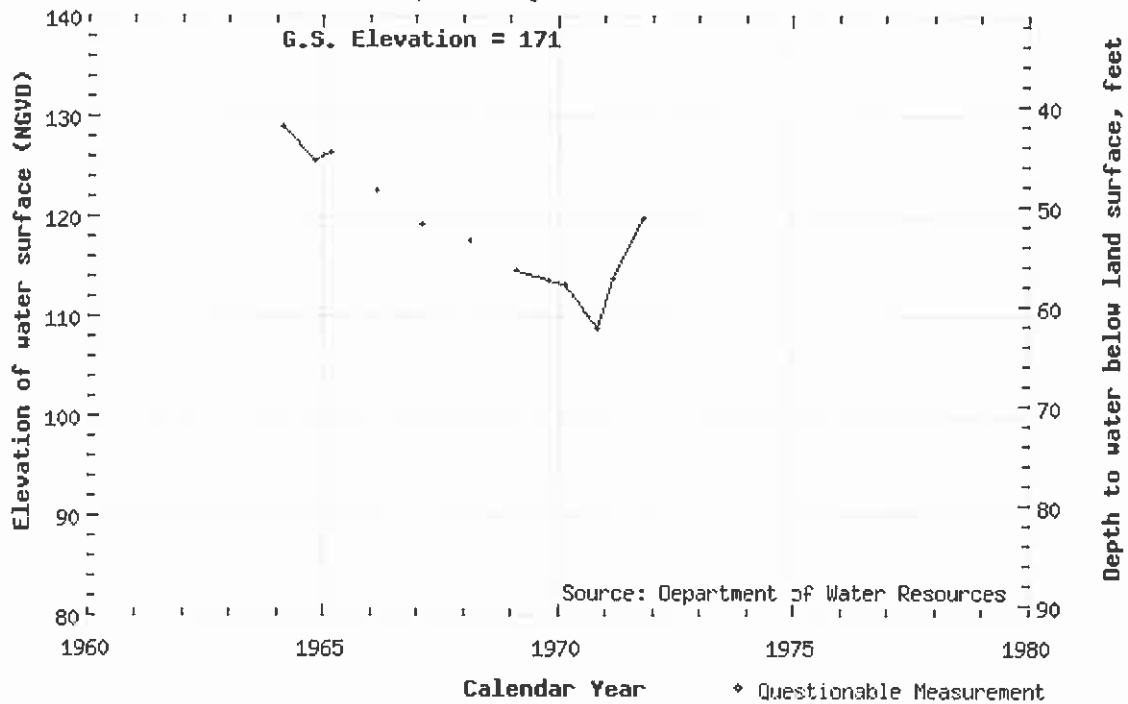
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San Joaquin Valley (Madera Basin)

