FINAL

AB3030
Groundwater Management Plan

Prepared for

Wheeler Ridge-Maricopa Water Storage District

November 2007

Todd Engineers
with Kennedy/Jenks Consultants

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AB3030 Groundwater Management Plan

Wheeler Ridge-Maricopa Water Storage District
Kern County, California

Prepared for:

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Executive Summary

Wheeler Ridge-Maricopa Water Storage District (District) wishes to increase the reliability and sustainability of water supply for its customers into the future. To achieve this goal, the District has secured several sources of imported water and manages these sources conjunctively with groundwater. To formalize this process and provide a coherent and transparent plan for the active management of groundwater, the District Board of Directors adopted a Resolution of Intention to Prepare a Groundwater Management Plan (GWMP) at a public hearing on March 15, 2006 (Appendices A and B).

This GWMP follows the guidance and requirements of AB 3030 as amended by SB 1938, the legislation that formed and modified the California Groundwater Management Act of 1992. The management area includes the District boundaries covering approximately 147,000 acres in the southern portion of the Kern County Subbasin (DWR designation 5-22.14) of the larger San Joaquin Valley Groundwater Basin. The goal of the GWMP is to determine how best to integrate groundwater into the District's water supply. To support this goal, objectives for the GWMP have been identified as follows:

- Assess the historical and current conditions in the groundwater basin with respect to water levels, water quality, and other conditions relevant to management
- Determine how the basin has responded to historical and current groundwater use
- Identify Basin Management Objectives (BMOs) for the benefit of the groundwater basin
- Develop management actions to support the BMOs and better integrate groundwater into the District's overall supply
- Provide for the implementation of management actions

For the assessment of the groundwater basin, water level records from about 150 wells across the District were plotted on hydrographs to evaluate the change in water levels over time. Groundwater contour maps were constructed to document the change in groundwater flow and indicate areas of significant groundwater pumping. Water quality data were reviewed and plotted on geochemical diagrams to illustrate changes in groundwater chemistry across the District. The assessment builds on and extends work by previous investigators across the basin (Wood and Dale, 1964; Associated Engineering Consultants, 1983; WRMWSD, 1981; BE, 1995; BE, 2006).

In addition, current and future in-District demands were reviewed along with State Water Project (SWP) Table A amounts and additional imported water secured by the District through various banking agreements. Available imported water amounts were evaluated for wet, average, and dry years to provide context on the incorporation of groundwater into the District's overall water supply. Information from a 2007 U.S. District Court ruling that affects the availability of SWP in 2008 was also considered.

Findings from the groundwater basin assessment and the demand review are summarized below.

Summary of Findings

- Over the last 50 years, groundwater levels and flow have been altered significantly in response to changing pumping patterns and importation of surface water.

- Historical overdraft of the groundwater subbasin was noted in the mid 1940s and was reported to be approximately 70,000 AFY in the western District by 1967. Although water level declines varied somewhat from subarea to subarea, almost all of the hydrographs indicated a decline of 100 feet to 300 feet from the 1950s to 1970 (Figure 9). The rate of decline averaged 8 to 12 feet per year over that 20-year period.

- Since 1970, an overall recovery of water levels has been observed in response to the importation of surface water by the District. Recovery of water levels has occurred at a rate slower than the decline. Recovery rates have averaged about 2 to 6 feet per year, faster during wet cycles and slower during dry cycles (Figure 9). Recent data indicate groundwater has risen to the early 1950s levels. Data indicate that water levels in most areas will continue to recover assuming current conditions of pumping.

- In the White Wolf Subarea, the decline and recovery of water levels occurred later in time than in other District subareas because of the later availability of imported water in that subarea.

- Groundwater generally flows from south to north across the District but flow directions have been altered in some areas due to groundwater pumping. A groundwater contour map generated for 2000 conditions illustrates four persistent pumping depressions that control groundwater flow even as the basin recovers (Figure 11).

- Groundwater throughout the District generally meets Class I or Class II irrigation water quality standards based on salinity as measured by electrical conductivity.

- Ambient groundwater is more highly mineralized in the western portions of the District as indicated by concentrations of total dissolved solids (TDS). The progression of increasing TDS from southeast to west results from the differences in source rocks and quality of surface water runoff.

- Changes in inorganic groundwater chemistry among the subareas are illustrated on trilinear diagrams (Figures 12 and 13). The Wheeler West and Maricopa subareas contain groundwater that has greater hardness and elevated chloride concentrations compared to the groundwater in Wheeler East and White Wolf subareas. However, some deeper wells within the White Wolf Subarea indicate similar water quality to western subareas.

- In 1991, 25 wells were tested for organic constituents in groundwater including volatile organic compounds (VOCs), pesticides, and chlorinated acids. Only five organic compounds were detected in any samples and all concentrations met drinking water objectives.

- In order to evaluate the response of the groundwater basin to groundwater pumping, estimates were made of annual pumping from 1971 to 2002 (Figure 15). These estimates indicate that an average of 61,461 AFY is extracted from the groundwater basin within the District boundaries. This amount accounts for approximately 25 percent of the average water demand within the District, including District areas outside of the Surface Water Service Area (SWSA).

- Although a water balance and estimate of perennial yield of the subbasin were not included in this assessment, a comparison of historical water level records and estimates of annual pumping provide a method to bracket a subbasin perennial yield. Using these data, a perennial yield between about 60,000 AFY and 120,000 AFY can be estimated. Establishing a more accurate perennial yield is recommended for continued groundwater management.

- Within the SWSA, water demand is estimated at 193,000 AFY. An assessment of State Water Project (SWP) entitlements indicates that SWP deliveries are sufficient for wet years, but are may be insufficient to meet demand in average and dry years (Table 4).

- To meet demand during critical periods, the District has secured additional imported water from local water banking programs including the Kern Water Bank, Pioneer Project, and Berrenda Mesa Project. As of December 2006, the amount of the District's supplies in storage from these projects was estimated to be 436,962 AF with some restrictions on the amount that can be withdrawn in a given year. Even with withdrawals from banked storage, local groundwater would still be required to meet in-District demands during multiple dry years or a critically dry year.

- To monitor groundwater conditions, the District has implemented a comprehensive monitoring program including water levels and water quality.

Proposed Basin Management Objectives (BMOs)

Based on the assessment of the groundwater basin and the need to incorporate groundwater into the District's water supply program, the following objectives have been identified for management of the groundwater basin.

- Prevent a return to historical overdraft

- Maintain groundwater quality
- Monitor water levels, water quality, and groundwater storage
- Estimate groundwater use and future demand
- Update progress on achieving BMOs

To achieve these objectives, groundwater management strategies and recommended actions for groundwater basin management have been developed.

Recommended Actions for Groundwater Basin Management

In consideration of the BMOs and ongoing groundwater management activities, the District is recommending the following actions for the GWMP. Recommended actions are discussed in Section 6 of this document and summarized below.

- Optimize the integration of the District's water sources
- Secure additional water sources, as necessary, to supplement current supplies
- Prepare a Groundwater Development Program
    - Evaluate perennial yield of the subareas
    - Implement a Well Maintenance Program for District wells
    - Determine the need for additional wells
    - Operate the basin to support BMOs
- Improve coordination with Kern County well ordinances
    - Obtain copies of permits from County for new wells drilled in the District
    - Coordinate well abandonment activities in the District with the County
- Continue and improve groundwater monitoring program
- Coordinate monitoring activities with other agencies
- Report progress on the GWMP annually and update the GWMP periodically
- Prepare an Integrated Water Resources Plan with neighboring agencies in the southern portion of the subbasin

A plan for implementation of the recommended management actions including a schedule is provided in Section 7.

1. Introduction

The Wheeler-Ridge Maricopa Water Storage District (District) covers approximately 147,000 acres of the southern end of the San Joaquin Valley in Kern County (Figure 1). The District provides water to agricultural customers through a combination of imported water from the State Water Project, imported water from several Kern County banking projects, and local groundwater. In addition, some agricultural water users in the District provide their own irrigation water through groundwater pumping.

To better manage these various water sources, the District has undertaken a number of studies related to increasing the reliability and quality of water supply for the benefit of District customers including the Report on Optimization and Enhancement of the water supplies of Kern County (Associated Engineering Consultants, 1983). To formalize this process and provide a coherent and transparent plan for the active management of its water supply, the District Board of Directors adopted a Resolution of Intention to Prepare a Groundwater Management Plan at a public hearing on March 15, 2006 (Appendices A and B).

1.1. Background

The District was formed in 1959 principally for the purpose of providing water from the State Water Project (SWP) to basin customers to alleviate severe overdraft conditions in the groundwater basin. When imported water became less reliable in the 1990s, the District took steps to secure additional dry year water supplies from the Kern Water Bank, the Pioneer Recharge Project, the Berrenda Mesa Recharge Project, and new District wells. Since that time, the District has increasingly managed imported water and groundwater conjunctively to increase water supply reliability.

The District has initiated the planning process under California's Groundwater Management Act of 1992, commonly referred to as AB 3030 (the assembly bill under which it was codified). AB 3030 was designed to provide local public agencies increased management authority over groundwater resources for the benefit of the State's groundwater basins. The legislation was developed in part in response to the U. S. Environmental Protection Agency (USEPA) Comprehensive State Groundwater Protection Programs.

The AB 3030 planning process was amended in 2002 by Senate Bill (SB) 1938, which provided additional guidance for groundwater management plans. Specifically, SB 1938 requires an agency to include certain components in their AB 3030 plan as a criterion for eligibility for the State's funding programs. In response to this legislation and other amendments, the Department of Water Resources (DWR) has developed a list of required and recommended components for inclusion in groundwater management plans, which is included in the DWR Bulletin 118, *California's Groundwater* (DWR, 2003). The list is reproduced in this GWMP as Appendix C.

This GWMP follows the guidance of AB 3030 (as amended by SB 1938) and DWR criteria. The GWMP documents future management actions planned by the District and provides an implementation schedule.

1.2. Goals and Objectives of the Plan

The District wishes to increase the reliability and sustainability of water supply for its customers into the future. To achieve this goal, the District has secured several sources of imported water and manages these sources conjunctively with groundwater. The goal of this GWMP is to determine how best to manage the groundwater basin for the integration of groundwater into the overall District supply. To support this goal, the following objectives have been identified:

- Assess the historical and current conditions in the groundwater basin with respect to water levels, water quality, and other conditions relevant to management
- Determine how the basin has responded to historical and current groundwater use
- Identify Basin Management Objectives (BMOs) for the benefit of the groundwater basin
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1.3. Public Participation

Prior to committing to the preparation of the GWMP, the District Board of Directors invited public comment by holding a public hearing on March 15, 2006 to consider adopting the intent to prepare the GWMP. The public was given an opportunity to ask questions at the hearing and interested parties were invited to participate in development of the GWMP. If the parties could not attend the public hearing, they could express their interest in writing to the District as explained in the public notice. Water managers at neighboring water agencies, as well as the Kern County Water Agency (KCWA), were also notified of the GWMP process. The item was on the Board agenda and was published in local newspapers in the area. The Public Notice of the March hearing, along with proof of publication, is included in Appendix A.

The District Board of Directors held a second public hearing on October 10, 2007 to present a Draft GWMP to the public and solicit comments to the plan. The draft plan was distributed to key stakeholders prior to the hearing. Comments provided during and after the public hearing were incorporated into this final GWMP. The District Board of Directors will consider plan adoption at a final public hearing, scheduled for November 14, 2007.

1.4. Accuracy of Values in Plan

Throughout this GWMP, areas and water volumes are shown to the nearest acre and acre-foot, respectively, as available from the original data source. In some cases, this results in large numbers that appear to be accurate to four or five digits, which may not be the case. Values that are measured directly, such as subbasin areas, water levels, and surface water deliveries, are likely accurate to two or possibly three significant digits.

Values that are estimated, such as areas of certain crops or groundwater pumping totals, are probably accurate to only one or two significant digits. All digits are retained in text and tables to avoid rounding small numbers to zero, to preserve correct column totals in tables, and to maintain as much accuracy as possible during subsequent calculations based on the information presented in this report.

2. Management Area

The District actively manages imported surface water and groundwater within its boundaries. As such, this GWMP covers lands within the District. A portion of the District is interwoven with lands managed by Arvin-Edison Water Storage District (Arvin-Edison WSD, as shown by the checkerboard pattern on Figure 2. Active groundwater management in this area will be coordinated with Arvin-Edison WSD.

2.1. District Boundaries

The District's service area encompasses approximately 147,000 acres of mostly agricultural lands at the southern end of California's San Joaquin Valley (Figures 1 and 2). The District provides water to approximately 90,000 acres of actively cropped farmland within its boundaries. The District is bordered to the north by the Arvin-Edison WSD, the Buena Vista Water Storage District, and the Kern Delta Water District. To the west the District is bordered by the West Kern Water District, and the Coast Ranges (Figure 2).

2.2. DWR Groundwater Basin

The District overlies the southern portion of the Kern County Subbasin within the larger San Joaquin Valley Groundwater Basin (DWR designation 5-22.14) (Figures 1 and 2). The Kern County Groundwater Subbasin covers almost two million acres (about 3,040 square miles) of Kern County. The District covers only about eight percent of the total subbasin surface area (Figures 1 and 2).

The subbasin is the southern-most extension of the San Joaquin Valley, a portion of the Great Central Valley of California. It is bounded on the north by the Kern County line and the Tule Groundwater Subbasin, on the east and southeast by the bedrock of the Sierra Nevada Foothills and the Tehachapi Mountains, and on the west and southwest by the marine sediments of the Coast Ranges and San Emigdio Mountains (DWR, January 2006). Groundwater storage within the subbasin has been estimated by the Kern County Water Agency (KCWA) at approximately 40,000,000 acre feet (AF).

Although the District only covers a small percentage of the groundwater subbasin, the subbasin can be managed separately due to the different source areas and sediments that have infilled the subbasin over time. Although hydraulically connected to the larger subbasin, the aquifer systems underlying the District formed from coalescing alluvial fans primarily from the San Emigdio Mountains to the south and a portion of the Tehachapi Mountains to the southeast, forming separate subareas that are distinct in geometry and sediments. The remainder of the subbasin is dominated by the alluvial fan associated with the Kern River, the largest drainage in the subbasin. Aquifers along the westernmost edge of the subbasin were deposited from the Coast Ranges. Groundwater from each of these areas is relatively segregated until converging at natural discharge areas in the central portion of the valley.

2.3. Physical Setting

The District is located at the southern end of the San Joaquin Valley, approximately 10 miles south of Bakersfield. The San Joaquin Valley is the southern half of the larger Great Valley, an elongated trough extending about 400 miles through the heart of the state. The San Joaquin River and its tributaries drain the northern two-thirds of the San Joaquin Valley northward toward San Francisco Bay. The southern third has had internal drainage since the Pleistocene Epoch and is characterized by several large dry lake beds. Two of these lake beds, Buena Vista Lake and Kern Lake, lie adjacent to the northern boundary of the District and represent the terminus of surface water drainage in the southernmost portion of the valley. Ephemeral streams from uplands south and west of the District flow across District lands toward the dry lakes.

2.3.1. Topography

Most of the land within the District covers the valley floor and the gently sloping foothills at the valley's southern edge, where the Coast Ranges and Tehachapi Mountains meet. Elevations within the District range from 295 feet above mean sea level (msl) at the northwesterly boundary to 1,865 feet at its eastern boundary (WRMWSD, May 2, 2006). The land surface within the District generally slopes from the foothills along its southern and eastern boundaries to the lower elevation along its northern boundary near historical dry lake beds in the west-central portion of the valley. Grades are generally less than 4 percent and the topography can generally be characterized as flat. The California Aqueduct crosses the District from west to east along an approximate ground surface elevation of 500 feet msl, rising to 1,250 feet msl as it extends over Wheeler Ridge and eventually exits the basin to the southeast (Figure 2). The Tehachapi Mountains and San Emigdio Mountains rise up from the valley floor to the south of the District, while the Temblor Range of the Coast Ranges and the Sierra Nevada Foothills rise up to the west and east of the District, respectively. Ground surface elevations within the contributing watershed of the District rise to above 7,000 feet msl in the San Emigdio Mountains south of the District boundary.

2.3.2. Geology

The southern portion of the San Joaquin Valley is an asymmetrical syncline that has been infilled with thousands of feet of sediment sourced from the Sierra Nevada, the Coast Ranges, and their southern extensions. The trough of the valley is offset to the west, resulting in the thickest section of sediments occurring west of the valley center. Two structural blocks, the Sierra Nevada on the east and the Coast Ranges on the west, have contributed mineralogically-distinct sediments that interfinger in the subsurface in the vicinity north of Wheeler Ridge. Within the District boundaries, much of the sediment has been sourced from the San Emigdio Mountains (Coast Ranges block) and Tehachapi Mountains (Sierra Nevada block) in the south. Coalescing alluvial fans have formed along the southern mountain front, resulting in heterogeneous and discontinuous lenses of gravels and sands with increasing silt and clay northward through the District.

Stratigraphic nomenclature for the subsurface units beneath the District is summarized on Figure 3. In general the nomenclature on the left half of the column relates to stratigraphy in the central and western portions of the District (Maricopa and

Wheeler West subareas). Nomenclature on the right half of the column more directly relates to subsurface units in the southeastern portion of the District (White Wolf and Wheeler East subareas). A surface geology map showing the distribution of these units across the study area is shown on Figure 4.

Basin sedimentation in the southern San Joaquin Valley began in the Jurassic Period from erosion of the rising Sierra Nevada in the east. Sediments were deposited onto the shelf edge of a shallow sea. Because the Coast Ranges orogeny had not yet begun, lands to the west were open to the ocean. Deposits thickened in the deeper water to the west, resulting in the very thick Franciscan Formation that was later uplifted in the Coast Ranges. Deposition proceeded through the Mesozoic and is characterized by more continuous units and an absence of deformation (Norris and Webb, 1990).

Tectonic activity associated with the uplift of the Coast Ranges began in the Tertiary Period and resulted in folding and faulting of sediments along the west side and a deepening of the valley floor. Thick sequences of marine sediments were deposited as the Coast Ranges orogeny continued. By the late Tertiary (Pliocene), the mountains had cut off the connection to the sea and marine waters had been drained from the valley. As deposition continued, nonmarine (continental) sediments were deposited across the valley.

These continental sediments have been penetrated in water supply wells drilled across the District. In the western two-thirds of the District where sediments were deposited from the San Emigdio Mountains, the consolidated Tulare Formation (Pliocene/Pleistocene) occurs at depths generally exceeding 600 to 1,000 feet (Figure 3). The Pleistocene Epoch was dominated by brackish and freshwater lakes resulting in thick deposits of clay occurring throughout the upper Tulare Formation. These include the widespread Cocoran Clay that has been mapped over much of the San Joaquin Valley and the equivalent of which has been correlated to clays beneath the Kern and Buena Vista dry lake beds on the northern boundary of the District (Figure 4) (Pacific Geotechnical, November 1, 1990).

The tectonic activity in the area has produced numerous geologic faults, many of which remain active today. The White Wolf fault is a cross-cutting feature that separates the southern end of the valley from a small subarea between the Tehachapi Mountains and Wheeler Ridge (Figure 4). The Springs fault, located approximately seven miles south and parallel to the White Wolf fault, is a smaller fault that also cross-cuts the southern edge of the valley (Figure 4). Both of these faults have offset aquifer units in the subsurface and impede groundwater flow to the north.

2.3.3. Land Use

The primary land use within the District is agriculture. Agricultural development expanded significantly in the mid 1940’s and added approximately 1,200 new acres of cropped land each year until the mid 1970s (BE, 1995). Agricultural acreage peaked in 1975 with about 108,000 acres of crops within the District. Since 1975, the total acreage of crops has decreased slightly, stabilizing at around 90,000 to 100,000 acres in the late

1980's (BE, 1995). DWR land use maps published in 1990 and 1998 indicate approximately 87,000 and 102,000 acres of plantings, respectively, within District boundaries during those years. District records indicate that about 84,000 acres of land were planted as of 2001 (a year with detailed GIS parcel-based coverage available) as shown in detail below.

Table 1
2001 Crops and Land Use Within the
Wheeler Ridge-Maricopa Water Storage District

Crop Type	Acres	Percentage of Planted Acres
Grapes - Wine, Table, and Raisin	17,469	21%
Cotton	16,302	19%
Wheat	6,769	8%
Other Grains	2,685	3%
Alfalfa	2,514	3%
Other Green Feeds	309	0.4%
Carrots	3,120	4%
Melons	2,134	3%
Tomatoes	2,056	2%
Peppers	1,292	2%
Lettuce	920	1%
Asparagus	440	0.5%
Other Mixed Produce	256	0.3%
Onions and Garlic	3,574	4%
Potatoes and Turnips	1,756	2%
Almonds	5,609	7%
Pistachios	1,540	2%
Walnuts	862	1%
Plums	605	0.7%
Peaches and Nectarines	956	1%
Other Deciduous Trees	809	1%
Oranges	10,159	12%
Lemons	1,489	2%
Grapefruit	408	0.5%
Total Cropped	**84,031**	100%
Less Double Cropped	1,692	
Subtotal Net Farmed	82,339	
Fallow and Miscellaneous	36,294	
Native Vegetation	29,192	
Total District	147,825	

The soils of the District are highly conducive to agriculture uses with 90 percent classified as having wide crop adaptability with no limitations. About 97 percent of the land within the District is considered irrigable (WRMWSD, May 2, 2006). As shown in Table 1, a wide variety of crops are grown within District boundaries. Grapes, cotton, and oranges account for about one-half of the acreage.

Historically, approximately six percent of agricultural lands have been planted more than once per year, a practice known as double cropping (BE, 1995). The remainder of District land is either left to fallow or remains as native vegetation as there is essentially no commercial, industrial, or residential land use within the district.

Since the mid 1990's, agriculture within the District has shifted from predominantly field crops, such as cotton, sugar beets and corn, to various tree (deciduous and subtropical) and vine crops, as summarized on Table 2 below. Acreage for field crops has declined about 21 percent from 1990 to 2001. Collectively, vine and tree crops have increased approximately 15 percent over that same time period. Almonds, citrus, and grapes were planted over as much as 40 percent of district agricultural lands as of 2001. Tree crops that were planted in the mid 1990's are now reaching maturity, which increases overall water demand.

Table 2

Change in Cropping Patterns 1990-2001

Cropping Patterns 1990							
Crop*	**Field**	**Grain**	**Pasture**	**Truck**	**Vine**	**Decid.**	**Subtrop.**
% of Cropped Acreage	45%	5%	2%	14%	14%	11%	9%
Cropping Patterns 1998							
Crop*	**Field**	**Grain**	**Pasture**	**Truck**	**Vine**	**Decid.**	**Subtrop.**
% of Cropped Acreage	30%	15%	4%	16%	16%	10%	10%
Cropping Patters 2001							
Crop*	**Field**	**Grain**	**Pasture**	**Truck**	**Vine**	**Decid.**	**Subtrop.**
% of Cropped Acreage	24%	9%	3%	16%	22%	12%	15%
% Change (1990 - 2001)	-21%	+4%	+1%	+2%	+8%	+1%	+6%

*DWR Crop Definitions:

Field Crops = Cotton, Safflower, Sugar Beets, Corn, Dry Beans, and others

Grain and Hay Crops = Barley, Wheat, Oats, Misc. Grains and Hay

Pasture = Alfalfa, Clover, Mixed Pasture, Native Pasture, Turf Farms

Truck = Truck, Nursery, and Berry Crops including Artichokes, Asparagus, Strawberries, Flowers, Melons, Potatoes, and others

Vine = Vineyards of Wine, Table, and/or Raisin Grapes

Decid. = Deciduous Fruits and Nuts including Apples, Cherries, Pears, Walnuts, Almonds, and others

Subtrop. = Subtropical Fruits such as Grapefruits, Lemons, Oranges, Dates, Avocado, Eucalyptus, and others

2.4. Hydrologic Setting

The study area is characterized by low precipitation, high potential evapotranspiration (ET), little available surface water, and relatively high water demand. As such, the area is highly dependent on imported water and groundwater. Details are provided in the sections below.

2.4.1. Precipitation

The climate in the southern San Joaquin Valley is hot and dry during the summer months with a cooler winter and rainy spring. In an average year, more than 85% of the total precipitation occurs between November and April. However, even with this rainy season, only small amounts of precipitation occur on the valley floor as indicated by annual precipitation records from the last 50 years. Over the last 30 years, average annual precipitation on a District-wide basis has been approximately 7.99 inches per year, based on a thiessen average of six weather stations across the area (data from water years 1977-2006).

Figure 5 shows annual precipitation data from the White Wolf Subarea, an area of the District with the highest precipitation. These data indicate an average annual precipitation of about 11 inches (Figure 5). Single year precipitation amounts vary widely, from more than 24 inches (1998) to as little as 4 inches (1972) (Figure 5).

The distribution of average annual rainfall within and south of the District is shown by contours of equal precipitation (isohyets) on Figure 6. These contours, obtained from the Kern County geographical information system (GIS) database, illustrate the occurrence of higher rainfall in the mountains south and southeast of the valley and lower precipitation on the valley floor. In areas of contributing watersheds to the south and southeast, average annual precipitation increases to more than 20 inches, accounting for most of the runoff into the GWMP area.

2.4.2. Evapotranspiration

Annual potential ET in the southern San Joaquin Valley is reported to be 49.00 inches by DWR (1974). The California Irrigation Management Information System (CIMIS) station nearest to the District (Arvin-Edison) indicates an average annual potential ET of 57.87 inches for the period from 1995 to 2006. The District-operated climate station at Greenlee's Pasture (Lat 35^{o} 4.6'N, Long 119^{o} 4.9'W) measured average annual evaporation of 66.5 inches over the period 1977-2006.

2.4.3. Surface Water

Surface water drains toward the District via a number of ephemeral stream channels from the south, east, and west. The San Emigdio Mountains in the south are drained by the larger drainageways of Santiago, San Emigdio, and Pleito creeks (Figure 6). The Tehachapi Mountains are drained by Tunis, El Paso, Pastoria and Grapevine creeks (Figure 6). Eastern drainageways from the Temblor Range contribute very little runoff due to low elevation and low precipitation. Ephemeral creeks draining east toward the District include Bitterwater and Bitter creeks (Figure 6).

Since the valley's formation in the Pleistocene, surface water hydrology has been characterized by internal drainage with surface water draining toward the central portion of the valley and evaporating in dry lakes. Drainages within the southern Kern County Subbasin flow toward the Kern and Buena Vista dry lakes in the central portion of the valley on the District northern boundary (Figure 6). Historically, flow continued from the Kern and Buena Vista lakes northward toward the larger Tulare Dry Lake until sedimentation altered the drainage. Most of the present-day flow is diverted or infiltrates into the subsurface prior to reaching the discharge area. This is especially applicable to the larger Kern River, the largest drainageway in the area, which flows westward from the Sierra Nevada north of the District. With the construction of Isabella Dam and numerous irrigation diversion structures, almost no water reaches the dry lakes (Wood and Dale, 1964). As such, many of the dry lake beds have been reclaimed and converted to agriculture.

2.4.4. Imported Water

The amount of SWP water imported into the District has varied from 8,112 AF (1991) to 250,067 AF (1981) since surface water deliveries began in 1971. Deliveries have averaged 170,052 AF. Since all of the deliveries are used for irrigation within District boundaries, up to 20 percent may potentially recharge the groundwater basin in the form of irrigation return flows.

2.4.5. Groundwater

2.4.5.1. Aquifers and Hydrostratigraphy

The primary aquifers beneath the District include the undifferentiated Plio-Pleistocene sedimentary deposits of the Tulare and Kern River Formations, and unconsolidated Quaternary alluvium consisting of older stream and terrace deposits, and more recent flood basin deposits (Figure 3). These formations are underlain by undifferentiated Tertiary sedimentary rocks and a crystalline basement complex. These deeper units are relatively impermeable and occur at depths that are not economically attractive for groundwater productions (BE, 1995).

The Tulare Formation occurs beneath the western portion of the District (Maricopa and Wheeler West Subareas) and crops out in the low foothills of the San Emigdio Mountains (Figure 4). This formation consists of up to 2,200 feet of interbedded, oxidized to reduced sands, and gypsiferous clays and gravels derived from the Coast Ranges. This formation also include clay layers equivalent to the Corcoran Clay Member, a vertical confining layer which has been mapped at depths ranging from 300 to 650 feet north of the District (Wood and Dale, 1964). More recent mapping determined that the equivalent clay layers dip south of the Kern and Buena Vista dry lake beds and are likely deeper than 3,000 beneath the central portion of the District (if they occur here at all) (Pacific Geotechnical Associates, November 1, 1990).

The Kern River Formation occurs throughout most of the southeastern and eastern portion of the subbasin, including the White Wolf and Wheeler East subareas (Figures 3 and 4). This formation consists of between 500 and 2,000 feet of poorly sorted lenticular deposits of clay, silt, sand, and gravel derived primarily from the Sierra Nevada. Both the Tulare and Kern River Formations are considered to be stratigraphically equivalent units as shown on the stratigraphic nomenclature column on Figure 3. Both are moderately to highly permeable and yield moderate to large quantities of water to wells (BE, 1995). The deeper Chanac Formation and Santa Margarita Formation, while less permeable, have also been penetrated by water wells in the area (BE, 2006).

The unconsolidated Quaternary alluvium, which comprises the upper portion of the primary aquifer system, is similar in lithology to both the Tulare and Kern River Formations. This alluvium consists of moderately to highly permeable older stream and terrace deposits and younger poorly permeable flood basin deposits (Wood and Dale, 1964). The older deposits tend to occur primarily along the subbasin margins and consist of up to 250 feet of Pleistocene-age lenticular deposits of clay, silt, sand, and gravel. The younger deposits occur primarily in the eastern and southern portion of the subbasin and consist of up to 150 feet of interstratified and discontinuous beds of clay, silt, sand, and gravel. Permeability within the alluvium tends to decrease from east to west, associated with the change in lithology and depositional environment from the Tehachapi Mountains to the San Emigdio Mountains. The permeability of the alluvial sediments also decreases northward across the District and is particularly low beneath the beds of Buena Vista and Kern Lakes (Figure 4) (BE, 1995).

Subsurface correlations and regional mapping with seismic data by Pacific Geotechnical (1990) were reviewed for the GWMP. Using geophysical logs provided by the District, Todd Engineers confirmed several of the subsurface units mapped by Pacific Geotechnical and identified at least three alluvial fan packages to a depth of approximately 1,500 feet beneath the central and western portions of the District (north of Wheeler Ridge and west to the western District boundary). Logs indicate numerous discontinuous layers and unconformities in both the Tulare formation and Pleistocene/Holocene alluvial sediments. Most clay layers cannot be correlated across the District and groundwater is expected to be unconfined to semiconfined to depths of 1,000 feet or more beneath the central portion of the District. More continuous confining layers have been noted in the western portion of the District (Maricopa Subarea, Figure 4) (BE, 1995).

Faults that act as barriers to groundwater within the Kern County Subbasin include the Edison, Pond-Pose, White Wolf, and Springs faults. Only the White Wolf Fault and Springs Fault occur within District boundaries (Figure 4). The White Wolf fault separates a southeastern alluvial subarea from the remainder of the Kern County Subbasin (referred to in this report as the White Wolf Subarea and defined in the following section). A study on groundwater flow in the vicinity of the fault indicates that groundwater levels are disrupted and groundwater flows across the fault only in certain areas and only during conditions of relatively high water levels (Hagan, 2001). Groundwater flow is also impeded across the Springs fault. Here, groundwater flowing northward from recharge areas in the Tehachapi Mountains rises along the fault trace and surfaces as springs, providing the fault with its name.

2.4.5.2. Subareas

USGS and others have noted gradational changes in aquifers, well yields, and groundwater quality from east to west within the District boundaries and have subdivided this portion of the groundwater subbasin into subareas based on source rocks, permeability, and water quality (Wood and Dale, 1964). These subareas were adopted and modified by Bookman-Edmonston (1995) and serve as a useful framework within which to evaluate changes in the GWMP study area over time. As such, these subareas are often referenced in this GWMP and are shown on Figure 7, along with wells used in the groundwater basin assessment. From west to east, subareas are referred to as Maricopa, Wheeler West, Wheeler East, and White Wolf subareas.

The Maricopa Subarea covers the western portion of the District and is surrounded by fine-grain marine source rocks of the Coast Ranges. The subarea is fed by relatively small ephemeral streams of poor water quality from the west and southwest.

The poorer surface water quality entering the subarea is emphasized by the names of the two western-most creeks, Bitterwater Creek and Bitter Creek (Figure 6). These conditions combine to create fine-grain aquifers with relatively poor well yields and highly mineralized groundwater quality. Aquifers are expected to be slightly coarser grained in the southern portion of the subarea, associated with deposition on the Santiago Creek alluvial fan.

East of Santiago Creek, lithologies in the San Emigdio Mountains change (Figure 4). Exposed outcrops contain Tertiary sediments of numerous formations and depositional environments. Erosion of these rocks, along with re-working by streams, has resulted in more coarse-grain deposits in the Wheeler West Subarea than seen in the Maricopa Subarea. This deposition, especially in the deeper zones beneath the San Emigdio Creek alluvial fan, has created more permeable aquifers with lower total dissolved solids (TDS) in groundwater. These source rocks are similar from Santiago Creek to Grapevine Creek and provide relatively similar aquifers throughout the Wheeler West Subarea (Figures 4 and 7).

The aquifers in Wheeler East and White Wolf Subareas have originated from source rocks in the Tehachapi Mountains, the southern extension of the Sierra Nevada (Figure 7). These aquifers are the most permeable in the District and contain the best groundwater quality with respect to natural mineralization.

The permeability changes within the aquifers are reflected in the well performance data available for study area wells. Specific capacity data reflect well yields and are related to the permeability of the aquifers in which the well is screened. These data have been compiled from District wells and estimated from Driller's Well Logs for other wells in the area. These data are presented on Figure 8 in units of gallons per minute per foot of drawdown (gpm/ft dd) and are color-coded for ranges in specific capacity. Although data are sparse, the distribution of specific capacities is consistent with higher permeabilities in the southeast, decreasing to the west. Most of the specific capacities in the White Wolf Subarea exceed 50 gpm/ft dd. Although wells in the Wheeler West Subarea have lower relative specific capacities, most of the specific capacities shown on the map are sufficiently high to allow wells to be pumped at rates of about 1,000 gpm or more.

2.4.5.3. Groundwater Recharge and Discharge

Recharge within the District is primarily supplied by the percolation of applied irrigation water. Depending on the timing and type of irrigation, more water is generally applied than can be consumed by the crop, resulting in deep percolation to groundwater. Historically, irrigation efficiencies reported by the KCWA have been about 80 percent, suggesting that roughly 20 percent of applied water percolates below the root zone, potentially recharging groundwater. It is recognized, however, that irrigation water delivered to areas outside the usable groundwater basin or to perched water areas may not significantly contribute to groundwater recharge.

Recharge also occurs as stream seepage from runoff in the small creeks and streams along the southern District boundary. Although stream gage data are sparse, observations by USGS (Wood and Dale, 1964) indicate that almost all of the streamflow originating from the surrounding uplands into the District infiltrates prior to leaving the District boundary in the north. Given the relatively high evapotranspiration rate and the low precipitation, there is likely no significant groundwater recharge from rainfall on the valley floor.

Subsurface inflow from the north has also been an important source of groundwater recharge. Groundwater pumping depressions have reversed natural gradients so that groundwater flows south into the District rather than toward the natural discharge areas near the dry lakes.

Discharge of groundwater from the District occurs primarily through the pumping of agricultural wells. Subsurface outflow to the north has been curtailed somewhat due to pumping near the northern District boundary.

2.4.5.4. Regional Groundwater Flow

Pre-development groundwater flow across the District was generally from recharge areas in the surrounding uplands to discharge at dry lakes in the north. These natural flow patterns have been interrupted since at least the 1940s by changing pumping patterns throughout the District. These changes over time are examined in more detail in the following section.

3. Assessment of the Groundwater Basin

In order to select appropriate BMOs and management actions for the GWMP, historical and current conditions of the groundwater basin beneath the District have been evaluated. The following sections provide a summary of that assessment.

3.1. Water Levels and Groundwater Flow

Over the last 50 years, water levels and groundwater flow have been altered significantly in response to changing patterns of groundwater pumping and importation of surface water. These changes are examined using water level data provided by the District, water level contour maps from various published documents, and hydrographs and water level contour maps constructed by Todd Engineers.

3.1.1. Water Level Data

The District maintains a water level database containing both available historical records and current monitoring data. Water level data were available for more than 480 wells in the District dating from 1949 to 2006. Locations and construction information for many of these wells were available in a separate District database and were matched to water level data using the state well number.

Almost all of the wells with water level data were originally drilled as deep agricultural wells with long perforated intervals. Many wells contain continuous perforations from about 200 feet to the total depth of the well, extending below 2,500 in some cases. The perforated interval in wells averages about 800 feet in length. The top perforation depth averages about 400 feet and the bottom perforation depth averages about 1,200 feet, although average well depths in the White Wolf Subarea are typically shallower than wells in the other subareas. Throughout most of the study area, these perforations commingle water from multiple aquifers including the recent and older alluvium and the deeper Kern River/Tulare Formation. As a result, water level data generally represent average heads for both the unconfined and semi-confined systems within the District boundaries.

To support the GWMP, hydrographs of water level data over time have been plotted for about 150 wells in the District. These hydrographs illustrate the trends and fluctuations in groundwater elevations over the last 55 years, documenting significant water level changes. Wells chosen for graphing included those with sufficiently long records and/or early measurements that pre-dated SWP importation (May 1971). These graphs were used interactively with well locations, construction data, and key water level contour maps to document changes in groundwater levels that have occurred from the earliest water level records in the 1950s through recent water level measurements in late 2005 and early 2006.

3.1.2. Water Level Trends and Fluctuations

Water level records throughout the District illustrate both long-term trends and seasonal fluctuations in the basin. Two major trends are evident in most wells: a significant decline in water levels associated with groundwater development in the 1950s and 1960s and a subsequent recovery associated with the importation of SWP water beginning in the early 1970s. Seasonal fluctuations are less well-documented but illustrate declines during the pumping season (generally January to September) and subsequent recovery in the late fall and winter months. Wells close to major pumping centers indicate seasonal fluctuations of 50 to 100 feet locally.

District-wide overdraft was first noted in the mid-1940s with the post-WWII expansion in agriculture and irrigation in the basin (BE, 1967). Overdraft conditions in 1967 were reported to be approximately 70,000 AFY in the western District (generally covering the Wheeler East and Wheeler West subareas) and about 45,000 AFY in the White Wolf Subarea). A myriad of problems associated with declining water levels were documented including:

- loss of well production and well abandonment
- increasing pumping costs with lifts exceeding 700 feet in some areas
- drilling of deeper wells that encounter marginal or unsatisfactory water quality
- land subsidence resulting in well destruction (BE, 1967).

In addition, the shallow alluvial aquifers were essentially dewatered during this time period, resulting in production from deeper and sometimes less permeable aquifers (BE, 1967).

Although water level declines varied somewhat from subarea to subarea, almost all of the hydrographs are consistent with a water level decline in the basin of about 100 to almost 300 feet during the 1950s and 1960s as shown by the example hydrographs on Figure 9. During these two decades, water levels appear to have declined in most parts of the basin by an average of 8 to 12 feet per year. The total water level decline associated with the post WWII expansion of agriculture is not fully documented, as only a few pre-1952 records exist.

Since 1970, an overall recovery of water levels is indicated by the data, but at a slower rate than the decline. Recovery rates have averaged about 2 to 6 feet per year, faster during wetter cycles and slower during droughts. In 1981, the District documented the elimination of overdraft and subsequent rise of waters levels since the importation of SWP water (WRMWSD, 1981). Data presented in a 1995 groundwater study documented the continual rise of water levels through the 1980s (BE, 1995). Water levels departed from the recovery during the drought conditions of the early 1990s and either flattened or declined in 1991 throughout the District. Since that time, water levels have continued to rise in almost all areas of the District. This basin decline and recovery in each subarea is illustrated by the example hydrographs shown on Figures 9 and discussed in more detail below.

3.1.2.1. Maricopa Subarea

Hydrographs were constructed for 18 wells in the Maricopa Subarea including five wells with at least one water level measurement before 1970. Although data are sparse, water levels appear to have been around 260 feet msl in the late 1950s and early

1960s. By 1971, water levels had dropped about 100 feet to a subarea average of about 160 feet msl as illustrated on the example hydrograph on Figure 9. The subsequent recovery occurred at only half of the pace of the preceding decline in most wells, with water levels rising about five feet per year. The example hydrograph for 32S/24E-24Q1 shows a slightly faster recovery than most wells in the subarea. By the 1990s, most of the wells appear to have recovered to late 1950s levels. Some wells in the Maricopa Subarea continue to rise (e.g., 11N/22W-9G02 and 12N/22W-30N02) while recent water levels in other areas appear to have stabilized (e.g., 32S/25E-30D01) (Figure 9).

3.1.2.2. Wheeler West Subarea

Hydrographs for 72 wells were constructed for the Wheeler West Subarea. Of these, 24 contained pre-1970 data with which to analyze pre-SWP declines. Nine of these hydrographs contain at least one water level measurement from the early 1950s. The decline and subsequent recovery of water levels in the subarea are illustrated by a typical hydrograph (Well 11N/21W-04H01) shown on Figure 9. Although water levels in this well do not necessarily reflect exact average values presented in the analysis below, the long record and central location of the well document the long-term trends and fluctuations in the subarea.

Monitoring data in the Wheeler West Subarea indicate current average water levels of about 250 feet msl. Although data are sparse and subject to unknown errors, hydrographs indicate an average water level decline of about 220 feet from 1950 to the early 1970s, dropping levels close to or below sea level in many areas (Figure 9). The rate of decline ranged from about 8 feet per year to 17 feet per year.

The subsequent basin recovery over the next 35 years resulted in an average rise in water levels of about 200 feet, closely approximating early 1950s levels. Water levels rose about 5 feet per year in most areas from the early 1970s through 1990. From 1990 to 2000, the basin recovery was slower (about 2 to 3 feet per year) due, in part, to increased pumping and decreased surface water deliveries in the early 1990s drought. Over the last five years, water levels have risen at a rate of about 4 feet per year throughout most of the subarea. Most of the hydrographs indicate that water levels are continuing to rise.

A comparison of hydrographs in the subarea shows that while overall water levels have declined and recovered together, wells have been affected over time by changing pumping patterns. For example, when comparing water levels from 11N/21W-4H01 to a well about five miles north in the subarea, 32S/26E-14N01, a change in flow direction is indicated. Prior to the importation of SWP water, water levels were higher in the northern well (14N01) due to pumping depressions in the south (Wood and Dale, 1964). After the importation from the SWP, water levels recovered quickly in the southern well (4H01) while pumping increased near the northern well, away from the SWP distribution area. This apparent reversal in flow is evident in other wells in the subarea, reflecting changes in pumping patterns. These pumping patterns are further illustrated in subsequent sections of this GWMP.

3.1.2.3. Wheeler East Subarea

Hydrographs for 26 wells were constructed in this subarea. Of these, only five contained measurements before 1970. In general, records are shorter and data are more difficult to interpret in this subarea. Wells in close proximity have significantly different water levels. Well construction data are not available for many of these wells to evaluate vertical gradients. Hydrographs from two Wheeler East wells located about two miles apart have water level differences of about 150 feet. This condition indicates a relatively high horizontal gradient of about 0.014 feet/feet. This is due, in part to the location of nearby pumping centers, but is also likely due to discontinuous aquifers in the subsurface.

Additional wells in the northern portion of the subarea have higher water levels than expected and are typically associated with relatively shallow perforated intervals (top perforation at about 100 to 200 feet). Other subarea wells appear to be perforated in intervals between about 400 feet and 1,200 feet. Although perforated intervals are often overlapping, the higher water levels consistently appear to occur in the shallowest wells. This area coincides with the southern limits of a "shallow groundwater" area mapped by KCWA and noted to be influenced by shallow clay layers in the subsurface (KCWA, 1990 and 1999).

Regardless of these differences, most wells reflect the sharp drop in water levels before 1970 and subsequent rise, consistent with water levels in adjacent subareas. The rate of decline appears to have been around 10 feet per year to 12 feet per year. Recovery has occurred more slowly, with water levels rising from about 6 feet per year to less than 2 feet per year. Most wells have risen an average about 3 feet per year from 1970 to 2005 (Figure 9).

3.1.2.4. White Wolf Subarea

Water level data were sufficient to construct 28 hydrographs for wells in this subarea. Of these, nine wells contained at least one water level record prior to 1971. A typical hydrograph for the area is included on Figure 9. Data indicate that in the 1950s, water levels averaged about 300 feet msl in the subarea (Figure 9). Water levels declined more than 150 feet over the next 20 years. Over the last 35 years, water levels have recovered almost 100 feet in the subarea, but have not yet reached 1950s levels.

Although the same general pattern of decline and recovery is evident in the subarea, the decline continued into the 1970s and the basin appears to be further from complete recovery than other subareas. This is due to the delay in SWP water availability in this subarea relative to the other subareas. SWP was not provided to this subarea until 1975, accounting for the water level rise at that time (WRMWSD, 1981; BE, 2006). Arvin-Edison WSD began importing surface water into the basin in 1967 and continues to deliver about 20,000 AFY of Central Valley Project water to the basin, also accounting for water level rise. In addition, active wells continue to extract water from this subarea, in part due to the higher permeability of the aquifers and better groundwater quality, and in part because large areas are not served with surface water.