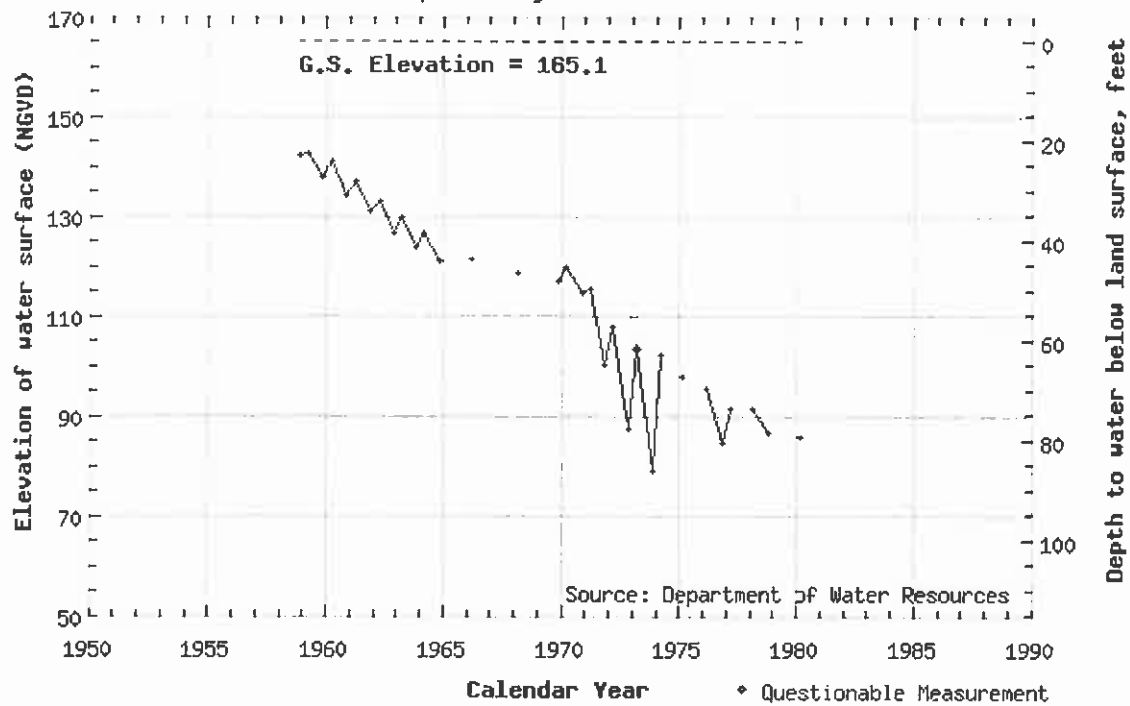
G.S. Elevation = 171



Groundwater Levels, 12S15E14L001M

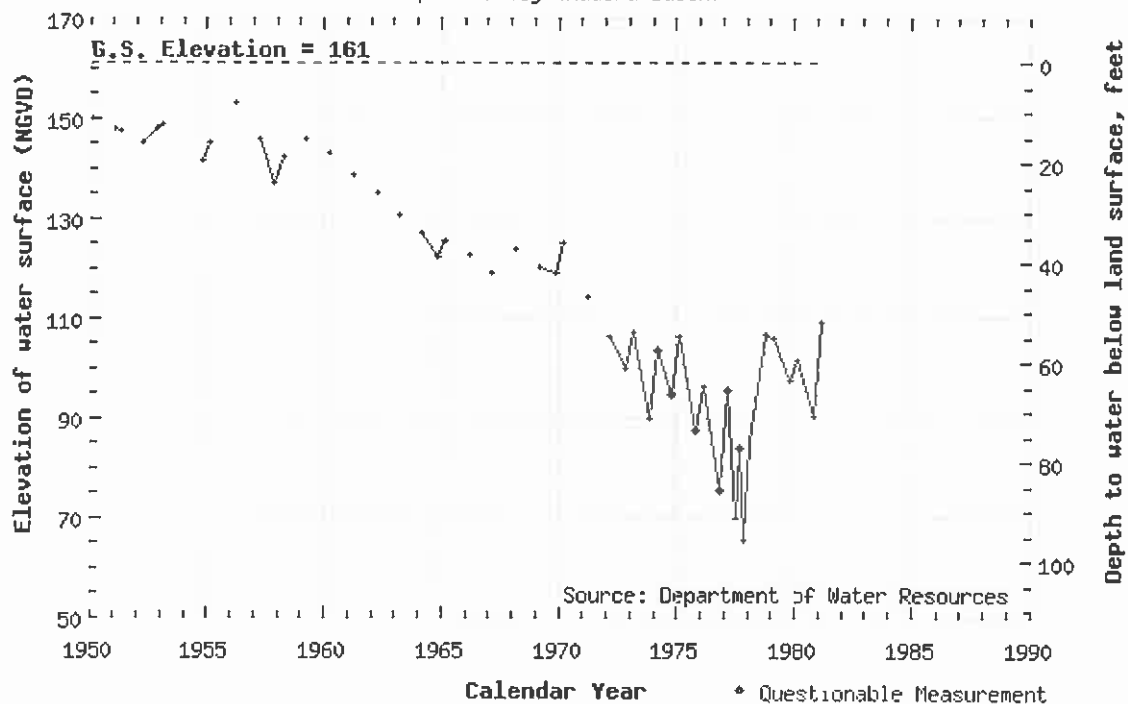
San Joaquin Valley (Madera Basin)