3.1.3. Groundwater Flow

Historically, groundwater flowed generally from south to north across the District from the recharge areas in the mountains to the lower elevations near the former dry lake beds (Wood and Dale, 1964; WRMWSD, 1981). As groundwater development increased over time, water levels declined more rapidly in the southern portion of the District, reversing the natural northerly direction of groundwater flow. This reversal persisted from at least the 1960s through 1990, even as basin levels rose in response to the importation of surface water and groundwater pumping patterns changed over time (WRMWSD, 1981; BE, 1995).

Water level contour maps covering portions of the District have been compiled and compared from various sources. Key contour maps include a USGS map for December 1958 water levels (Wood and Dale, 1964), two maps prepared by the District for 1970 and 1981 (WRMWSD, 1981), and a map prepared by Bookman-Edmonston for water levels in 1990 (1995). KCWA also monitors water levels in the basin and produces water level contour maps in their annual reports. Although these maps only cover a small portion of the District, they were incorporated into the review. For the GWMP, Todd Engineers supplemented these maps with a contour map for 2000. Collectively, these maps allow for an evaluation of changes in groundwater flow for each decade from about 1960 through 2000.

The earliest data available for the groundwater flow analysis is a map constructed by USGS for December 1958 (Wood and Dale, 1964). On that map, three major pumping depressions are evident including one in each of the Maricopa, Wheeler West, and Wheeler East subareas as shown on Figure 10. Although these depressions are not depicted on the 1970 water level contour map prepared by the District, water levels are generally lower in these areas and are generally lower throughout the entire District. Regional flow patterns from north to south appear to be reversed (presumably due to pumping) throughout each subarea except the White Wolf Subarea. Water levels are generally below 150 feet msl across the District with a large portion of the southern District containing water levels below sea level.

Maps from 1980 and 1990 mirror the same groundwater flow directions seen in 1970, but water levels have risen substantially. In addition, a pumping depression in the northern portion of the Wheeler West Subarea is indicated by the data. This area is outside of the SWP distribution system and still relies on groundwater pumping for water supply. Although water levels continue to rise, even in the area of the pumping depression, it remains visible in all of the post-1980 data.

The northern pumping depression is evident on the 2000 water level contour map prepared for this study and shown on Figure 11. Although water levels have risen and the area below the 100-foot contour is smaller than on previous maps, the depression persists. Additional pumping depressions are evident in the southern portion of Wheeler West, Wheeler East and in White Wolf subareas (Figure 11).

3.2. Groundwater Quality

Groundwater quality is generally suitable for irrigation use throughout the District, although significant water quality changes are noted from one subarea to another. Ambient groundwater quality and spatial variability across the study area were examined using water quality data provided by the District and geochemical plots constructed by Todd Engineers for this GWMP.

3.2.1. Water Quality Data

The District maintains a database of water quality data compiled from a variety of sources including their own water quality monitoring program. Data have been entered into an Access database containing more than 12,000 records from 389 wells. Data are generally available from November 1951 through October 1999, although inorganic data are available in one well (11N/20W-02H) for a sampling event in February 1910.

Analyses are mostly for inorganic constituents, including general minerals and metals. In 1991, analyses in approximately 25 wells were expanded to include organic chemicals, including volatile organic compounds, pesticides, and chlorinated acids.

3.2.2. Inorganic Water Quality

Recognized systems for classifying irrigation water have been based on the salinity hazard as measured by electrical conductivity (EC) together with the sodium hazard as reflected by the sodium absorption ration (SAR), but other constituents may also be considered including as boron, sodium, and chloride. The District employs the system in use by DWR based on studies at the University of California at Davis, which considers hazards related to salinity, sodium, boron, sodium, and chloride. Groundwater throughout most of the District meets Class I or Class II irrigation water quality standards for salinity (WRMWSD, 1981). Class I water is suitable for all crops grown in the District with an EC value of less than 1,000 microsiemens/cm (uS/cm). Class II meets the water quality requirements of most crops with the exception of some salt sensitive vegetable crops and has typical EC values between 1,000 uS/cm and 3,000 uS/cm (equivalent to TDS concentrations between about 700 mg/L and 2,000 mg/L). Class III water is generally too saline to be tolerated by most crops with an EC value of more than 3,000 uS/cm (TDS concentration greater than about 2,000 mg/L).

KCWA combined subbasin-wide water quality data through 1990 from many wells and time periods to construct a regional map depicting TDS concentrations for both unconfined and the deeper confined groundwater systems (KCWA, 1999). Both maps indicate TDS concentrations generally above 1,000 mg/L across the District, with the exception of the White Wolf Subarea where TDS concentrations are generally below 500 mg/L. In addition, maps indicate significantly higher TDS concentrations (2,000 to more than 5,000 mg/L) in the Maricopa Subarea.

This increase in TDS from southeast to west reflects the differences in source rocks and surface water runoff and has been documented over time by numerous investigators (Wood and Dale, 1964; WRMWSD, 1981). District-wide water quality mapping conducted by the District with data from 64 wells confirmed this pattern of highly mineralized water in the Maricopa Subarea and lower mineralized water (better water quality) in the White Wolf Subarea. An evaluation of inorganic water quality by the District in 1981 noted that no major change in water quality was indicated by the data from 1970 to 1980 (WRMWSD, 1981). Although the updating and redrafting of water quality contour maps were beyond the scope of this report, a review of recent data reflects similar water quality patterns.

In order to analyze and illustrate varying water quality across the District, inorganic water quality data were plotted on trilinear diagrams. This geochemical plotting technique groups anions and cations concentrations in total milliequivalents per liter (meq/L) to categorize types of groundwater. A summary trilinear plot of groundwater data from each subarea is shown on Figure 12. As seen on the trilinear, groundwater quality can be generally grouped by subarea. Water quality data from the Maricopa and Wheeler West subareas plot in the transitional area between hard water and saline type water. Data from White Wolf plots as a calcium-bicarbonate water and demonstrates a different water quality signature from the other subareas. Wheeler East data also indicate a geochemical signature distinct from other subareas, but the interpretation is based on limited data.

Although data were limited, there did not appear to be significant differences in the geochemical signatures through time for nearby wells within one subarea. Similarly, there did not appear to be significant differences between deep and shallow wells within each subarea, with the possible exception of White Wolf Subarea. Several of the deeper wells in White Wolf Subarea appeared to have a different signature from other White Wolf wells as shown on Figure 13. These wells contain water quality more similar to wells in the Wheeler West and Maricopa subareas as shown on Figure 12.

3.2.3. Organic Constituent Testing

During the 1991 sampling events, approximately 25 wells were monitored for organic chemicals, including volatile organic compounds (VOCs), pesticides, and chlorinated acids. Only three wells detected any of the compounds and only five organic compounds were detected in these wells. These detections are summarized below:

Table 3
Detections of Organic Compounds Tested in 1991

Organic Constituent Detected	Concentration (ug/L)	Subarea	Date
Ethylbenzene	4.2	Wheeler West	09/04/91
Toluene	11	Wheeler West	09/04/91
Xylenes	32	Wheeler West	09/04/91
2,4-D Dichloro-phenoxyacetic acid	1.9	Wheeler West	02/06/91
MBAS	20	Wheeler East	03/08/91

The first three compounds above are petroleum hydrocarbons, the fourth is an herbicide, and MBAS is typically associated with detergents. None of these detections exceed the maximum contaminant level (MCL) for drinking water and do not indicate significant water quality problems.

3.3. Groundwater Use

Prior to 1967, the only source of water supply in the basin was groundwater. Since that time, the District has secured additional water sources including water from the SWP. Within the portions of the District collectively known as the Surface Water Service Area (SWSA), the District delivers water via a network of distribution lines and turnouts (Figure 14). This water supply consists of SWP water diverted from the California Aqueduct, water obtained from Kern County banking projects, local surface water, and groundwater pumped from the District's 17 groundwater wells. The District records the volume of water drawn from each source and delivered to customers.

Although the water supply provided by the District meets most of the water demand, there are water users within the SWSA who supplement surface deliveries with groundwater pumped from private wells. In addition, there are water users outside of the SWSA but within the District boundary whose entire water supply is drawn from private wells. The total volume of groundwater extraction within the District is the combination of water pumped from these private wells and pumping at the 17 District wells. While the District maintains records of the volume of water pumped from its own wells, data are not available on the number of private wells in operation nor the volume of groundwater extracted from these wells.

3.3.1. Estimates of Historical Crop Demand

In order to evaluate the response of the groundwater basin to groundwater production, the amount and general locations of groundwater extractions were estimated. This effort involved an evaluation of historical water demand (corrected for effective precipitation) in the District over time and the subtraction of water delivered, recognizing that demand not met by surface deliveries would need to be met with groundwater. Domestic pumping is not included in the analysis and assumed to be negligible compared to irrigation pumping.

Since water use within the District is allocated nearly entirely for agriculture, water demand can be closely approximated by estimating the total volume of water applied to all crops within the District on an annual basis. The annual volume of applied water can be determined by calculating water demand for each type of crop on a per-acre basis, accounting for the effects of effective precipitation and irrigation efficiency, and multiplying by the planted acreage of each crop within the District. Once the total volume of water applied to all crops has been calculated, the gross volume of groundwater extraction can be determined by subtracting the volumes of surface water deliveries and non-local groundwater deliveries recorded by the District. This evaluation was conducted on an annual basis from 1971 through 2001.

Required amounts of applied water for each type of crop grown within the District were obtained from KCWA water supply reports and supplemented with data from DWR (1974). The data presented in the reports were collected through a series of interviews with growers, farm advisors, and other persons having knowledge of agricultural practices in the San Joaquin Valley portion of Kern County. Since these data are based on the prevalent irrigation practice in Kern County for each crop, corrections for effective precipitation were not made to these data. If applied water was not known and available data were crop demands only, effective precipitation and irrigation efficiency were used to adjust the data.

ET data for the estimated growing season of the principal crops were available from DWR (1974). Reference ET data for the area were available from a nearby CIMIS station (Arvin Edison CIMIS Station #125, Lat: 35° 12' 22"N, Long: 118° 46' 40"W). Data from this station indicate an average year potential ET within the District of approximately 58 inches (in) or 4.83 acre feet per year (AFY). Crop coefficients for a variety of crops grown within the District were also collected from CIMIS. A crop coefficient is an experimentally derived number, which when multiplied by a reference ET yields an estimate of crop water demand. Crop coefficient values vary throughout the growing season as a crop grows and expands or reduces its ground cover. For the purpose of the analysis presented here, an average crop coefficient for the entire growing season of each crop was determined from the CIMIS data. These growing season crop coefficients were then multiplied by reference ET on a monthly basis to establish a crop water demand.

In order to adjust the crop water demand predicted by the CIMIS data to account for effective precipitation, a water balance was constructed using the CIMIS reference ET data and precipitation data from a nearby DWR climate station (DWR Station Number 6754-00, Elevation 1179 ft, Lat 34° 93' 00"N, Long 119° 38' 00"W) (Figure 5). This water balance was used to determine actual ET on a monthly basis from the given reference ET and gross precipitation amounts in the absence of irrigation. Actual ET was then subtracted from reference ET in order to determine the fraction of ET that would need to be supplied by irrigation for each month. These remainders were then multiplied by the appropriate growing season crop coefficients to determine an adjusted crop water demand for each crop type.

Once historical crop water demand had been estimated, data were corrected for irrigation efficiency. Because a certain percentage of the water applied to the crops within the District will percolate past the root zone before being used by the crop, the applied water demand of each crop exceeds the crop water demand by some amount related to the efficiency of irrigation. The hydrologic inventory prepared by Bookman-Edmonston (1995) together with District delivery records suggest that on average, the volume of water applied to all crops within the District SWSA exceeded the calculated crop water demand by 22 percent for the period 1971 to 1990. These sources also suggest that irrigation efficiency tended to improve at a rate of about 2 percent every 10 years. Since the analysis presented here focuses on the period from 1971 to 2001, applied water demand was assumed to exceed crop water demand by 21 percent on average for that period reflecting the observed trend of improving irrigation efficiency over time. Crop water demand was therefore adjusted upward by 21 percent to produce an estimate of applied water demand.

The per acre applied water demands calculated as described above were averaged and compared to the crop applied water guidelines published by Kern County in 1999.

Conversations with WRMWSD personnel suggested that these guidelines may over-estimate the required applied water volume for most crops within the District. For this reason calculated applied water demand results that exceeded the Kern County applied water demand guidelines for the same crop were not used. When no crop coefficient was available for a crop type, the Kern County applied water demand guideline was used. The applied water demand results were then multiplied by the appropriate cropped acreage for each crop type for each year from 1971 to 2001.

Once completed, the analysis described above produced a chronology of the total annual applied water volume within the WRMWSD for each year from 1971 until 2001. During that period, on average 238,098 AF of water was applied to all crops within the WRMWSD on an annual basis. The largest volume of water was applied in 1981 (301,992 AF), while the smallest volume was applied in 1971 (162,223 AF). The average acreage cropped each year within the WRMWSD was 88,021 acres. Cropped acreage gradually increased from 65,750 acres in 1971 to a peak of 107,889 acres in 1981. After 1981 cropped acreage fluctuated in response to climatic conditions, farm market conditions, and the availability of surface water deliveries from the SWP.

3.3.2. Estimates of Groundwater Extraction

To calculate the total volume of groundwater pumping needed to satisfy applied water demands, surface water delivery records for the study period were obtained from the District. District water deliveries are composed chiefly of surface water obtained from the SWP, but also contain water originating from banking projects and District back-up wells in addition to surface water obtained from sources other that the SWP. The volume of groundwater pumped within the District that supplements surface water deliveries was subtracted from the total volume of water deliveries to obtain the volume of water derived only from surface and non-local groundwater sources. This volume of delivered water was then subtracted from the total volume of applied water calculated for each year in order to estimate the annual volume of groundwater pumping within District boundaries. Again, domestic pumping was assumed to be negligible in the analysis.

The annual estimated volume of groundwater pumping computed for each year of the study period is presented in Figure 15. On average, approximately 61,461 AFY of groundwater pumping was calculated to have occurred on annual basis during the study period. The volume of pumping calculated for each year was found to vary proportionally with cropped acreage during years when surface water deliveries were near average for the period. In general, groundwater pumping provides about one-quarter of total applied water demand in the District as shown by the total water deliveries on Figure 16.

Pumping volumes spike during drought years when surface water delivery volumes are reduced below average (Figure 15). Reductions in cropped acreage during drought periods, primarily through the fallowing of high water demand crops such as cotton, helped to reduce the magnitude of these spikes. The highest level of groundwater pumping during the study period occurred in 1977 when 136,365 AFY of groundwater was pumped. This peak pumping volume is slightly more than twice the average volume pumped, and during this year groundwater pumping supplied slightly less than two-thirds of the total applied water demand. The smallest volume of groundwater pumping occurred in 1975 when only 10,669 AFY of groundwater was pumped.

Although groundwater production spiked in 1991 to more than 120,000 AFY to account for drought conditions and lack of sufficient imported surface water, many growers chose to fallow acreage that year, reducing the amount of groundwater pumping that would have been required. With the change in cropping patterns from field to more permanent crops, demand has hardened slightly and groundwater will become more important as a supplemental source during droughts in the future.

3.3.3. Estimated Locations of Groundwater Extraction

Since no records are available on the volumes of water pumped from the nearly 500 privately operated groundwater wells within District boundaries, there is little information available to indicate where pumping is occurring. In order to better evaluate the response of the groundwater basin to pumping volumes and plan for future District extractions, the location of groundwater pumping has been estimated. This estimate considers the District SWSA, distribution systems, crop water demand, and deliveries by parcel in 2001. Estimates are compared to water level contour maps for a check on basin response.

An analysis using the project GIS compared a parcel map of planted crop type for 2001 with water deliveries to each parcel containing a turnout from the District's distribution system. The per acre applied water volume values previously calculated were used to determine the water demand for each agricultural parcel based on the type of crop planted there. Where the delivered volume of water was less than the water demand for that parcel a shortfall was noted for that area. Sometimes the delivered volume is more than required for the parcel, and it is assumed that water will be conveyed to a nearby parcel for use.

As an additional analysis, parcels were subdivided into six zones reflecting distances from the aqueduct. Using GIS, zones were established in the following intervals: 0 to 0.25 mile from the aqueduct, 0.25 to 0.5 mile, 0.5 to 1 mile, 1 to 2 miles, 2 to 4 miles, and greater than 4 miles from the aqueduct. Parcels were ranked on the probability of pumping based on delivery shortfall and zone. The initial relative probability ranks established for each parcel based on its location in each zone were then adjusted to reflect the configuration of the District water supply network. Recognizing that not all of the water delivered to a parcel with a turnout is necessarily used at that parcel, the relative probability of pumping occurring at a parcel with a turnout was nonetheless considered to be less than at those parcels without turnouts. A final adjustment to the probability rank was made to reflect the type of crop planted on the parcel. All parcels which were listed as fallow or as containing native vegetation were removed from the ranking scheme.

The results of the pumping analyses were compared to the water level contour map prepared for water levels in 2000 (Figure 11). Areas where the probability of pumping was high correlated well to the pumping depressions indicated on the water level contour map. This analysis indicates that most of the pumping in the District occurs along the northern portions of the Wheeler West and Wheeler East Subareas. However, pumping is also indicated in local areas in the central portions of the District and in the White Wolf Subarea.

3.3.4. Water Sources and Future Demand

As previously discussed, most of the demand within the District is met by SWP deliveries diverted from the California Aqueduct with groundwater as a supplemental source. In addition to SWP and groundwater, the District has a variety of options for additional water sources through contracts with local groundwater banking programs. This section examines the reliability of surface water deliveries either from SWP or groundwater banking programs and compares the supply to future demands in the District.

Records detailing the annual volume of surface water delivery during the study period were provided by the District. In addition to SWP water and local groundwater pumped within the District, the supply furnished by the District consists of surface water and groundwater obtained through contracts with nearby water districts or other entities outside of District boundaries. Additional supplies include water stored in the Kern Water Bank and other banking projects. Within the SWSA, the District provides water supply via the distribution system illustrated on Figure 14. Water is delivered to the turnouts and diverted to each parcel owner's fields via privately owned pipelines or ditches, where it is then applied to crops. The volumes of District surface water deliveries from 1971 through 2001 are presented on Figure 16.

It is assumed for purposes of this analysis that all supplies available to the District are cost-equivalent. SWP Table A Amount, Article 21 water, recovered banked water and in-District groundwater are assumed to be equally available and able to be utilized to meet the demands of the District's growers without regard to varying cost.

To estimate future surface water deliveries required, future water demand was examined. The District's service area contains a mix of annual row crops along with permanent crops such as trees and vines. It is assumed for this GWMP that the acreage devoted to row crops for 2007 and beyond is 17,420 acres with an estimated ultimate applied water demand of approximately 40,000 AFY. Acreage of permanent crops is assumed to increase to 55,615 acres, with an estimated ultimate applied water demand of approximately 153,000 AFY (WRMWSD District Board Memorandum, January 2005). Total future applied water demands in the SWSA are thus estimated at approximately 193,000 AFY in normal to dry periods, with demand likely to be somewhat less during wet periods. This demand assumes that private groundwater pumping will continue outside of the SWSA.

In 1959, the District was formed to join the SWP as a Member Unit of the KCWA and to receive a surface water supply from northern California via the California Aqueduct. The District's authority to execute a water supply contract for State Water Project supplies and to construct a water distribution system was approved by the

District's landowners in 1967. For a wide variety of hydrologic, environmental, contractual and economic reasons, the year to year reliability of the SWP supply has been irregular. The need for local reliability programs is exemplified by the estimates of SWP delivery reliability discussed below.

3.3.4.1. State Water Project Water (SWP)

As a KCWA Member Unit, the District has an SWP entitlement through its contract with KCWA of 197,088 acre-feet (AF) per year. Based on the Department of Water Resources (DWR) SWP Delivery Reliability Report 2005, the SWP would deliver to KCWA an average of 77% of contract Table A Amount (formerly referred to as "entitlement") for the 2025 demand scenario (which assumes full demand from all SWP contractors). Thus the District can expect 77% of its contract amount of 197,088 AF in years with average hydrologic conditions.

The Reliability Report also assesses potential deliveries during critically dry and multiple dry year periods. In a single critically dry year, the SWP could deliver 5% of contract Table A Amounts, and during a four year dry period, could deliver 33% of contract Table A Amounts. Utilizing the District's estimated ultimate demands, Table 4 displays the District's SWP water supplies in various hydrologic year types:

Table 4
State Water Project Supply for Various Hydrologic Conditions

SWP Contract Table A Amount (197,088 AF)	Wet Year Allocation (100%) (AF)	Average Year Allocation (77%) (AF)	Multiple Dry Years Allocation (33%) (AF)	Critically Dry Year Allocation (5%) (AF)
Supply (AF)	197,088	151,758	65,039	9,584
In-District Demand (AF)	193,000*	193,000	193,000	193,000
Overage/(shortage) (AF)	4,088	(41,242)	(127,961)	(183,416)

* During wet years, in-District demand for SWP supplies can actually decrease to about 170,000 AF (R. Kunde, personal communication)

The District is also able to obtain access to SWP "Article 21" water when it is made available under certain hydrologic conditions. This water (defined in Article 21 of the water supply contracts, formerly called "Interruptible Water") is offered only periodically, usually in wet hydrologic year types, when excess flows are available in the Delta. It is described in the DWR State Water Project Delivery Reliability Report (2002, 2005) as a supply that can be used to augment reliability of SWP Table A Amount, if it can be delivered during the short time it is available to offset service area demands or to banking programs where it can be stored for later withdrawal during dry periods. Due to the short duration of its availability and capacity constraints at Edmonston Pumping Plant, Article 21 water is generally delivered most readily to agricultural contractors and San Joaquin Valley banking programs.

Article 21 water is not available in all year types and when available, is delivered only for limited periods of time, usually December through March (i.e., in wet months). For this reason, an SWP contractor must be able to utilize Article 21 water relatively quickly. The District is able to utilize Article 21 water either by delivering it directly for in-District use, or by delivering it to groundwater banking storage.

In May 2007, the U.S. District Court in Fresno ruled that the existing 2005 biological opinion for Delta smelt, issued by the U.S. Fish and Wildlife Service, did not comply with the federal Endangered Species Act. The biological opinion guides pumping operations for the Central Valley Project and State Water Project to ensure no long-term jeopardy to the health and habitat of Delta smelt. Until a revised biological opinion is prepared by the U.S. Fish and Wildlife Service, the Court on August 31, 2007 ordered certain interim "remedies" or actions to protect endangered fish species. These remedies collectively amount to cuts in statewide water supply for about one year (Calendar Year 2008).