G.S. Elevation = 165.1



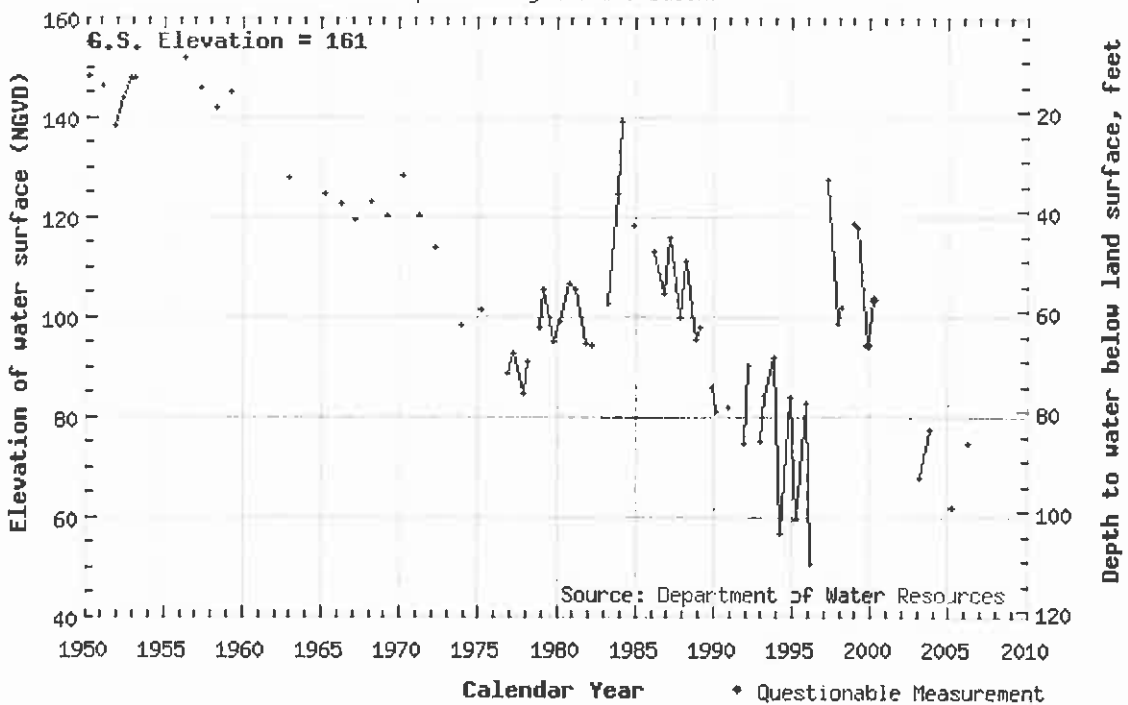
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San Joaquin Valley (Madera Basin)



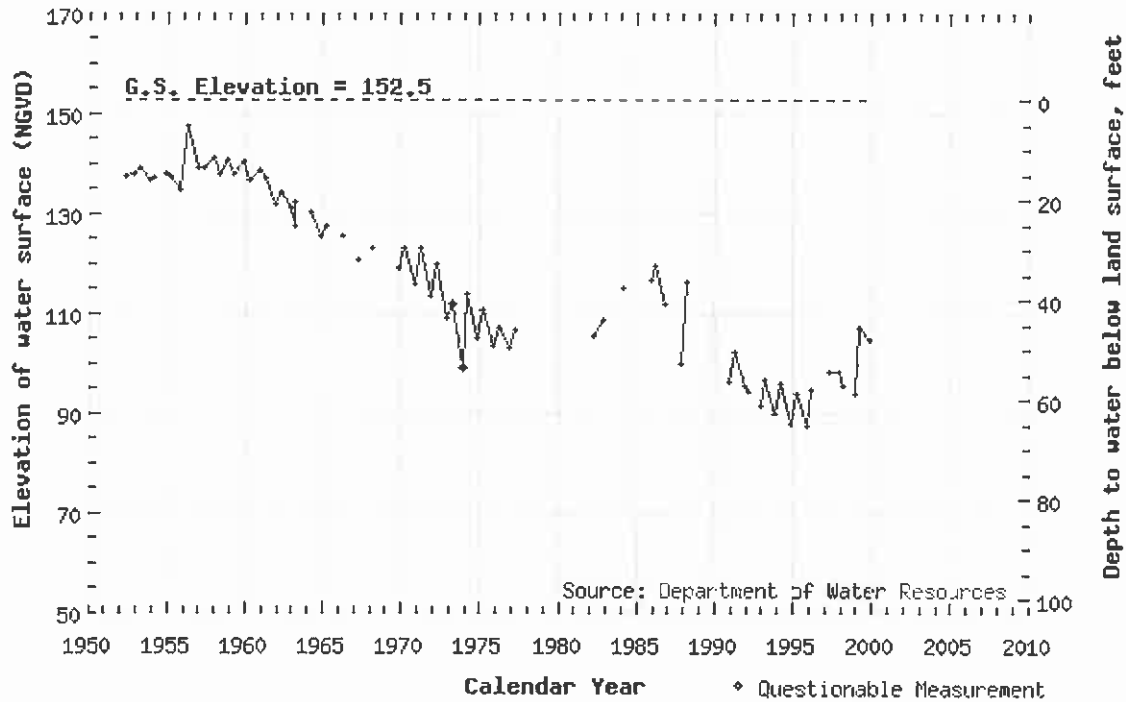
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San Joaquin Valley (Madera Basin)