DWR has analyzed the operational water allocation impacts of these interim remedies on 2008 SWP allocations. As of the date of this report, the worst case dry year scenario analysis for 2008 allocations is 27% of contract amounts; worst case normal year is 56% and worst case wet year is 62%. Best case wet year scenario is 71% of contract amounts, so at minimum there is a 29% loss of regulated water supply in a wet year. The remedies impose restrictions on Delta pumping during the wettest portions of the water year which, in addition to the above mentioned reduction of regulated water supply, limit access to Article 21 water and other peak flows. This reduces the ability of the SWP contractors to store such water in groundwater banking programs for later recovery during periods of shortage.

Allocations of regulated water to the District during 2008, based on its contract amount of 197,088 AF per year, during these interim conditions are as follows:

Table 5
State Water Project Supply Allocation for 2008

SWP Contract Table A Amount (197,088 AF)	Best Case Wet Year Allocation (71%)	Worst Case Wet Year Allocation (62%)	Average Year Allocation (56%)	Worst Case Dry Year Allocation (27%)
Supply (AF)	139,932	122,195	110,370	53,215
In-District Demand (AF)*	190,000	185,000	185,000	165,000
Overage/(shortage) (AF)	(50,068)	(62,805)	(74,630)	(111,785)

* Estimated 2008 in-District demand provided by District

In addition to loss of Contracted Table A Amounts, the impact of these pumping limitations to the District is loss of the flexibility to store what would have been wet year surplus water, such as Article 21 water, in District banking programs. Within the

District, these pumping limitations will initially result in increased groundwater pumping within the District, withdrawals from banking storage (based on the demands previously discussed), increased costs, and, if continued, loss of permanent crops, among other things.

While the court order is only expected to be in place for one year, these types of reductions may continue as part of the revised biological opinion and/or until the Delta system is improved. Long-term impacts to SWP supplies will be analyzed when the revised biological opinion is released to the public.

It is apparent from Tables 4 and 5 and the discussion above that SWP supplies alone are not capable of meeting all in-District demands under all conditions. However, in hydrologically wet years, the amount of water available has historically been more than what is required in-District (R. Kunde, personal communication). Due to these varying conditions, the District has entered into water banking programs to increase the reliability of its SWP supplies by "evening out" the water supply available in all year types to meet in-District demands. This is achieved by storing surplus water that may be available to the District, as described below.

3.3.4.2. Water Banking Programs and the District

Water agencies in Kern County are leaders in groundwater banking programs, which provide dry-year reliability through underground storage of surface supplies available during wet periods. The District has made major efforts to improve its SWP reliability by diversifying its water banking storage portfolio. The banking programs in which the District participates significantly improve its ability to meet in-District demands during dry periods. The District has been an active participant in the establishment and operation of such programs, and has stored water in the programs listed below.

3.3.4.3. Kern Water Bank

The Kern Water Bank was formally established in 1995 on 20,000 acres of property originally acquired by DWR. The Kern Water Bank Authority (a joint powers authority) owns and operates the bank. The District is a member of the Authority, and has a 24.03% share of the storage and recovery capacity of the water bank, with maximum annual recovery capacity of 57,600 AF. The District's current (December 2006) storage balance is 312,552 AF.

3.3.4.4. Pioneer Project

The KCWA Pioneer Project was established in 1998 on about 2,200 acres in southwest Bakersfield. KCWA has a priority right to up to 25% of project capacity, which it has not yet exercised. The remaining 75% of capacity is allocated among participants with recharge priority and those with recovery priority, based on percentage of participation. The District is a recovery priority participant, with 26% of the recovery priority, and a current maximum annual recovery capacity of 27,000 AF. The Pioneer Project Recovery Participants are planning to install three new wells in 2007. These new wells will add about 10,700 AFY of recovery capacity; the District's share would be about 2,800 AFY, of a total recovery capacity of 29,800 AFY. The current 27,000 AFY and additional 2,800 AFY assume that KCWA has not yet exercised its rights to its 25% share. For the purposes of this analysis, the after-2007 recovery capacities available to the District are utilized, for a total of 29,800 AFY (when KCWA exercises its rights, the District share will be 22,350 AFY). The District's current (December 2006) storage balance is 113,891 AF.

3.3.4.5. Berrenda Mesa

This is a joint project of Berrenda Mesa Water District and KCWA, initiated in 1999 on property owned by Berrenda Mesa. The District is a participant, with a 17.83% share in the program, and a maximum annual recovery capacity of 6,400 AF. The District's current (December 2006) storage balance is 10,519 AF.

3.3.5. Assessment of Future Groundwater Use in SWSA

Table 6 displays maximum annual recovery capacities (rounded as described in the District 2007 Supply/Demand Estimate, R. Kunde, personal communication), past withdrawals of record, and current storage balances for each banking program.

Table 6
Supplemental Supply from Banking Programs

Banking Program	Recovery Capacity (AFY)	Withdrawals (AF) (year)	Water in Storage Balance (AF)[1]	Number of Years Recovery Available[2]
Pioneer Project	29,800[3]	-13,749 (2001)	113,891	3.8
Berrenda Mesa	6,400	-1,400 (2001)	10,519	1.6
Kern Water Bank	57,600	- 16,656 (2001) - 400 (2002) - 1,497 (2004)	312,552	5.4
TOTAL	91,000		436,962	

[1] As of December 2006
[2] Total in storage divided by maximum annual recovery capacity
[3] Maximum withdrawal capacity; will be reduced after KCWA exercises capacity rights

The District would be able to access its water banking accounts to make up all or part of SWP shortages during average and dry periods, as shown in Table 6. As previously mentioned, for the purposes of this analysis, all water supplies are considered to be equivalent in cost, therefore the withdrawals from banked storage displayed are the maximum required to meet in-District demands in a given year type. Actual amounts withdrawn could be less, depending on the amount of groundwater pumped to meet a portion of that demand.

A summary comparison of the District's supply and demand for various hydrologic conditions is presented on the following table.

Table 7
Supply and Demand for Various Hydrologic Conditions in SWSA

Supply and Demand	Wet Year Allocation (100%) (AFY)	Average Year Allocation (77%) (AFY)	Multiple Dry Years Allocation (33%) (AFY)	Critically Dry Year Allocation (5%) (AFY)
SWP Contract Table A Amount	197,088	151,758	65,039	9,584
In-District Demand (SWSA)	193,000*	193,000	193,000	193,000
Overage/(shortage)	4,088	(41,242)	(127,961)	(183,416)
Pioneer Recovery Capacity		29,800	29,800	29,800
Berrenda Mesa Recovery Capacity		6,400	6,400	6,400
Kern Water Bank Recovery Capacity		57,600	57,600	57,600
Total Maximum Recovery Capacity		93,800	93,800	93,800
Shortage Not Met by Banking Recovery	NA	NA	(34,161)	(89,616)

* During wet years, in-District demand for SWP supplies can actually decrease to about 170,000 AF (R. Kunde, personal communication)

In wet hydrologic years, in-District demands can be met entirely with SWP supplies, and the surplus amount could be stored in one of the District's banking program accounts or at an in-District groundwater storage project. Under average year conditions, a portion of in-District demands would need to be met by pumping local groundwater or by withdrawals from banked storage, or a combination of both. However, the conditions in a single critically dry year and in multiple dry year periods, even with maximum withdrawals from banked storage, would require the use of local groundwater to meet all assumed in-District demands of 193,000 AFY. This need for local groundwater during such periods will be increased when KCWA exercises its right to recovery capacity from the Pioneer Project, reducing the District's recovery capacity from 29,800 AFY to approximately 22,350 AFY.

This analysis assumes that the demands of permanent crops are fixed, that is, acreage under permanent crops cannot be fallowed during such dry periods and thus cannot be assumed to be utilized to reduce water demand. However, the amount of banked water or groundwater demand could be reduced under these hydrologic conditions by fallowing of some portion of lands under row crops.

It is also assumed for this GWMP that the District has a great amount of flexibility in determining the priority of use of each supply source: SWP Table A Amount, Article 21 water, recovered banked water and in-District groundwater. The order in which these supplies are called upon by the District will depend upon their relative availability, relative cost, and in-District demand patterns throughout a given water year.

3.4. Land Subsidence

Land subsidence in the San Joaquin Valley has been well-documented and exceeds 28 feet in some areas of the basin (Lofgren, 1975). These occurrences of subsidence have been related to one of the following factors:

1. groundwater withdrawal
2. hydrocompaction (a one-time densification of soils when wetted)
3. extraction of oil and gas, and
4. oxidation of organic soils.

Although each of these subsidence types may be applicable in some areas of the Kern County Subbasin, organic soils subject to oxidation are not typically associated with known conditions inside District boundaries. As such, this type of subsidence has not investigated further for this GWMP.

Investigations on possible subsidence due to groundwater withdrawal or hydrocompaction within District lands have been conducted in connection with the construction of the California Aqueduct (BE, July 1967). At that time, groundwater levels had reached historical lows and engineers wanted to assess the possibility of subsidence creating damage to the Aqueduct. USGS published a study of land subsidence in the Kern County Subbasin south of Bakersfield, including the District service area (Lofgren, 1975). This investigation focused on the thickness and depth of clay layers subject to dewatering in the subsurface and the correlation of declining heads with geodetic leveling.

Subsidence of more than one-half foot interpreted by USGS to be related to groundwater extraction is shown on Figure 17 (Lofgren, 1975). Although the area of interpreted subsidence encompasses a large portion of the northeastern District, the magnitude of subsidence is relatively small. Within this area, subsidence ranged from 0.5 feet to more than four feet (Figure 17). Subsidence greater than one foot was limited to the eastern portion of the Wheeler West and Wheeler East subareas. Subsidence of greater than four feet was limited to a small area about three miles north of Wheeler Ridge (Figure 17). An increase in subsidence magnitude (up to six feet) was indicated by cumulative maps from 1936 to 1975, but data were judged to be less reliable (Lofgren, 1975). All measurements were subject to correction from tectonic activity, which included both downwarping and uplift associated with active faults and folds, including movement along the White Wolf fault and uplift along Wheeler Ridge.

Although these data are more than 30 years old, subsidence has likely been halted since these measurements. Water levels reached their record low in the early to mid 1970s prior to importation of surface water. The availability of SWP water resulted in decreased pumping and increased recharge, raising water levels. As long as water levels (including head in deeper aquifers) remain higher than the 1970s levels, subsidence due to groundwater withdrawals is not expected to worsen.

Hydrocompaction is a more surficial type of subsidence in that compaction occurs in the shallow soil layers rather than in relatively deep clay layers associated with groundwater withdrawal. The process is physical realignment of soil particles into a more compact orientation after certain types of unsaturated soils are wetted. Hydrocompaction is viewed generally as a one-time event and once compacted, soils are not subject to further significant subsidence. Soils subject to hydrocompaction have been mapped in three areas of the District by USGS (Lofgren, 1975) and are shown on Figure 17.

The occurrence of subsidence at oil and gas fields in Kern County has been noted by numerous investigators, although the magnitude of this type of subsidence is thought to be relatively small (Kern County, June 15, 2004). USGS reports a total subsidence of less than one-half foot in the four oil and gas fields in the County over several decades (between 10 and 30 years) (Lofgren, 1975). Most of the oil fields in Kern County that have been correlated to subsidence occur outside of the District boundaries. One measurement in a field within the District, North Tejon Field (east of Wheeler Ridge), indicated subsidence of approximately 0.3 feet from 1953 to 1965. Because hydrocarbon production and re-pressurizing of fields are regulated by others and because the impacts are assumed to be relatively small in magnitude, subsidence associated with oil and gas extraction was not investigated further in this GWMP.

4. Monitoring Program and Protocols

Nine state and local agencies have active monitoring programs within the Kern County Subbasin (DWR, January 20, 2006). Four agencies, including the District, DWR, KCWA, and Arvin-Edison WSD conduct groundwater monitoring within the District boundaries. The District coordinates their activities with other agencies, although some wells are included in more than one monitoring program. KCWA compiles and maps water levels from more than 1,400 wells throughout the area, but mapping does not cover the entire District area (KCWA, 2003). General activities for programs conducted within the District boundaries are described below.

4.1. Water Level Monitoring

Water level monitoring has been conducted in the District since the 1950s. USGS generated early water level contour maps for 1958 and the District has continued these efforts. Water levels are generally available for all subareas of the District from 1958 to 2006.

4.1.1. District Water Level Monitoring Program

The District monitors water levels in approximately 100 wells twice annually. Most of the monitored wells are agricultural wells that are out of service or inactive during the monitoring period. Although an effort is made to keep wells in the program on a long-term basis, the list of monitored wells is continually being revised based on well access and recent water level data. Locations of wells that have been used to monitor water levels are shown on Figure 18.

Monitoring typically occurs in February and October when water levels are nearing the annual maximum and minimum levels. The monitoring frequency has recently been increased; prior to 2005, water levels were only measured once per year.

Water levels are recorded using one of four different measuring devices, including an electric sounder, a plunker, airline, or acoustic sounder. The appropriate monitoring device is selected based on well construction and access.

The District maintains these data in a water level database in Access format. Data have been collected for 517 individual wells; however the number of measurements varies from one to 58 records. The earliest water level data date back to 1950. Data from the 1950s and 1960s are relatively sparse with 93 percent of all data collected after 1970. Approximately 23 percent of all water level data were collected in the last decade, with a similar portion of data collected in each of the three and a half previous decades. Since 2000, 221 individual wells have been monitored resulting in 478 water level measurements. The longest record for a single well extends from 1950 to 2003, but consists of only 16 individual water level measurements. Most of the wells in the program contain about 25 measurements over a 20 year period.

4.1.2. DWR Water Level Monitoring

In addition to water level monitoring conducted by the District, DWR monitors water levels in an additional 64 wells within District boundaries. Collection of data at these wells began as early as 1960. Water level measurements are generally collected on a quarterly basis. Although there is some variability in the period and frequency of these records, water levels for most of these well are generally available after about 1975. As part of this GWMP, available data have been downloaded from the DWR website and incorporated into the District's water level database.

4.1.3. Additional Water Level Monitoring

KCWA conducts a large-scale monitoring program that includes more than 1,000 wells, including several wells within District boundaries. Data from these wells are incorporated into KCWA mapping and assessment of subbasin-wide water levels provided in their water supply reports (KCWA, 2003). Arvin-Edison WSD measures water levels from an additional 35 wells on lands located within District boundaries.

4.2. Water Quality Monitoring

Water quality data that document variability across the District and changes over time are essential to effective groundwater basin management. As such, water quality monitoring is an integral component to the District's monitoring program. Numerous other agencies also conduct water quality monitoring adjacent to or within the District. These programs are summarized briefly below.

4.2.1. District Water Quality Monitoring Program

The District conducts water quality monitoring in key wells across their service area. Currently 14 active agriculture wells are included in the program with several alternate locations in the event that a program well cannot be sampled. These wells are highlighted on Figure 18. Water samples are collected from these wells in June or July of each year and analyzed for general minerals, boron, SAR and Langlier indices, a program designed to evaluate the suitability of water quality for irrigation.

The District maintains these data in an Access database. In addition to data from their ongoing monitoring program, the District has also compiled and entered historical water quality data into their database. These data generally date back to the 1960s but contain data from one well sampled in 1910 and five wells sampled in the 1950s. Remaining data are from 1960 through 2006. The District database contains more than 12,000 analyses in samples from 406 wells.

Included in the database are 133 different water quality parameters including metals, volatile organic compounds (VOC) and fuel oxygenates, major and minor anions and cations, total hardness, conductivity, total alkalinity, pH and TDS. Although some data are available for more than 400 wells, the number of constituents analyzed varies from well to well. Many of the wells in the database contain at least one complete analysis for the major anions and cations, with the exception of potassium, which is absent from many of the cation analyses. Almost all of the 406 wells have at least one value for TDS, total hardness, and pH. Analyses for VOCs and other organic contaminants are available for 29 wells with data dating back to 1991.

4.2.2. Water Quality Standards for User Input Program

The District has considered water quality requirements for groundwater wells involved in the District's User Input Program, whereby groundwater can be pumped into the District conveyance system and delivered to customers. Standards for the User Input Program are based on accepted irrigation standards for Class I water as previously described. Wells that produce directly to the District distribution system are tested for irrigation water analyses each year that they operate under the User Input Program. Wells that discharge to the California Aqueduct are tested for Title 22 constituents prior to operation. Moreover, wells pumping into the aqueduct may be re-sampled as requested by a water quality working group composed of DWR staff and State Water Contractor representatives.

4.2.3. Water Quality Monitoring by Other Agencies

Other agencies monitor water quality with and adjacent to the District. Arvin-Edison WSD, whose boundaries overlap District boundaries, monitors water quality in 25 representative Arvin-Edison WSD wells, 31 target landowner wells, and 23 alternative landowner wells on an annual basis with a comprehensive water quality survey conducted every five years. An irrigation water analysis is performed for each groundwater sample (Provost & Pritchard, June 2003). Arvin-Edison WSD also monitors groundwater quality from wells used to supply water for the aqueduct as well as water quality in surface conveyance systems serving their district.

KCWA has a comprehensive water quality monitoring program and has compiled historical water quality data throughout the Subbasin, including wells in the District (Iger, May 11, 2006; KCWA, 1999). They also coordinate and assist other local agencies with data collection and analysis.

4.2.4. GAMA Monitoring near Bakersfield

In connection with the State's Groundwater Ambient Monitoring and Assessment (GAMA) program, Lawrence Livermore National Laboratory (LLNL) and the State Water Resources Control Board (SWRCB) conducted a contamination vulnerability assessment for the Bakersfield area (LLNL, November 2004). The study area includes a small portion of the District's service area on the north, although no wells within about five miles of the District boundary were included in the assessment. Samples from 43 active drinking water supply wells in and around Bakersfield were analyzed. Results from these analyses indicated that approximately 75 percent of the wells detected one or more of the VOCs analyzed, although concentrations were generally low. These impacts are likely associated with the more commercially- and industrially-developed areas around Bakersfield compared to the agricultural lands of the District. Wells closest to the District boundaries were not impacted. However, sampling results emphasize the vulnerability of the aquifer to potential water quality impacts from surficial sources and the need to include a variety of constituents in the water quality monitoring program.

Additional sampling in the area is planned for the continuation of the GAMA program in Kern County. USGS has already collected water samples in the subbasin and will be conducting analyses for pharmaceuticals and organic compounds. Data results are expected in early 2007.

4.3. Surface Water Monitoring

Although recharge from most of the ephemeral streams that flow into the District is relatively small, runoff from creeks flowing into the White Wolf Subarea is significant. Surface water runoff that recharges groundwater in the White Wolf Subarea has been estimated to average 7,000 AFY (BE, 1975). In addition, surface water in this area is used to supplement water deliveries by the District. As such, surface water monitoring is considered for the District's monitoring program.

Surface water runoff in the Tunis Creek and Pastoria Creek watersheds is known to contain good water quality from historical sampling and no significant changes in land use. Accordingly, runoff that is accepted for District delivery is tested in the field for pH, temperature, and EC only.

Streamflow is difficult to measure with stream gages in this area due to the ephemeral nature of the streams and high stage flow events. Although substantial streamflow data exist for the Kern River (the main drainageway in the subbasin), only limited data are available for the creeks on the south and west side. USGS has measured streamflow at two stations in the study area: San Emigdio Creek (USGS Site No. 11195500) and Pastoria Creek (USGS Site No. 11195600). Data for San Emigdio Creek spans a variety of hydrologic conditions from 1959 through 1981. Measurements on Pastoria Creek are available from 1964 through 1971.

Because the water quality in the groundwater basin is controlled in part by surface water runoff from recharge zones west, south, and southeast of the District, changes in land use including development and other activities in these upland areas may merit monitoring by the District. Although current development in these foothills is sparse, the District could consider policies to protect the recharge zone. For example, the District could work with county land use planners to mitigate commercial or industrial activities that generate runoff containing pollutants in the recharge areas.

4.4. Imported Water Monitoring

The amount of imported water from the SWP is monitored when diverted into the District conveyance system. The District also tracks the amount of water from other sources contributing to the surface water deliveries to District customers.

4.5. Land Subsidence Monitoring

Given the water level rise over the last three decades and the relative absence of major buildings and structures over the area, the risk of problems in the District from land subsidence seems low. As long as water levels are operated above the historic lows that occurred in the early to mid-1970s, additional subsidence due to groundwater withdrawal is not expected. If groundwater production increases within District boundaries or if the groundwater basin is operated over a wide range of water levels in the future, subsidence monitoring should be considered. Areas of groundwater banking projects in Kern County, in particular, have conducted land subsidence monitoring. For example, DWR has installed a network of extensometers at the Kern Water Bank and extensometers have been monitored at the Semitropic Water Storage Bank.

Monitoring ground subsidence in this area is problematic due to the changing ground surface elevations due to tectonic activity that is ongoing today in the area as evidenced by changing bench mark elevations and earthquake activity. Even with the superior technologic advances that have been developed over the last few years, selecting a reliable reference point is difficult (D'Onofrio, May 11, 2006). The District should investigate and coordinate with other subsidence monitoring activities ongoing in the County by USGS, DWR, and others.

4.6. Climatic Monitoring

There are six climate stations within District boundaries where monthly rainfall and evaporation are measured, including a CIMIS station. In addition, data are also compiled and tabulated by KCWA for 40 stations including those maintained by DWR, Kern County Planning Department, Arvin-Edison WSD, Tehachapi-Cummings County Water District, the National Weather Service, and others (KCWA, 2003).

4.7. Coordination with Other Programs

Due to the overlapping nature of District boundaries with Arvin-Edison WSD boundaries, any management activities would necessarily impact groundwater beneath the adjacent District. Surface water deliveries to the overlapping areas are provided to Arvin-Edison WSD. As such, a data exchange and cooperative monitoring program with Arvin-Edison WSD may be beneficial to both agencies. The coordination should consider data transfers and possible agreements with laboratories to provide data in a mutually acceptable electronic format.

KCWA also conducts comprehensive groundwater monitoring throughout the area (KCWA, 1999). This monitoring program generates some data in and around the northern District boundary that would be beneficial for continuing District analysis of the groundwater basin. As such, opportunities for increased data sharing may exist. Additional agencies adjacent to the District either coordinate monitoring with KCWA or monitor wells too far away from the District operations to provide significant benefits (West Kern Water District, 1997; Kern Delta Water District, 1996).

5. Basin Management Objectives

As part of the GWMP development, Basin Management Objectives (BMOs) have been established for the benefit of the groundwater basin. These objectives are a key component of an AB 3030 plan and guide future management actions. Applicable BMOs for this GWMP are listed below:

- Prevent a return to historical overdraft conditions preliminarily defined as:
    - chronic water level declines
    - levels below historical lows that may exacerbate subsidence
- Maintain groundwater quality throughout the District
- Monitor water levels, water quality, and groundwater storage
- Estimate groundwater use and future groundwater demands on the basin

BMOs are qualitative for this first GWMP in the District. As management actions proposed in this plan are accomplished, the District can assign more quantitative values to several of the BMOs above. Each of these BMOs is briefly described below.