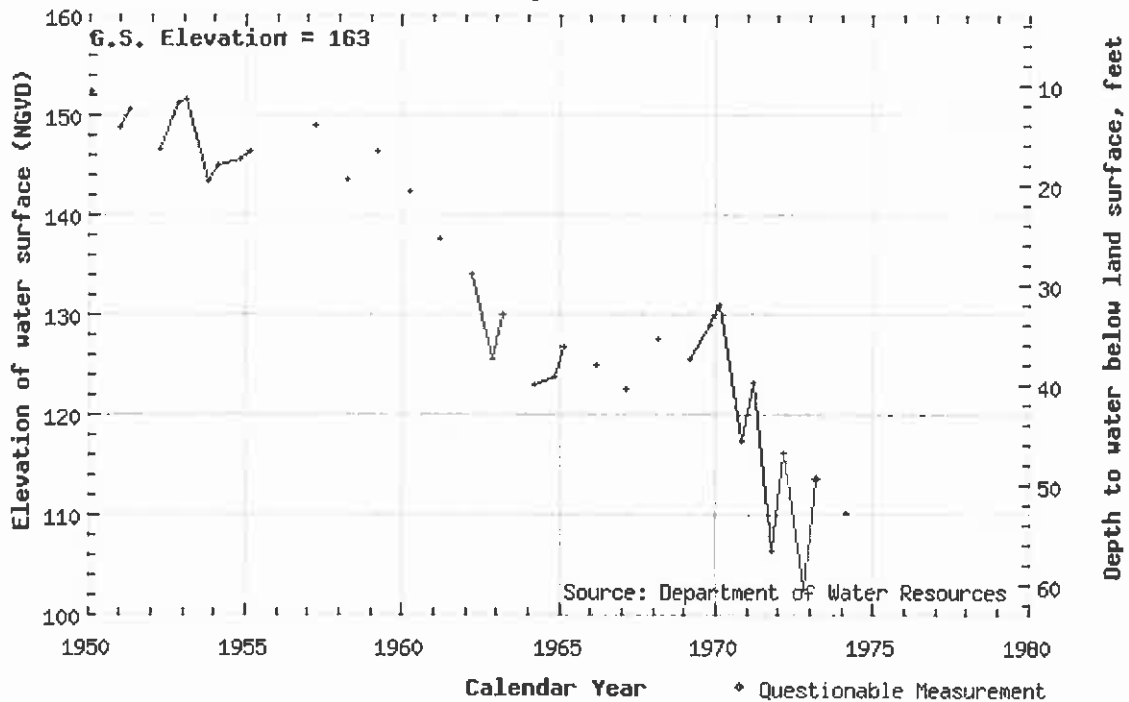
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San Joaquin Valley (Madera Basin)