5.1. Prevent a Return to Historical Overdraft

Since the importation of SWP water into the District in 1971 (1975 for the White Wolf Subarea), overdraft conditions have been reversed and water levels have risen. Although water levels in most areas of the District are continuing to rise, levels in some areas have stabilized. Currently water levels are at a 35-year high and appear to have recovered to equivalent levels recorded in the early 1950s for most areas in the District.

In order to establish an acceptable range of water levels in the basin, the District will evaluate the perennial yield of the plan area and potential operational parameters as part of their groundwater development program. For example, the District might consider such factors as pumping lift costs in the basin, decreasing well yields, and other limiting factors to develop threshold values of minimum acceptable water levels and management actions required to maintain those levels. At a minimum, the historical lows in the basin during the late 1960s and early 1970s are to be avoided. Preventing the historical overdraft conditions will provide a sustainable supply of groundwater to support uses in the plan area.

5.2. Maintain Groundwater Quality

Although data are limited, there is no indication of groundwater degradation in the basin over time. Current conjunctive use practices of using groundwater as a supplemental supply depend on maintaining acceptable water quality at wells where water is pumped into the delivery system. The District has evaluated water quality requirements for these wells based on Class I irrigation water quality standards. Although groundwater meeting Class II irrigation water may be used in an emergency, Class I water is preferred. As such, a BMO of this plan is to maintain the equivalent of Class I water quality in areas that currently meet these standards. Achieving this objective will support conjunctive management already in progress, thereby increasing the reliability of the supply.

5.3. Monitor Water Levels, Water Quality, and Groundwater Storage

The District's current monitoring program and protocols are provided in Section 4 of this GWMP. As the District implements management actions contained in this plan, the monitoring program will be re-evaluated and updated to better coordinate with other agency monitoring and to provide the data necessary to support management decisions in the basin. This evaluation will consider:

- network
- frequency
- equipment
- parameters
- annual reporting
- quality assurance/quality control

The program will also provide monitoring for management actions and progress on BMOs. The data provide the understanding of the response of the groundwater basin to changing conditions, which is required for sustainable use as a long-term supply.

5.4. Estimate Groundwater Use and Future Groundwater Demands

The first step has been taken toward achieving this BMO through the contents of this GWMP. The basin assessment in this GWMP estimates historical groundwater use in the basin from 1971 through 2001. The future role of groundwater within the SWSA has been evaluated by assessing the reliability of all water sources available to the District. This analysis indicated that while participation by the District in banking programs has increased the reliability of the overall water supply, the District will continue to operate its water wells if required to help meet contract water demands within the SWSA.

5.5. Update the Progress on Achieving BMOs

Progress in fulfilling BMOs should be monitored and updated, especially as more details and criteria are defined for ongoing management of the groundwater basin. Several management actions in this GWMP will assist the District in developing more quantitative BMOs for the future.

6. Management Actions

6.1. AB3030 Checklist

AB 3030 provides a list of components to consider for possible inclusion into a GWMP. These components can serve as a checklist for ensuring that a GWMP considers a wide variety of management actions to meet BMOs. Pursuant to California Water Code Section 10753.7, a GWMP may include actions relating to any or all of the following conditions:

- Mitigation of conditions of overdraft
- Replenishment of groundwater extracted by water producers
- Facilitation of conjunctive use operations
- Identification of well construction policies
- Administration of a well abandonment and well destruction program
- Development of relationships with state and federal regulatory agencies
- Control of saline water intrusion
- Regulation of the migration of contaminated groundwater.
- Construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.
- Identification and management of wellhead protection areas and recharge areas.
- The review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.
- Monitoring of groundwater levels and storage

An additional item that may be considered in a GWMP is the potential impact to streams from management actions. However, since streams in the study area are ephemeral, management actions are not anticipated to impact surface water drainages.

The items in the above list, reproduced from the Water Code, have been re-ordered and grouped below to facilitate discussion of similar conditions and issues. Related issues and their appropriateness for management actions by the District are discussed briefly below. Ongoing management activities by the District are also discussed.

6.1.1. Overdraft, Replenishment, and Conjunctive Use

With importation of SWP water, the groundwater basin has recovered significantly from historical overdraft conditions. The District is committed to continued basin recovery and prevention of overdraft. To reach this goal, the District has several ongoing programs to allow imported surface water, banked water, local surface water, and local groundwater to be used conjunctively.

Since 1990, the District has obtained additional surface water by purchasing water from various sources outside of its SWP Table A entitlement, when economic and available, and by participating in various water exchanges. It has also increased the dry year reliability of its water supply by storing imported water in banking projects such as the Kern Water Bank, the Pioneer Project, and the Berrenda Mesa Project. These measures directly support BMOs by minimizing local groundwater production within the SWSA and maximizing return flows. With an increase in the number of water supply sources, over-reliance on any one source, including groundwater is mitigated.

The imported supply is used primarily for irrigation within the District and, as such, represents a significant component of recharge to the groundwater basin. Historically, irrigation efficiencies in the basin have ranged between 70 and 80 percent, allowing the remaining applied water to percolate to groundwater. Even though efficiencies have been improved in many areas, the imported water remains an important supply to the groundwater basin.

The District operates 17 wells in the White Wolf Subarea (13 wells) and Wheeler West Subarea (4 wells) to augment surface water supply during drought years (Figure 18). Since at least the early 1990s, the District has permitted the delivery of local groundwater to their distribution system in years of limited imported supplies. Historically, these volumes have been relatively small compared to the overall amount of water delivered. The District has supplied groundwater to the system in four of the last 14 years with amounts ranging from about 2,705 AFY up to 6,507 AFY (2001).

Because the wells are run infrequently, maintenance is an issue for the District. During well performance testing in 2000, some form of maintenance was required on most wells before they could be pumped. At that time, two of the wells were inactive pending repairs and redevelopment before they could be put back into service. Although six of the wells were installed in 1992, remaining wells were drilled in the 1950s and 1960s. However, many of the older wells continue to perform well and have retained 80 to 100 percent of the original specific capacity. Specific capacities during the well tests ranged from 5 gallons per minute per foot of drawdown (gpm/ft dd) to 59 gpm/ft dd with most specific capacities over 30 gpm/ft dd. Most of the wells are pumped between 1,000 gpm and 2,000 gpm.

The District's conjunctive use program also allows private well owners to augment the water supply by feeding groundwater into the surface water conveyance system under certain conditions as determined by the District Board of Directors. This User Input Program allows groundwater and runoff from local surface water sources to be put into the delivery system to supplement imported water supply. By increasing the number of sources and amount of water available, the supply is made more reliable.

The District recently completed a pilot project in the White Wolf Subarea for a groundwater storage and recovery program (BE, April 27, 2006). The project involved hydrogeologic investigations, monitoring and production well installation and testing, infiltration testing, and groundwater modeling. Although the program was originally scoped for a project near Pastoria Creek, the project was moved to the vicinity of Grapevine Creek to allow direct recharge through spreading basins and avoidance of confining layers at the initial location. Alternative operational parameters were evaluated with a groundwater model including recharge volumes of 25,000 AFY and 50,000 AFY for three years, a four-year resting period, and a three-year extraction period from recovery wells. Results from the pilot project concluded that such a recharge and recovery project in the vicinity of the District's 850 Canal near Grapevine Creek is technically feasible and recommended additional evaluation. The District is currently evaluating the economics and next steps for this project.

6.1.2. Well Construction and Relationship with Other Agencies

The District has an interest in ensuring that wells are properly designed and maintained within District boundaries. Improperly designed or abandoned wells can function as conduits for contamination of aquifers. In addition, knowledge of well locations and construction allows for a better understanding of the groundwater system and supports management decisions.

Well construction standards are provided in the Kern County Code, Chapter 14.08 (Kern County, 2002). Drilling contractors must be registered with the County. A permit is required for well construction, rehabilitation, or abandonment. Work must commence under the permit within 90 days of its issuance. Within 30 days of completion of the work, a report must be filed with the County. This report is usually a copy of the Water Well Driller's Report that is required by California Water Code Section 13751 and provided to DWR. Well construction standards mirror the Water Well Standards published by DWR (1991) and provide requirements on siting, construction methods, materials, annular seals, development, disinfection, and testing. Wells without an operable pump that have not been used for one year are defined as "out of service". These wells must either be sealed at the surface and registered as "out of service" wells subject to periodic inspection or destroyed in accordance with County Code. Construction standards, especially well seals, are also monitored by KCWA.

These requirements seem sufficient to support BMOs, and additional well ordinances within the District do not appear necessary at this time. However, better coordination with the County is recommended to maintain an accurate well inventory and allow for a better understanding of well activity within the District. The District will continue to coordinate with the County to ensure that proper well procedures are followed.

6.1.3. Groundwater Quality and Wellhead/Recharge Zone Protection

The District lies at the upgradient extent of the aquifers in each of the District subareas. Surface water runoff from the San Emigdio Mountains, the southern portion of the Temblor Range, and the southern extent of the Tehachapi Mountains has the potential to impact groundwater beneath the District. Development in the recharge zone is sparse currently, but should be monitored for potential impacts to water quality.

The District has evaluated water quality standards for groundwater wells that may provide water into the District's delivery system. Water quality requirements are based on accepted irrigation water quality standards and ensure that the delivery water will not be injurious to crops.

Water from any source placed in the delivery system has the potential to recharge groundwater, either through managed recharge projects or through irrigation return flows. Because the groundwater system no longer flows naturally out of the District, salts associated with imported water represent a loading to the groundwater basin. Although no long-term degradation has been indicated in the water quality assessment, the District will consider practices and policies to prevent human-related degradation from occurring, such as actions relating to pesticide or salt management.

6.1.4. Monitoring Groundwater Levels and Storage

The District has maintained a comprehensive water level, water quality, and imported water monitoring program. Details on monitoring locations and protocol are discussed in detail in Section 4 of this GWMP. Numerous other agencies also conduct monitoring in and adjacent to District boundaries. Highlights of these programs are also provided in Section 4. There may be opportunities to better coordinate monitoring activities with other agencies or arrange for data sharing. In addition, the current monitoring program may require modification to better support BMOs for the basin.

6.2. Recommended Management Actions

In consideration of the BMOs and the ongoing groundwater management activities, the District is recommending the following actions for the GWMP. Recommended actions are summarized in the list and discussed in more detail below.

- Optimize the integration of the District’s water sources
- Secure additional water sources, as necessary to supplement current supplies
- Prepare a Groundwater Development Program
  - Evaluate perennial yield of the subareas
  - Implement a Well Maintenance Program for District wells
  - Determine the need for additional wells
  - Operate the basin to support BMOs
- Improve coordination with Kern County well ordinances
  - Obtain copies of permits from County for new wells drilled in the District
  - Coordinate well abandonment activities in the District with the County
- Continue and improve groundwater monitoring program
- Coordinate monitoring activities with other agencies
- Report progress on the GWMP annually and update the GWMP periodically
- Prepare an Integrated Water Resources Plan

6.2.1. Optimize the Integration of the District’s Water Sources

The assessment conducted in Section 3 of this GWMP is the first step in the integration process. Contracts with SWP and other banking projects in the County have significantly increased the reliability of the District’s supply. However, during prolonged droughts and critically dry years, local groundwater will be needed to supplement supply. Optimization of these sources, including when and how much of each supply to use under what conditions, will increase the certainty of a cost efficient water supply for basin users into the future. Importantly, this optimization will support the BMOs in ensuring that the groundwater basin does not return to sustained overdraft conditions.

6.2.2. Secure Additional Water Sources as Needed

Beginning in the 1990s, the District secured water supplies from a number of sources in addition to its State contract water supply, most of which was banked in its banking projects, decreasing reliance on the groundwater basin in times of shortage. The District will continue to bank SWP supplies (including Article 21 water), when available, as well as other cost effective supplies (such as high flows on the Kern River) to the extent that banking capacities are available. The District will continue to evaluate available supplies relative to demands and take measures to secure additional supplies for its customer, the contract water users, as necessary.

6.2.3. Prepare a Groundwater Development Program

To ensure proper, long-term management of groundwater and the efficient use of groundwater wells, it is recommended that the District prepare a Groundwater Development Program. This program directly supports BMOs in evaluating perennial yield and operational levels in the plan area.

6.2.3.1. Evaluate Range of Operating Water Levels

A groundwater development program fits well into the integration of the District's water sources. Recognizing the amount of water available from all sources and developing a plan for conditions under which each source is used is the backbone of the District's operations and effective groundwater management. Components of a groundwater development program include an analysis of potential operating water levels in the underlying groundwater basin supported by an ongoing assessment of perennial yield.

The perennial yield of a groundwater basin is the amount of water that can be pumped as a long-term average without adverse impacts in the basin. Because the definition of adverse impacts is different from one area to another and may change over time, perennial yield is expected to be re-assessed over time based on the ongoing collection of groundwater data. In the assessment of the groundwater basin prepared for this GWMP, pumping and changes in water levels over an approximate 35 year period were examined. Water levels rose on a District-wide basis, even in areas of known groundwater pumping, with an average pumping of about 61,000 AFY. Therefore, under the conditions of the last 35 years, a perennial yield of 61,000 AFY could likely be sustained on an average basis.

During 1991 when pumping increased to more than 120,000 AFY, water levels were observed to decline on almost all of the hydrographs with sufficient water level data. The recovery continued over the next four years when pumping returned to 60,000 AFY to 80,000 AFY. These data indicate that pumping 120,000 AFY may cause adverse water level declines if continued on a sustained basis. However, pumping at this level for several years during drought conditions does not appear to have adversely impacted the basin. These data qualitatively bracket an average sustainable perennial yield for the

District between 60,000 AFY and 120,000 AFY under current conditions. The return flows from imported water sources should not be discounted as an important contributor to the continued recovery of basin water levels. If less imported water or less return flow is available on a continuing basis, the effect on perennial yield would need to be considered.

The perennial yield analysis will assist in defining a range of acceptable water levels in the subbasin. For the purposes of this initial GWMP, the BMO for water levels is qualitative, but will need to be better defined for the future operation of the basin. One example may be the desire to keep water levels within the range of water levels in the 1950s prior to the dramatic declines in the 1960s. Hydrographs indicate that current water levels in the basin are either at or are approaching levels from the early 1950s in most subareas.

6.2.3.2. Implement a Well Maintenance Program

For the District’s existing wells, a well maintenance program should be instituted to ensure long-term well performance. The most prevalent problems for wells in alluvial aquifers include physical plugging of the formation in and around the screen, iron precipitation, biologic fouling, and corrosion/casing failure (Driscoll, 1986). Proper well design is the best preventive maintenance for well failures including the planning for long term drawdown when perforated intervals are selected. Wells that are allowed to deteriorate over time may permanently lose a large percentage of the original specific capacity, even when the best rehabilitation techniques are employed.

The maintenance program should contain a schedule for pumping existing wells at least two to three times each year. During pumping, water levels should be monitored to determine the current specific capacity, which in turn is compared to past estimates of specific capacity. Declining specific capacity reflects a loss of overall efficiency and usually results in an increase in pumping lifts and energy costs. Although a general decrease in specific capacity over time is anticipated, a significant decrease may warrant re-development or other well maintenance activities. The pumping schedule should also allow for re-development techniques to occur at some frequency (e.g., every five years).

The maintenance of the well pump should also be a part of the maintenance program. The operation of the pump should be checked against its original design curve. The pump and wellhead should be checked for possible changes in noise, heat, vibration, or oil consumption and whether there has been cracking or uneven settlement around the pad.

Well diagrams should be maintained for each well showing geology, well construction, pump placement, typical static and pumping water levels, wellhead equipment, and other pertinent well information. Record keeping of well maintenance activities including updates of well diagrams should also be part of the program.

6.2.3.3. Determine the Need for Additional Wells

As the groundwater development program is implemented, the use of wells in other portions of the basin away from pumping centers should be considered. This need could be met through the drilling and construction of new wells or through the use of inactive existing wells. Advantages for new District-owned wells include the ability to design a long-term high performance well to meet District needs. However, if existing wells are available with sufficient design criteria and relatively high specific capacities, a significant cost savings could be achieved, especially if the well is to be used infrequently. As part of the Groundwater Development Program, the District should explore the potential use of private wells, evaluating new well locations or candidate existing wells with regard to location relative to current pumping, well performance, and groundwater quality.

6.2.4. Improve Coordination with Kern County Well Ordinances

Kern County Code Chapter 14.08 contains requirements for construction, rehabilitating, deepening, or destroying a well in the County (Kern County, 2002). As required in the Code, the Kern County Environmental Health Services Department issues agricultural and domestic water well permits documenting these activities in the County. Tracking the location and number of new wells in District boundaries would allow the District to better anticipate changes in the groundwater system. As part of the GWMP, the District will coordinate with the County to determine a reasonable procedure for providing well data to the District. Discussions will allow the District to better understand the County's current permitting procedures and file management and to identify a cost effective method of timely data transfer.

6.2.5. Continue and Improve Groundwater Monitoring

District monitoring activities are summarized in Section 4 of this GWMP. These data are important in understanding changes in the groundwater basin and supporting management decisions. The District intends to continue the program. In addition, the District should develop written objectives for the program, closely tied to BMOs, and optimize monitoring locations, frequency, constituents, and protocol to meet those objectives. Specifically, the District should consider adding additional sampling points to its Key Well water quality program and expanding the range of constituents tested to help determine whether pumping patterns have led to the migration of poor quality water toward known persistent pumping depressions.

6.2.6. Coordinate Monitoring Activities with Other Agencies

Monitoring programs conducted by adjacent water districts, KCWA, DWR, and others are summarized in Section 4. The District is already aware of the programs and participates in data sharing with other agencies. As the District formalizes its monitoring programs to support BMOs, there may be opportunities to optimize monitoring by increasing coordination with other programs.

6.2.7. Report the Progress of the GWMP Annually and Update the GWMP Periodically

As District objectives and management actions evolve, progress on the GWMP activities should be recorded. It is recommended that the District prepare a progress report on the GWMP on an annual basis. By preparing an annual report, stakeholders are kept informed on how the basin is being managed and key groundwater data are updated. The update would record current groundwater conditions and any operational changes that have been made with respect to groundwater management. The annual progress reports can be brief and streamlined, providing details on special studies, as necessary, similar to existing District practices.

The GWMP should be updated periodically to reflect changes in proposed management activities. The plan update would consider appropriate modifications to BMOs, management actions, and the basin monitoring program. The District is proposing an update every five years, building on the groundwater data developed in Annual Progress Reports.

DWR recommendations for the contents of annual reports and/or plan updates are provided in Appendix C and summarized below:

(a) monitoring results including historical trends
(b) management actions accomplished during the reporting period
(c) progress of achieving BMOs and suggestions for modification, if any
(d) proposed management actions for the future
(e) coordination with other water management and land use agencies

7. Implementation Plan and Schedule

The GWMP provides a roadmap for managing the local groundwater resource and achieving BMOs. Because this is the District's first GWMP, there are several data gaps to fill before moving from qualitative to quantitative BMOs. That process is supported by the recommended management actions contained in this plan. The GWMP should be viewed as an active document to be revised and updated as management actions require revision. It is recommended that the GWMP be updated annually. Details on plan implementation are provided in the following sections.

7.1. Steps for Implementation

The steps required for implementing each of the management actions recommended above are outlined below. The steps provide a guideline for District activities, but may be revised as management actions are implemented.

7.1.1. Optimize the Integration of the District's Water Sources

1. Review the analysis and assumptions provided in Section 3 of this GWMP.
2. Determine cost of recovery for each banking contract and evaluate uncertainty associated with each source.
3. Identify certain conditions for which each supply can best be used and establish a priority of use for each source.
4. Evaluate the integration of local groundwater as a water source along with the results of perennial yield calculations from the Groundwater Development Program as outlined below.

7.1.2. Secure Additional Water Sources

1. Assess the need for additional supplies from the analysis above.
2. Identify potential water sources, evaluating the likelihood for meeting District objectives and costs.
3. Secure additional supplies as needed.

7.1.3. Prepare a Groundwater Development Program

1. Evaluate a range of operating water levels and perennial yield in District areas of the subbasin.
2. Implement a Well Maintenance Program for District wells.
3. Determine the need for additional wells.
4. Operate the basin to support BMOs.

7.1.4. Improve Coordination with Kern County Well Ordinances

1. Work with Kern County officials to establish an ongoing procedure for getting copies of permits for new wells drilled in the District.
2. Generate a well inventory for wells in the District.
3. Coordinate well abandonment activities in the District with the County.

7.1.5. Continue and Improve Groundwater Monitoring Programs

1. Prepare a written monitoring plan with objectives that support BMOs.
2. Identify monitoring locations and alternates for water level and water quality monitoring programs in the plan.
3. Document monitoring frequency, protocols, constituents to be analyzed, and QA/QC measures.

7.1.6. Coordinate Monitoring Activities with Other Agencies

1. Provide the monitoring plan to adjacent agencies including Arvin Edison WSD, Kern Delta Water District, West Kern Water District, and KCWA.
2. Obtain details on the agencies monitoring plans.
3. Review plans for duplication or efficiencies for coordinated efforts.

7.1.7. Report on GWMP Progress Annually and Update the GWMP Every Five Years

1. Document status of management actions and current groundwater conditions approximately one year after the adoption of the GWMP.
2. Use Annual Progress Reports to evaluate the results of the actions and their ability to support BMOs on a five-year interval.
3. Quantify BMOs to the extent they can be supported by data.
4. Identify new management actions as needed.

7.1.8. Prepare an Integrated Regional Water Resources Management Plan (IRWMP)

1. Conduct a series of exploratory meetings on the interest and opportunities for an IRWMP with adjacent agencies.
2. Explore funding options.
3. Execute agreements and determine scope.
4. Retain consulting firm for plan preparation.

7.2. Funding

Since none of the preliminary management actions require large capital expenditures, financing will be covered in the District's current operating budget. Funding options for an IRWMP will be determined through several exploratory meetings with adjacent agencies.

7.3. Schedule

Plan implementation can begin immediately upon District Board approval. Activities are assumed to continue into 2009. Several activities are best conducted in coordination with the Integrated Regional Water Management Plan (IRWMP), although all of the activities (with the exception of the IRWMP) can also be conducted by the District alone. A preliminary schedule of activities follows. The schedule assumes that this GWMP is adopted in the third quarter of 2007.