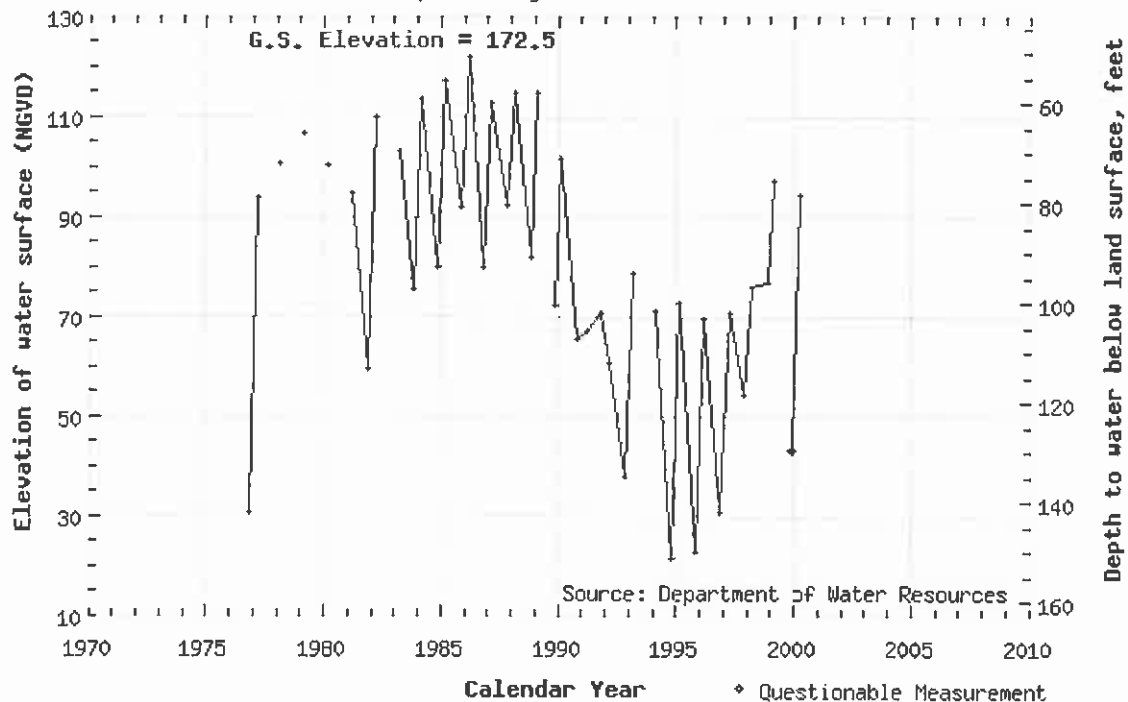
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San Joaquin Valley (Madera Basin)



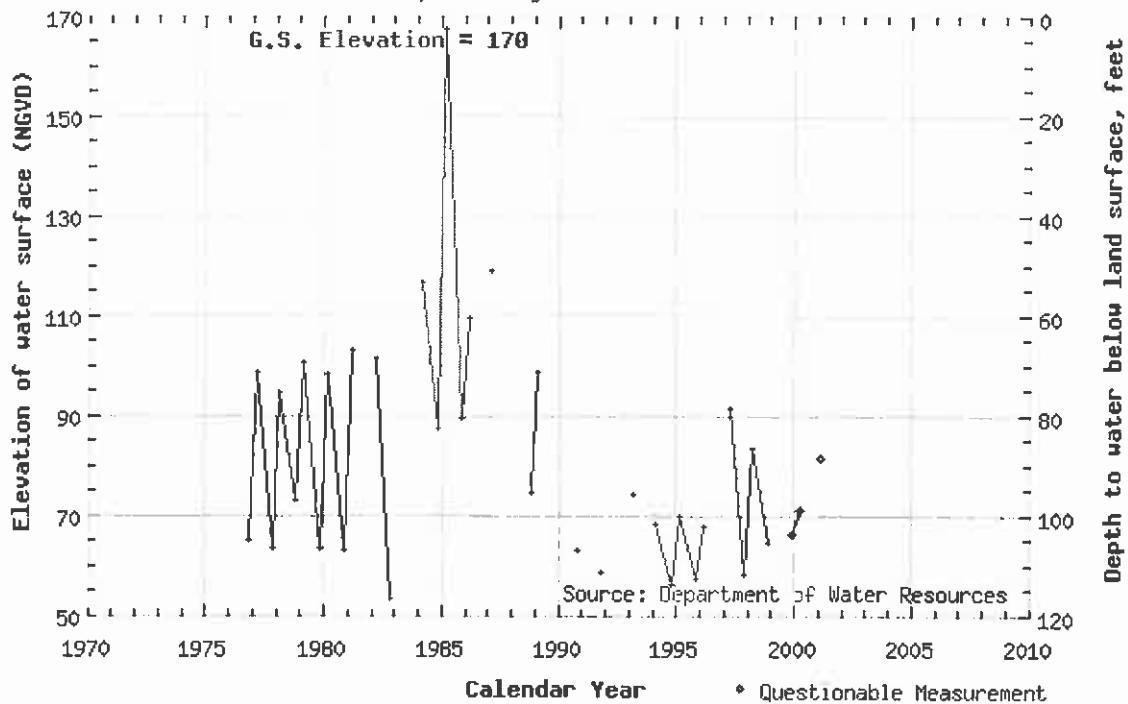
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San Joaquin Valley (Madera Basin)



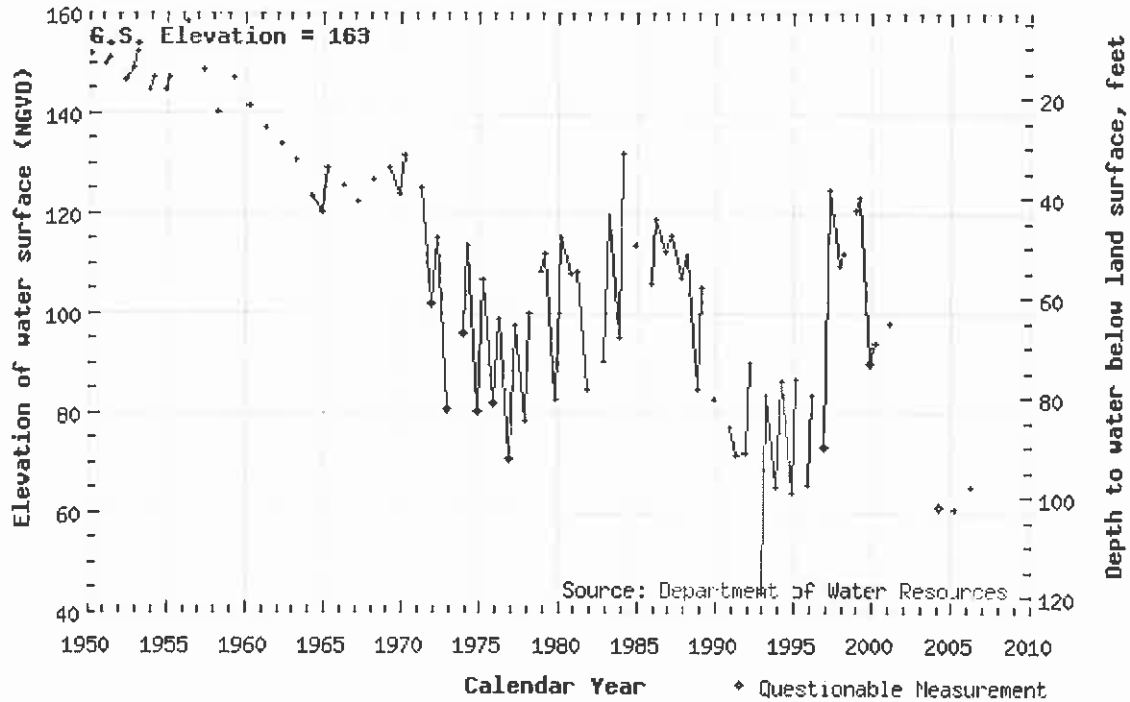
Groundwater Levels, 12S15E23A001M

San Joaquin Valley (Madera Basin)



Groundwater Levels, 12S15E27C001M

San Joaquin Valley (Madera Basin)



Groundwater Levels, 12S15E25N001M

San Joaquin Valley (Madera Basin)