Preliminary Schedule for GWMP Implementation

PLAN ITEM	2008				2009	
	Q1	Q2	Q3	Q4	Q1	Q2
Optimize Water Sources	■	■	■	■		
Secure Additional Sources			■	■	■	■
Prepare Groundwater Development Plan	■	■	■	■		
Coordinate with Kern County	■					
Improve Groundwater Monitoring		■	■	■		
Coordinate Monitoring with Others			■	■		
Report on the GWMP Progress				■		
Prepare IRWMP	■	■	■	■	■	■

The optimization of water sources and the groundwater development plan could be conducted on parallel tracks and begin immediately. Securing additional water sources would best be evaluated after the optimization process and groundwater development plan have begun to identify appropriate amounts that would be needed under certain conditions. In addition, the coordination process with Kern County on well permits and records could begin immediately.

Potential improvements and documentation of the groundwater monitoring program would rely, in part, on early data developed during the groundwater development plan, including data from the perennial yield assessment. As such, the commencement of this item follows the commencement of the groundwater development plan by one quarter. As the monitoring plan is developed, discussions with other agencies could begin on coordinated monitoring efforts and data sharing. The GWMP progress report should be conducted approximately one year after adoption. The IRWMP could begin immediately after plan adoption and is expected to extend into 2009.

8. References

Anderson, Stephen C., Diane K. Sanchez, and Arvey A. Swanson, Preliminary Evaluation of State Water Project Ground Water Storage Program, White Wolf Basin, State of California Department of Water Resources, Southern District, September 1979.

Associated Engineering Consultants, Report on Investigation of Optimization and Enhancement of the Water Supplies of Kern County, Report and Executive Summary, Prepared for Water Agencies of Kern County, January 1983.

Bertoldi, Gilbert L., Richard H. Johnston, and K.D. Evenson, Ground Water in the Central Valley, California – A Summary Report, Regional Aquifer System Analysis, USGS Professional Paper 1401-A, 1991.

Bookman-Edmonston (BE), Groundwater Storage and Recovery Pilot Project in White Wolf Basin, Final Pilot Project Report, Prepared for Wheeler Ridge-Maricopa Water Storage District, April 27, 2006.

Bookman-Edmonston (BE), Groundwater Storage and Recovery Pilot Project in White Wolf Basin, Phase 3 – Groundwater Exploration and Analysis Memorandum, Prepared for Wheeler Ridge-Maricopa Water Storage District, August 3, 2004.

Bookman-Edmonston (BE), Groundwater Storage and Recovery Pilot Project in White Wolf Basin, Phase 2 – Subsurface Geotechnical Exploration Technical Memorandum, Prepared for Wheeler Ridge-Maricopa Water Storage District, February 27, 2004.

Bookman-Edmonston (BE), Groundwater Storage and Recovery Pilot Project in White Wolf Basin, Phase 1 – Data Review Technical Memorandum, Prepared for Wheeler Ridge-Maricopa Water Storage District, June 17, 2003.

Bookman-Edmonston (BE), Ground Water Studies, Prepared for Wheeler Ridge-Maricopa Water Storage District, September 1995.

Bookman-Edmonston Engineering (BE), Report on Investigation of Planned Operation and Management of the White Wolf Ground Water Basin, Prepared for Wheeler Ridge-Maricopa Water Storage District, June 1975.

Bookman-Edmonston Engineering (BE), Memorandum Report of Ground Water Studies and Recommended Program for Monitoring Ground Water Conditions in the Wheeler Ridge-Maricopa Water Storage District, Prepared for Wheeler Ridge-Maricopa Water Storage District, August 1971.

Bookman and Edmonston (BE), Report on Feasibility of Construction of an Irrigation Distribution System for Wheeler Ridge-Maricopa Water Storage District, July 1967.

California Department of Water Resources (DWR), San Joaquin Valley Groundwater Basin, Kern County Subbasin, Groundwater Basin Number 5-22.14, last update January 20, 2006.

California Department of Water Resources (DWR), California Well Standards, Bulletin 74-90, June 1991.

California Department of Water Resources (DWR), San Joaquin District, Ground Water Study, San Joaquin Valley, First Progress Report, June 1980.

California Department of Water Resources (DWR), San Joaquin District, Ground Water Study, Third Progress Report, Computer Model Modifications and Projections of Future Ground Water Conditions, District Report, September 1985.

California Department of Water Resources (DWR), Vegetative Water Use in California, Bulletin 113-3, 1974.

Dale, R.H., J.J. French, and H.D. Wilson, Jr., The Story of Ground Water in the San Joaquin Valley, California, U.S. Department of the Interior, Geological Survey Circular 459, Washington 1964.

Diamond, Jonathan and Alex K. Williamson, A Summary of Ground-Water Pumpage in the Central Valley, California, 1961-77, USGS Water-Resources Investigations Report 83-4037, October 1983.

D'Onofrio, Don, Invited Panelist, Groundwater Monitoring: Designing a Program of Maximum Value, Joint Groundwater/Water Quality and Small Agencies Track, Association of California Water Agencies (ACWA) Spring Conference, May 11, 2006.

Fujii, Roger, and Walter C. Swain, Areal Distribution of Selected Trace Elements, Salinity, and Major Ions in Shallow Ground Water, Tulare Basin, Southern San Joaquin Valley, California, USGS Water-Resources Investigations Report 95-4048, 1995.

Hagan, Karin, The Effects of the White Wolf Fault on Groundwater Hydrology in the Southern San Joaquin Valley, California, Thesis presented to the faculty of the School of Arts and Sciences of California State University, Bakersfield in partial fulfillment of the Requirements for the Degree of Master of Science in Geology, December 2001.

Iger, Rick, Invited Panelist, Groundwater Monitoring: Designing a Program of Maximum Value, Joint Groundwater/Water Quality and Small Agencies Track, Association of California Water Agencies (ACWA) Spring Conference, May 11, 2006.

Kern County, Kern County General Plan, June 15, 2004.

Kern County, Kern County Code Chapter 14.08, Water Supply Systems, 1989, modified 1990 and 2002.

Kern County Water Agency, Water Supply Report 1990, September 1991.

Kern County Water Agency, Water Supply Report 1991, December 1992.

Kern County Water Agency, Water Supply Report 1992, December 1993.

Kern County Water Agency, Water Supply Report 1993, February 1995.

Kern County Water Agency, Water Supply Report 1994, January 1996.

Kern County Water Agency, Water Supply Report 1995, January 1998.

Kern County Water Agency, Water Supply Report 1996, July 2000.

Kern County Water Agency, Water Supply Report 1997, August 2001.

Kern County Water Agency, Water Supply Report 1998, March 2002.

Kern County Water Agency, Water Supply Report 1999, May 2003.

Kern Delta Water District, Groundwater Management Plan, October 15, 1996.

Land, Paul E., and David C. Mitchell, Cal Canal Gas Field and Rio Viejo Oil Field, California Department of Conservation, Division of Oil & Gas, Publication No. TR29, 1983.

Land, Paul E., and Larry Bright, Yowlumne Oil Field, California Department of Conservation, Division of Oil & Gas, Publication No. TR23, 1978.

Lawrence Livermore National Laboratory (LLNL), California GAMA Program: A Contamination Vulnerability Assessment for the Bakersfield Area, prepared in cooperation with the California State Water Resources Control Board, November 2004.

Lofgren, Ben E., Land Subsidence Due to Ground-Water withdrawal, Arvin-Maricopa Area, California, USGS Professional Paper 437-D, 1975.

Mitchell, David C., The Effects of Oilfield Operations on Underground Sources of Drinking Water in Kern County, California Department of Conservation, Division of Oil & Gas, Publication No. TR36, 1989.

Pacific Geotechnical Associates, Inc., Confining Clay Mapping Study, Kern County, California, (Southern San Joaquin Valley), November 1, 1990.

Provost & Pritchard, Groundwater Management Plan for Arvin-Edison Water Storage District, June 2003.

Page, R.W., Geology of the Fresh Ground-Water Basin of the Central Valley, California, with Texture Maps and Sections, Regional Aquifer System Analysis, USGS Professional Paper 1401-C, 1986.

Saleh, Dina K., Joseph L. Domagalski, Charles R. Kratzer, and Donna L. Knifong, Organic Carbon Trends, Loads, and Yields to the Sacramento-San Joaquin Delta, California, Water Years 1980 to 2000, Water-Resources Investigations Report 03-4070, 2003.

Swain, Walter C., and Lowell F.W. Duell, Jr., Water-Quality Data for Shallow Wells in the Western and Southern Tulare Basin, San Joaquin Valley, California, May to August 1989, USGS Open-File Report 92-655, 1993.

Todd Engineers, Technical Review of Groundwater Level Monitoring and Water Balance Analysis for Improvement District No. 4, Prepared for Kern County Water Agency Improvement District No. 4, December 2001.

West Kern Water District, Groundwater Management Plan, February 1997.

Wheeler Ridge-Maricopa Water Storage District (WRMWSD), Ground Water Investigation, A Ten-Year Report, Prepared by Martin Milobar, Staff Engineer, and Don Terndrup, Engineering Assistant, July 1981.

Wheeler Ridge-Maricopa Water Storage District (WRMWSD), District Board Memorandum, Future Water Requirements, from Wm. A. Taube, January 11, 2005.

Wheeler Ridge-Maricopa Water Storage District (WRMWSD), White Wolf Groundwater Storage and Recovery Pilot Project, PowerPoint presentation by Tom Suggs, Staff Engineer, November 2006.

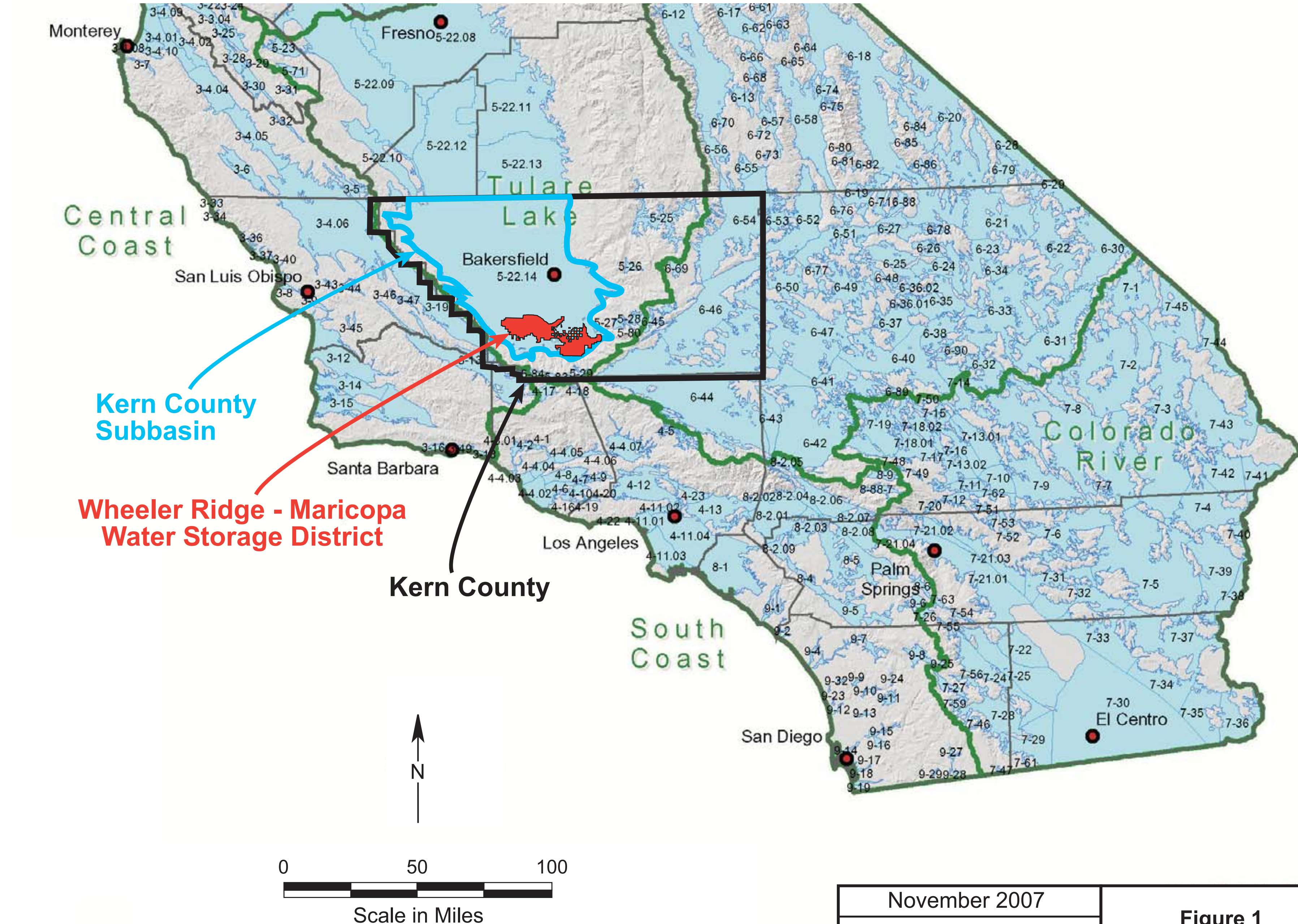
Williamson, Alex K., David E. Prudic, and Lindsay A. Swain, Ground-Water Flow in the Central Valley, California, Regional Aquifer System Analysis, USGS Professional Paper 1401-D, 1989.

Wood P.R. and R. H. Dale, Geology and Ground-Water Features of the Edison-Maricopa Area, Kern County, California, USGS Water Supply Paper 1656, 1964.

U. S. Department of the Interior Geological Survey (USGS), Water Resources Division, Basic Data for Three Lacustrine Clay Deposits in the Southern Part of the San Joaquin Valley, California. Menlo Park, California, 1967.

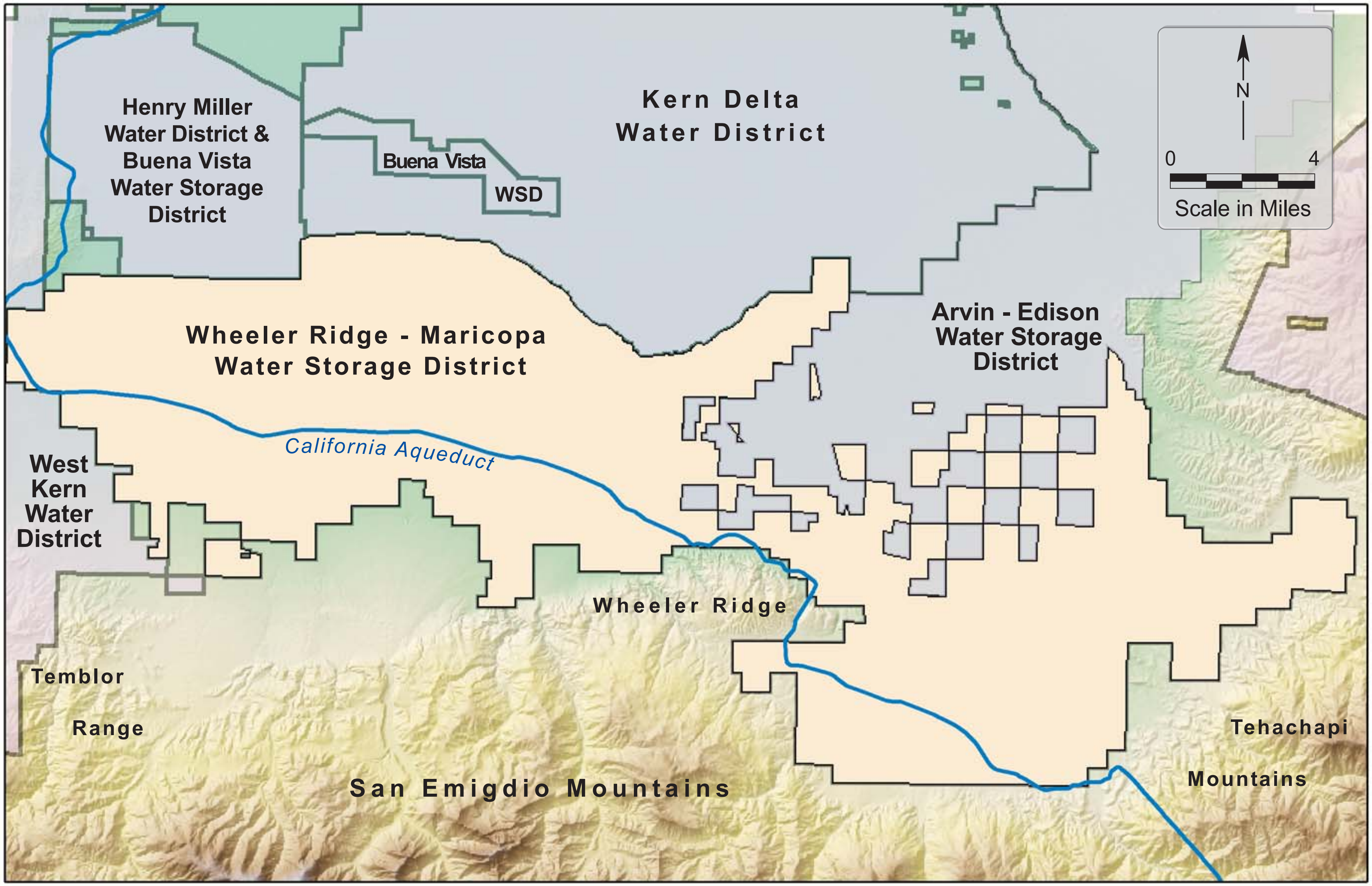
U. S. Geological Survey (USGS), Measuring Human-Induced Land Subsidence from Space, USGS Fact Sheet 069-03, http://pubs.water.usgs.gov/fs06903, last modified August 18, 2005.

Figures



Source: Department of Water Resources, Bulletin 118, 2003.

November 2007	**Figure 1**
TODD ENGINEERS Emeryville, California	**Kern County Subbasin**



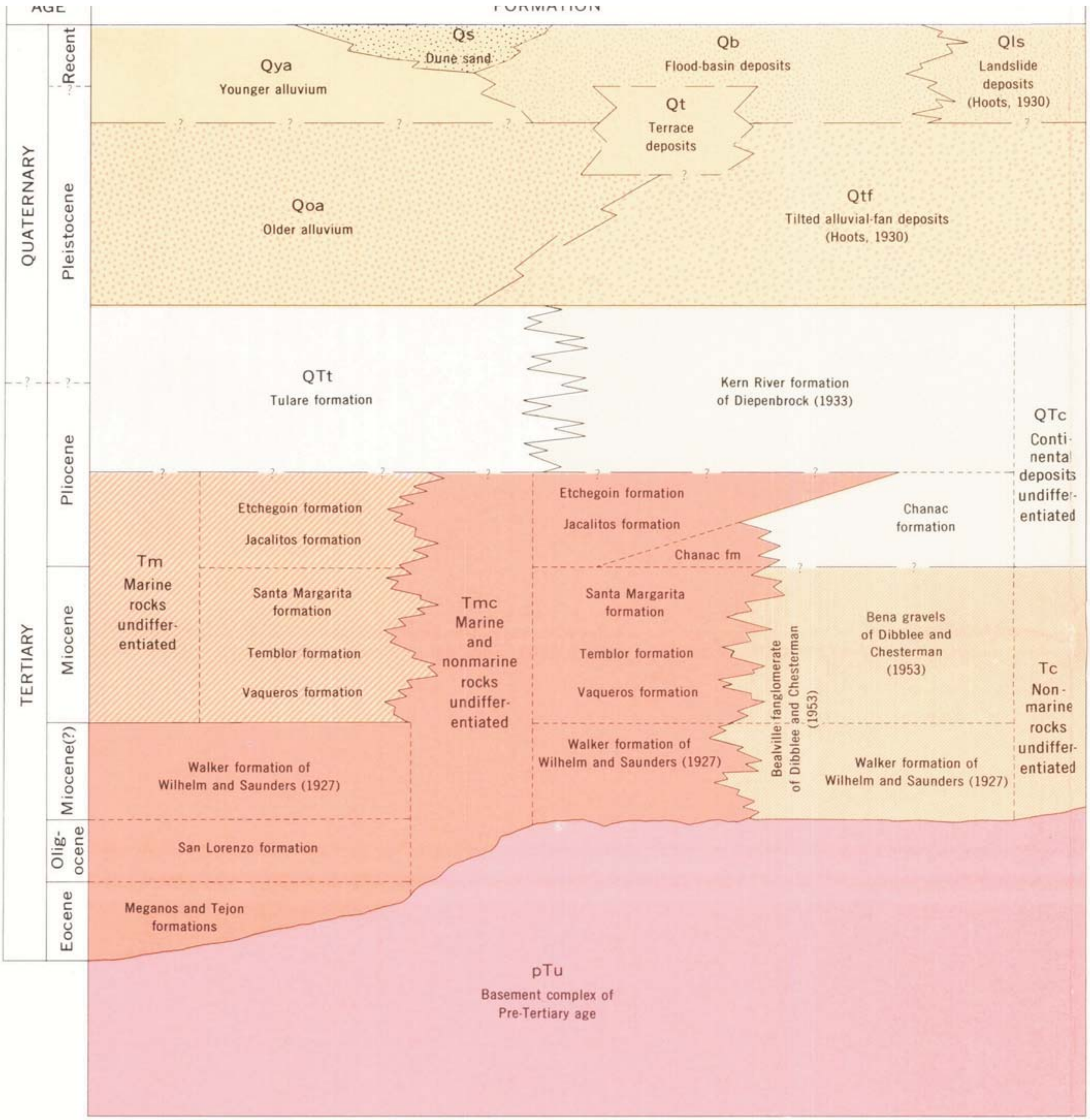
Source: DWR GIS Coverage

November 2007	**Figure 2**
TODD ENGINEERS Emeryville, California	**Water Agencies**

Stratigraphic Nomenclature

Maricopa/Wheeler West Subareas

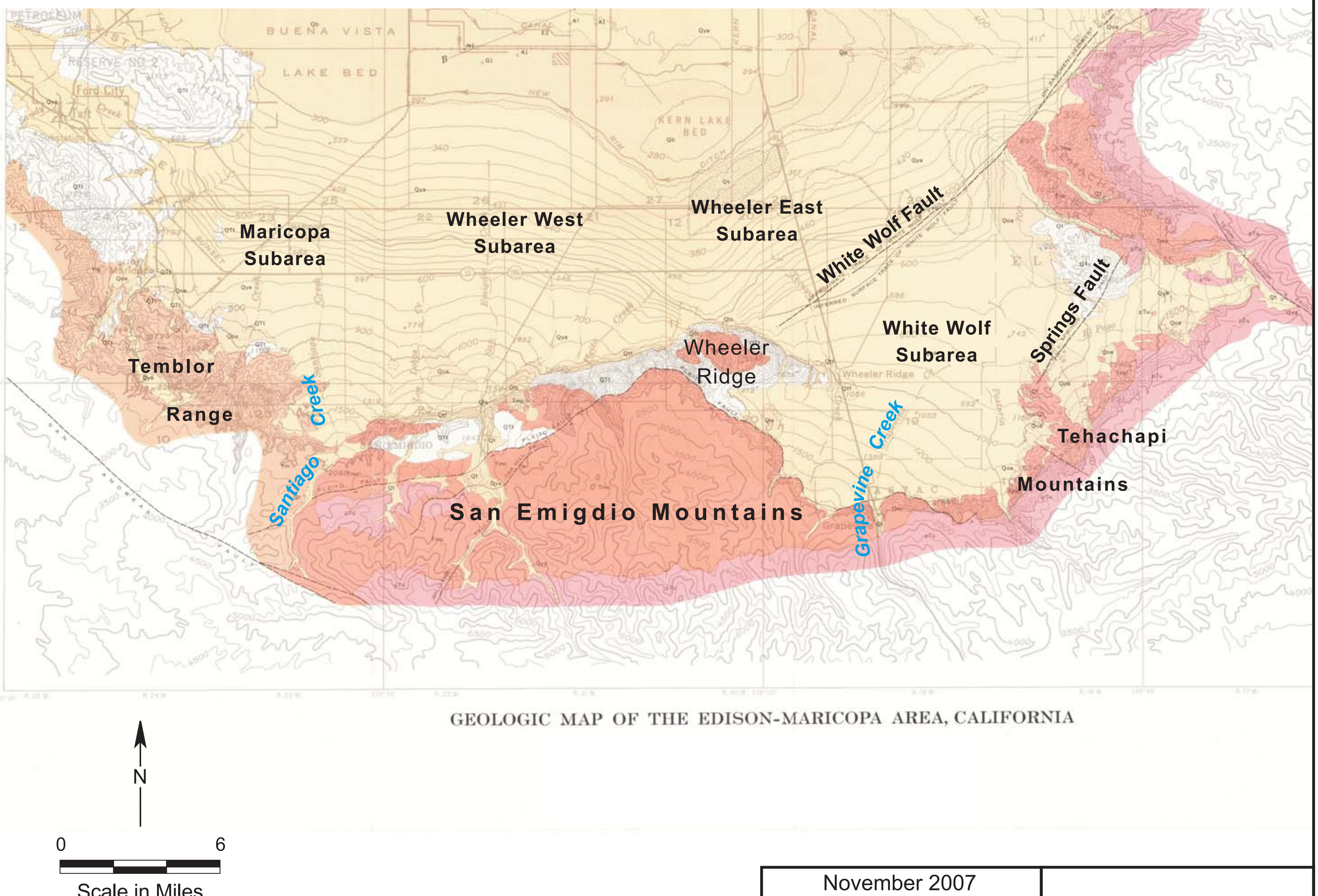
White Wolf/Wheeler East Subareas



DIAGRAMMATIC STRATIGRAPHIC SECTION IN THE EDISON-MARICOPA AREA

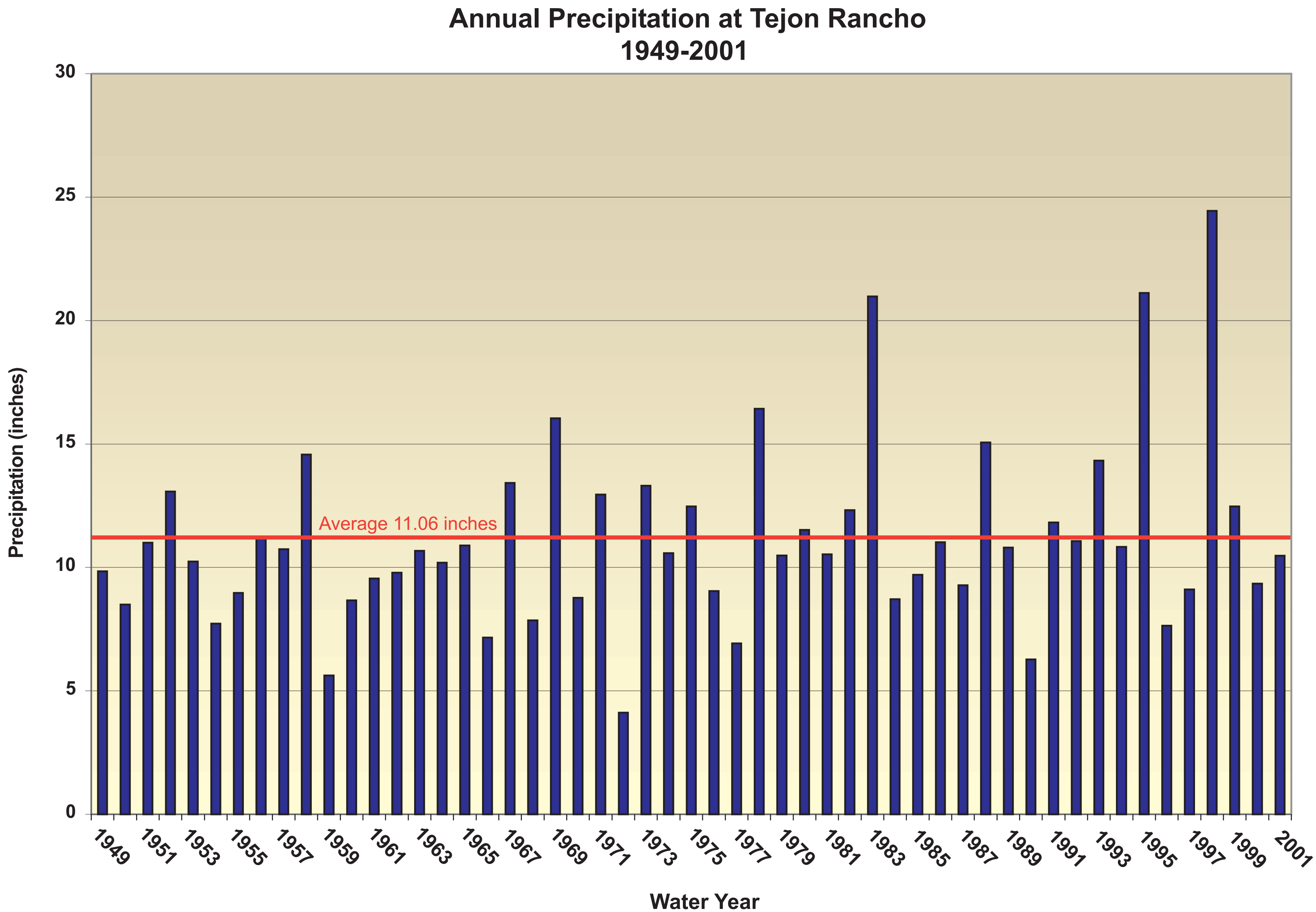
Source: Wood and Dale, 1964.

November 2007	**Figure 3**
TODD ENGINEERS Emeryville, California	**Stratigraphic Nomenclature**



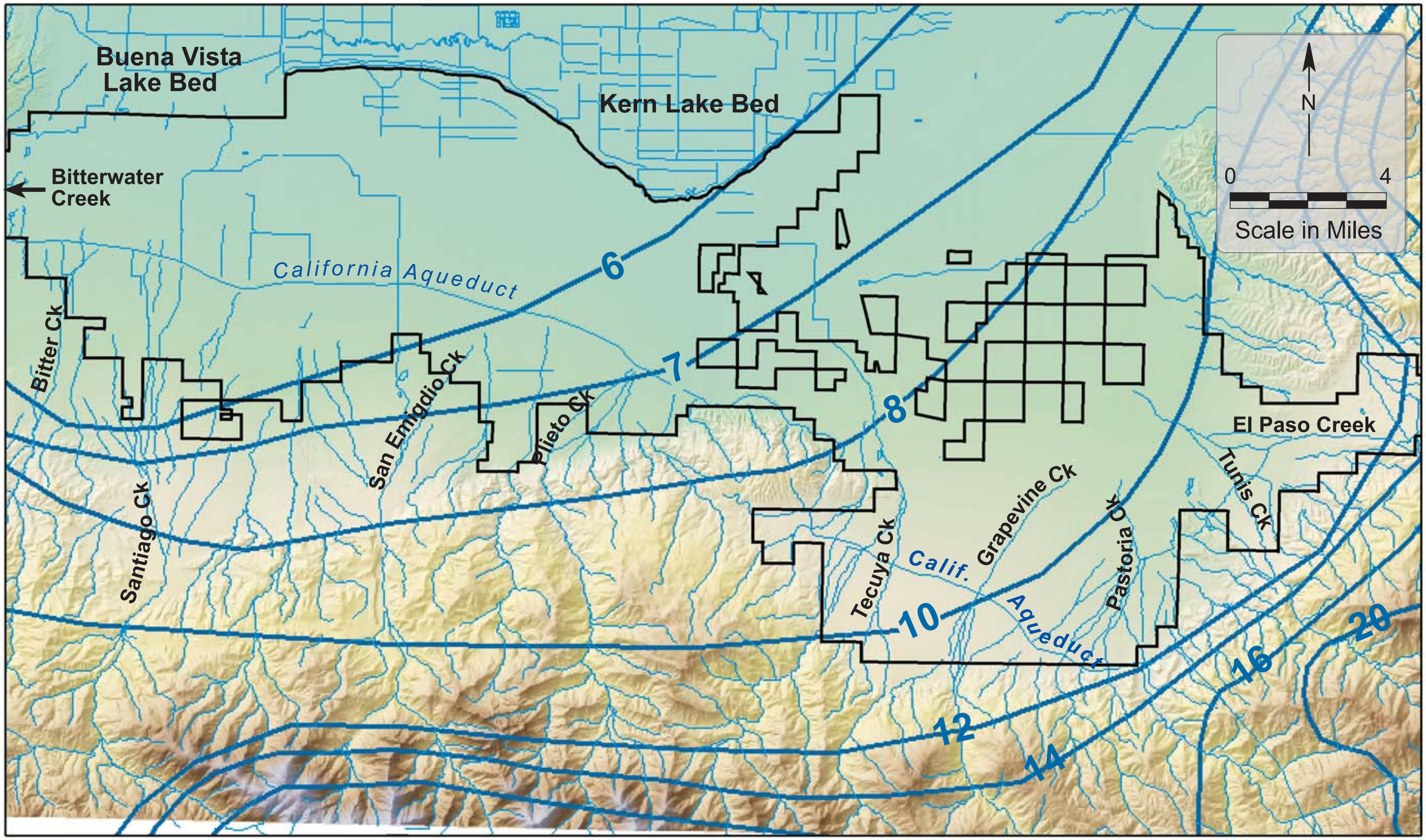
Source: Wood and Dale, 1964.

November 2007	**Figure 4** **Geologic Map**
TODD ENGINEERS Emeryville, California	



Tejon Rancho Gage DWR Station Number 8839-00,
Elevation 434 m, Lat 35° 00' 36", Long 118° 45' 00"
District-wide average annual precipitation is 7.99 inches (water years 1977 - 2006),
Thiessen average of six weather stations.

November 2007	Figure 5
TODD ENGINEERS Emeryville, California	**Annual Precipitation at Tejon Rancho**

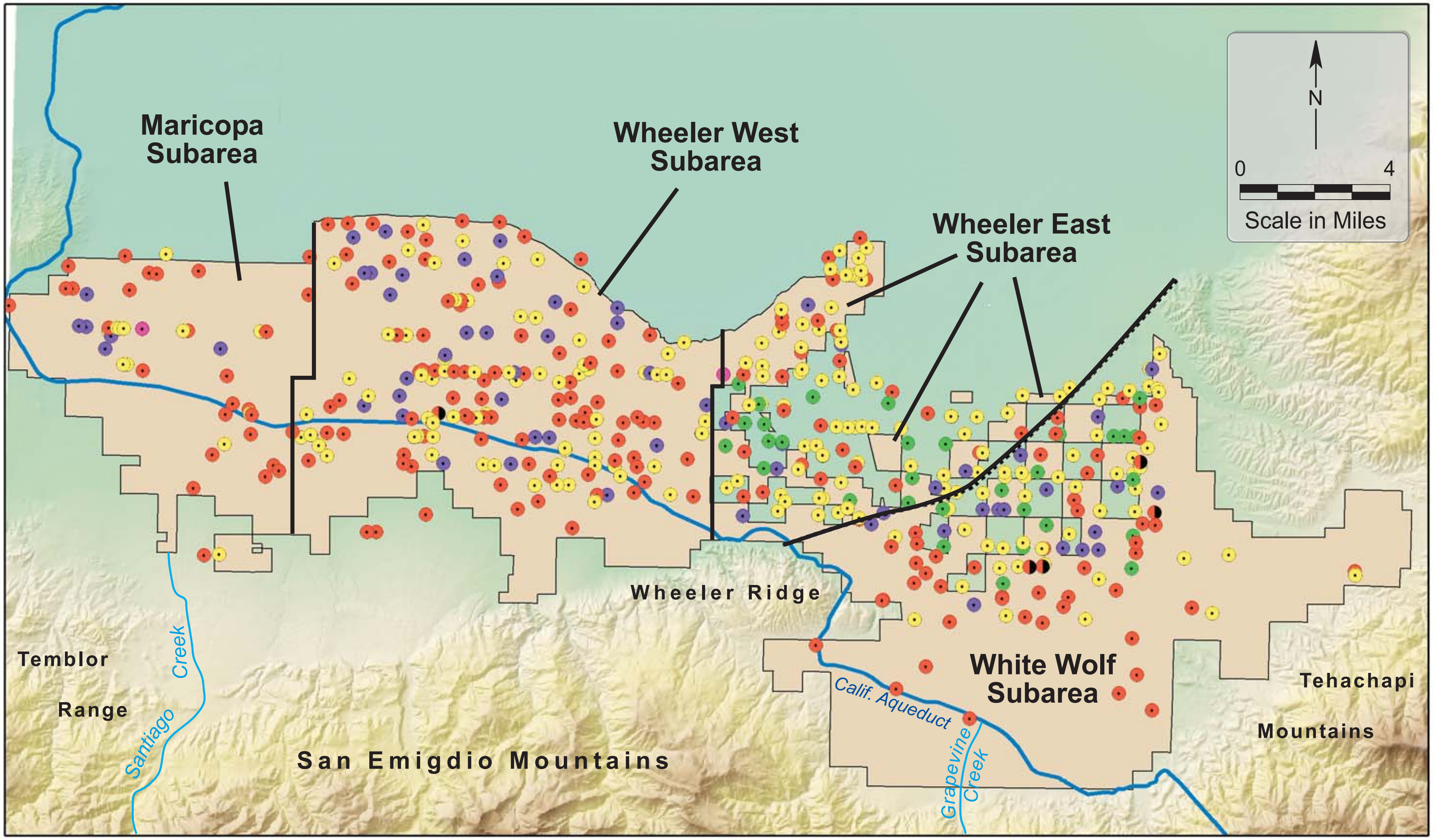


Wheeler Ridge - Maricopa WSD Boundary

8 Line of equal annual precipitation in inches

Source: Isohyetal contours from Kern County GIS Coverage

November 2007	Figure 6 Average Annual Precipitation Contours
TODD ENGINEERS Emeryville, California	



Legend

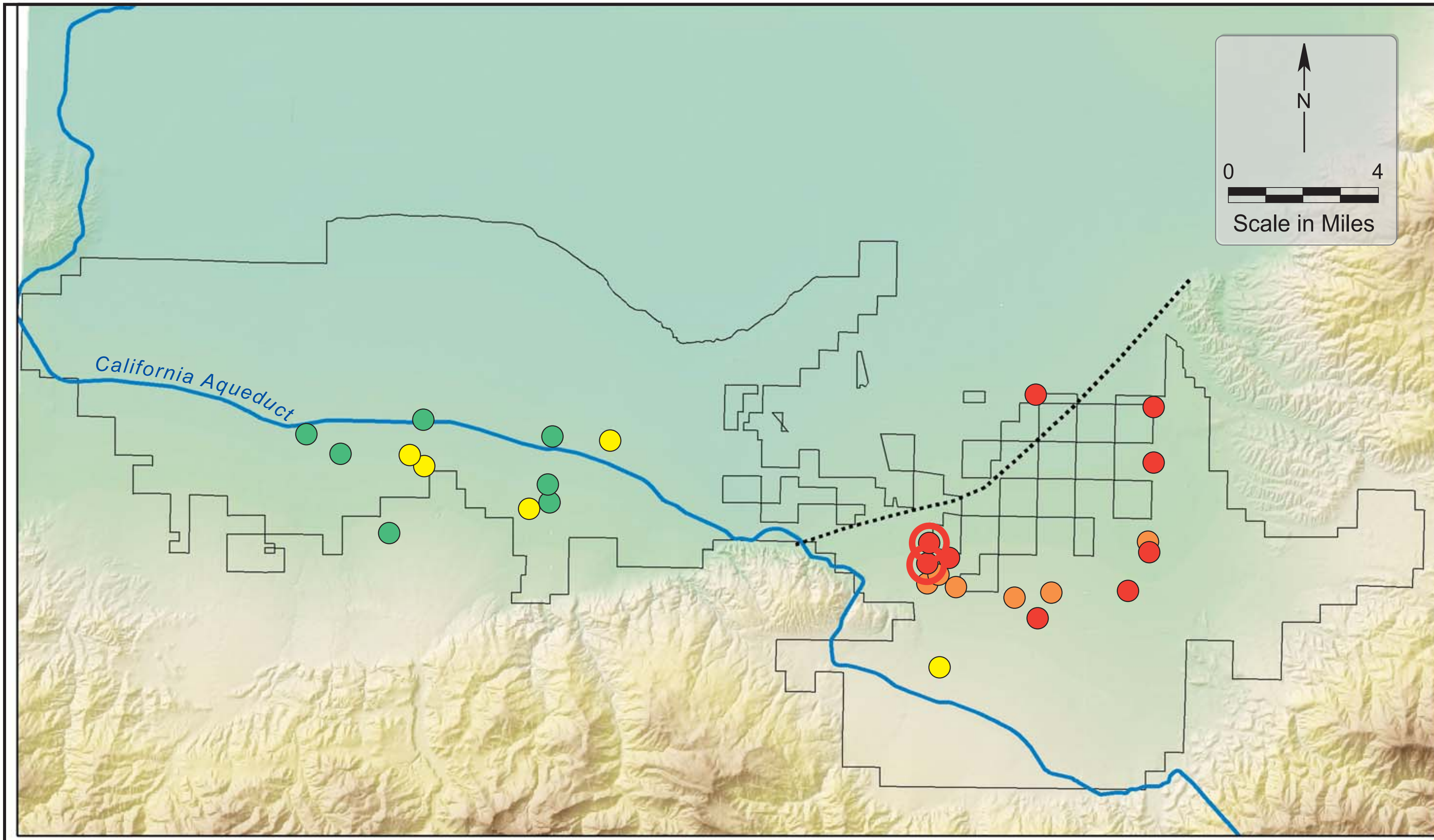
Irrigation and Monitoring Wells with data from the following agencies:

- WRMWSD
- DWR
- Arvin Edison WSD
- Not Monitored

November 2007

TODD ENGINEERS
Emeryville, California

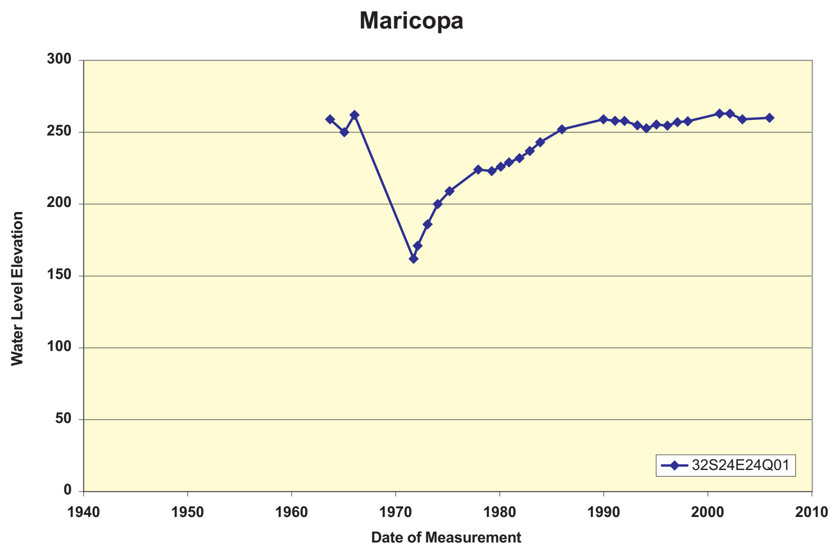
Figure 7
Subareas and Wells

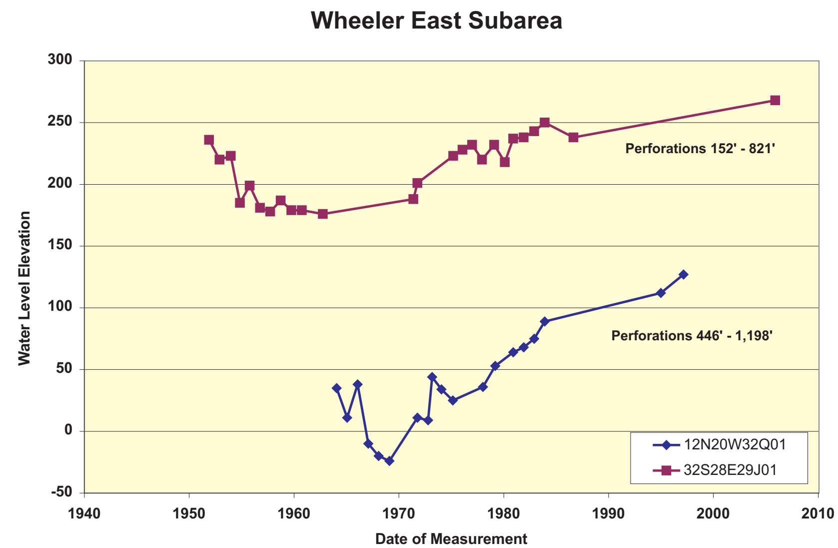


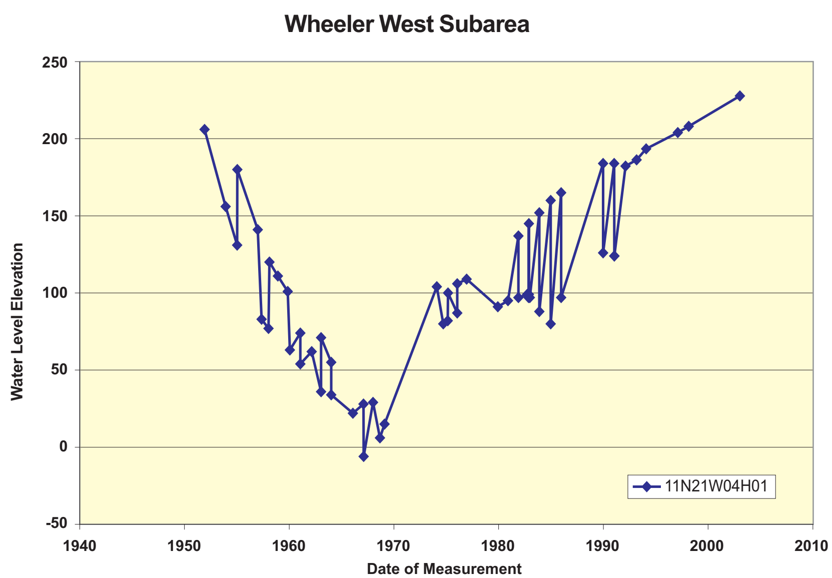
<10 gpm/ft dd
10-20 gpm/ft dd
20-50 gpm/ft dd
50-100 gpm/ft dd
>100 gpm/ft dd

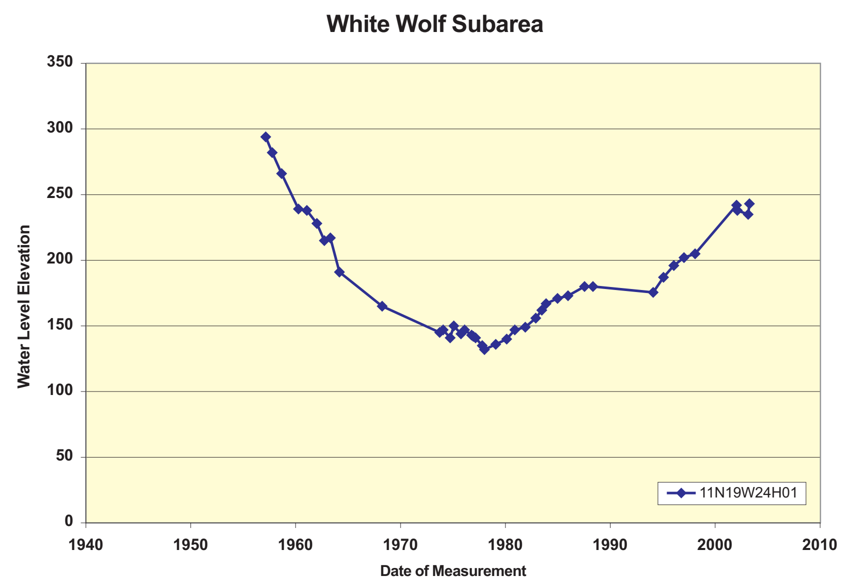
Specific Capacity data derived from well tests, in gallons per minute per foot of drawdown (gpm/ft dd)

November 2007	**Figure 8**
TODD ENGINEERS Emeryville, California	**Specific Capacity Data**

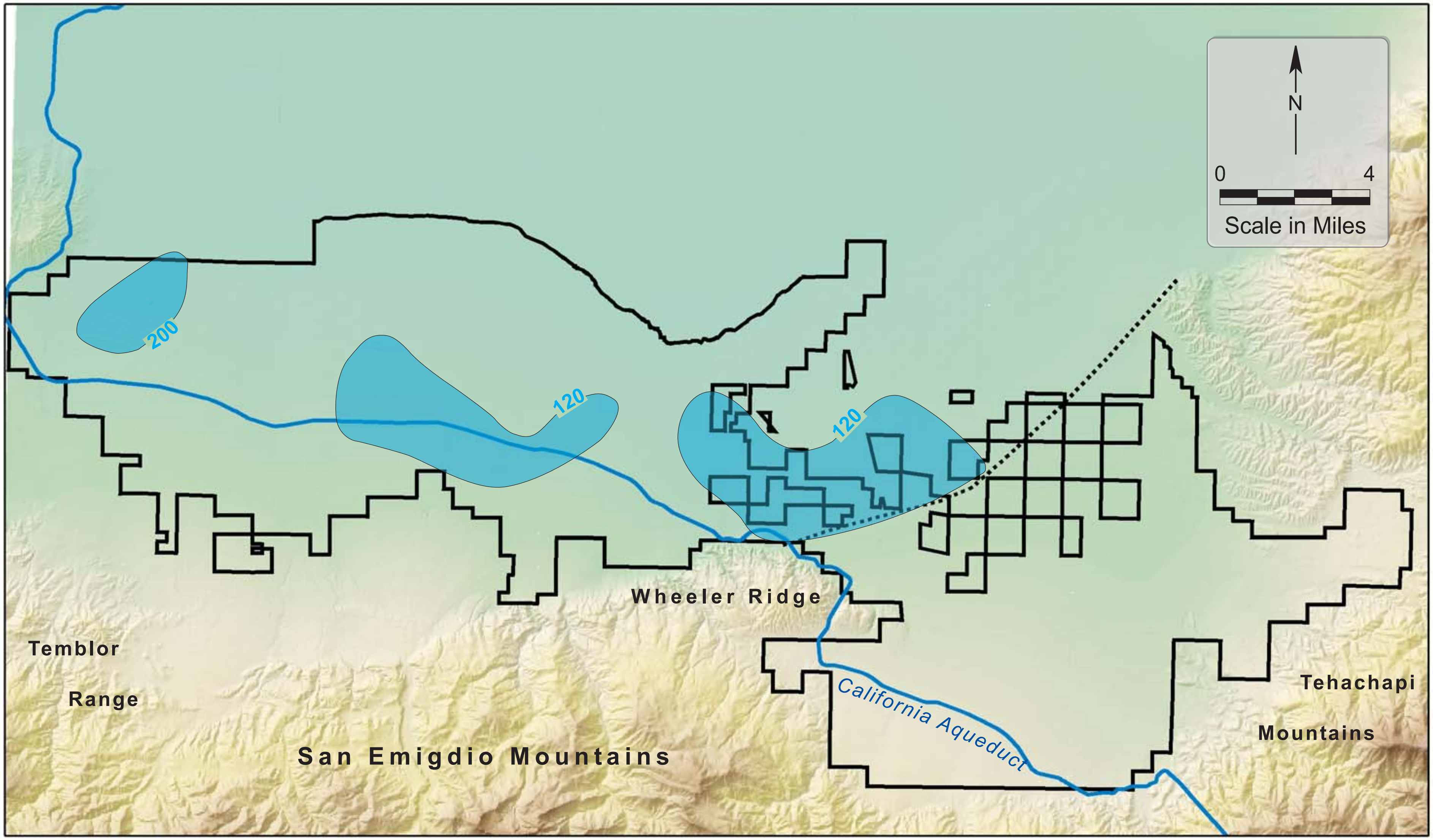








November 2007	**Figure 9** **Example Hydrographs by Subarea**
TODD ENGINEERS Emeryville, California	

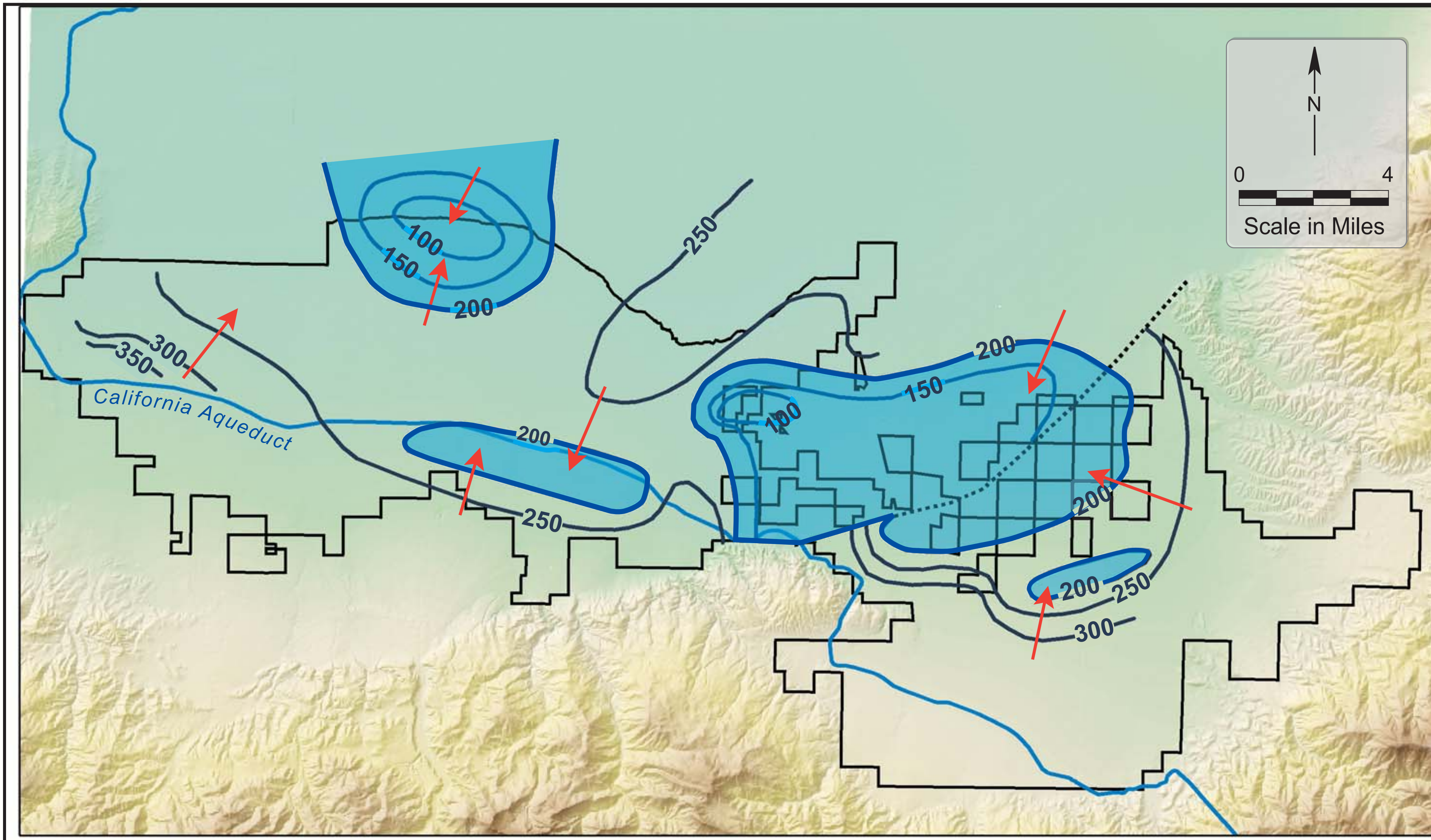


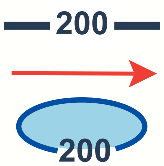
Pumping depression from December 1958
water level contour map.

200 Area of water levels lower than elevation, indicated in feet, msl.

Source: Wood and Dale, 1958.

November 2007	**Figure 10** **Historical Pumping Depressions 1958**
TODD ENGINEERS Emeryville, California	





Lines of equal water levels in feet, msl for January through March 2000

Generalized direction of groundwater flow

Area of water levels lower than an elevation of 200 feet, msl.

November 2007

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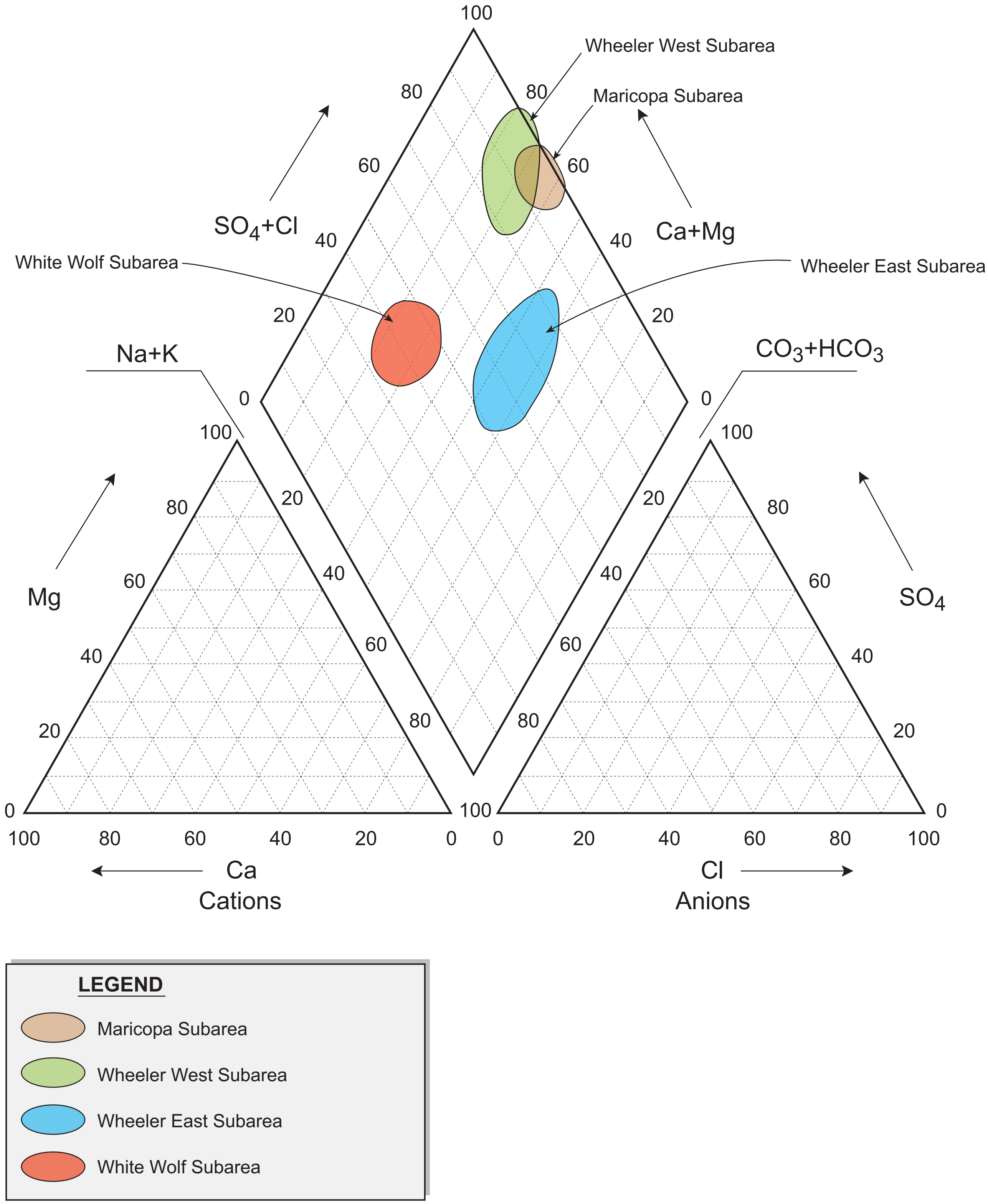
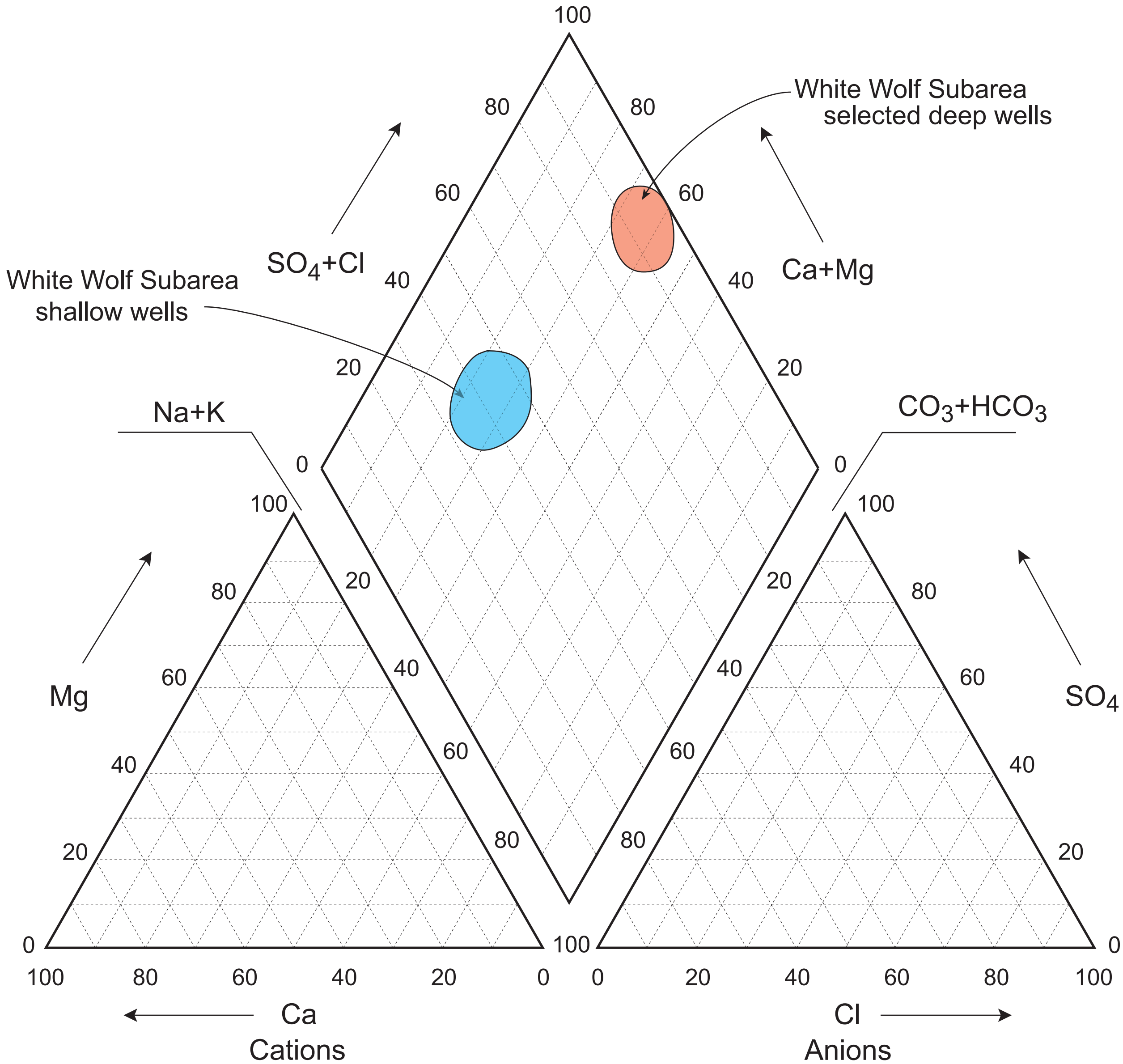
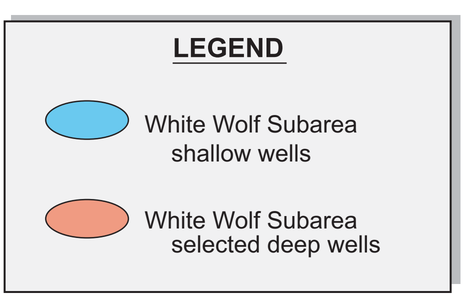
Emeryville, California

Figure 11
Water Level Contour Map 2000

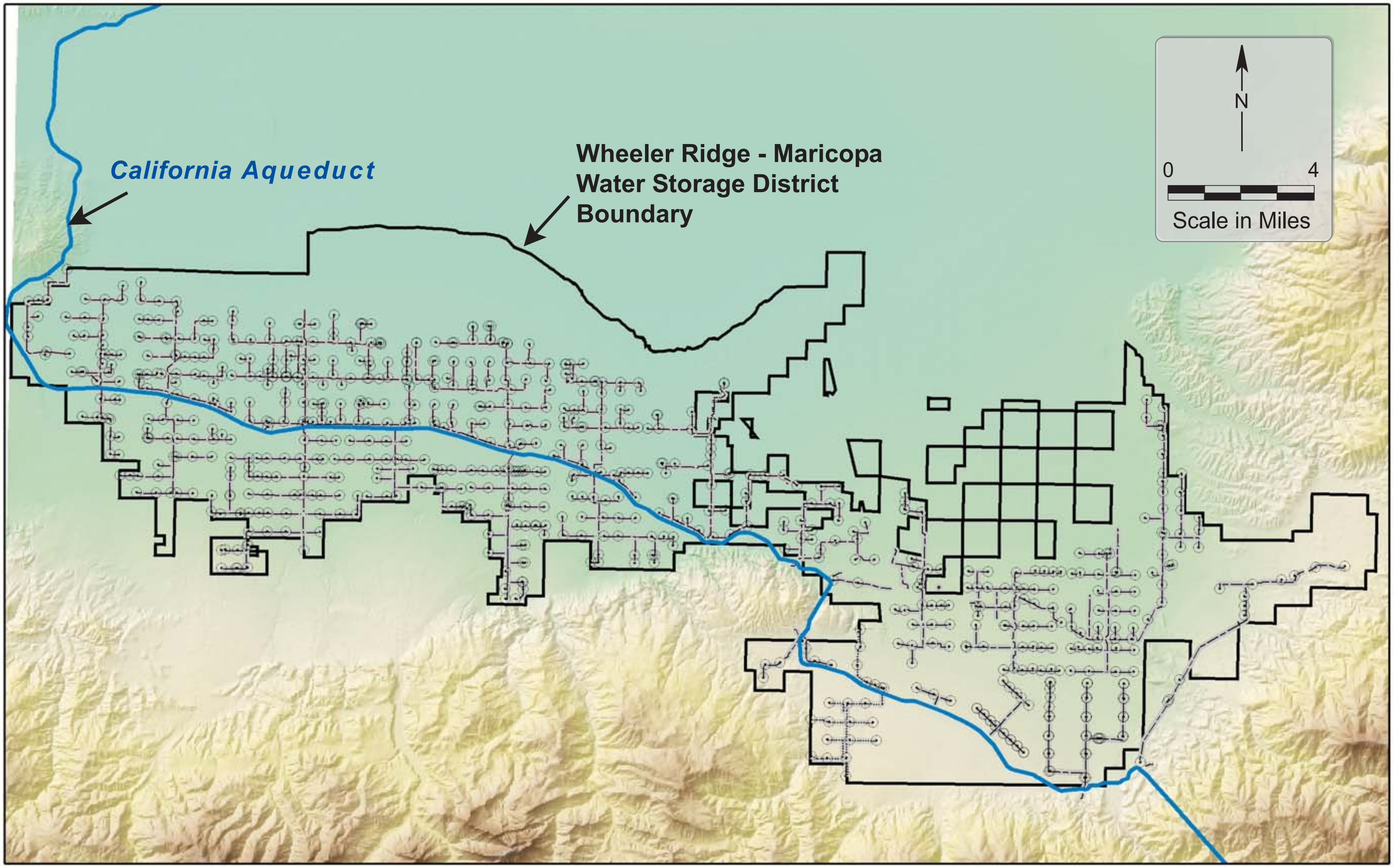


November 2007	**Figure 12**
TODD ENGINEERS Emeryville, California	**Trilinear Diagram Groundwater Quality by Subarea**





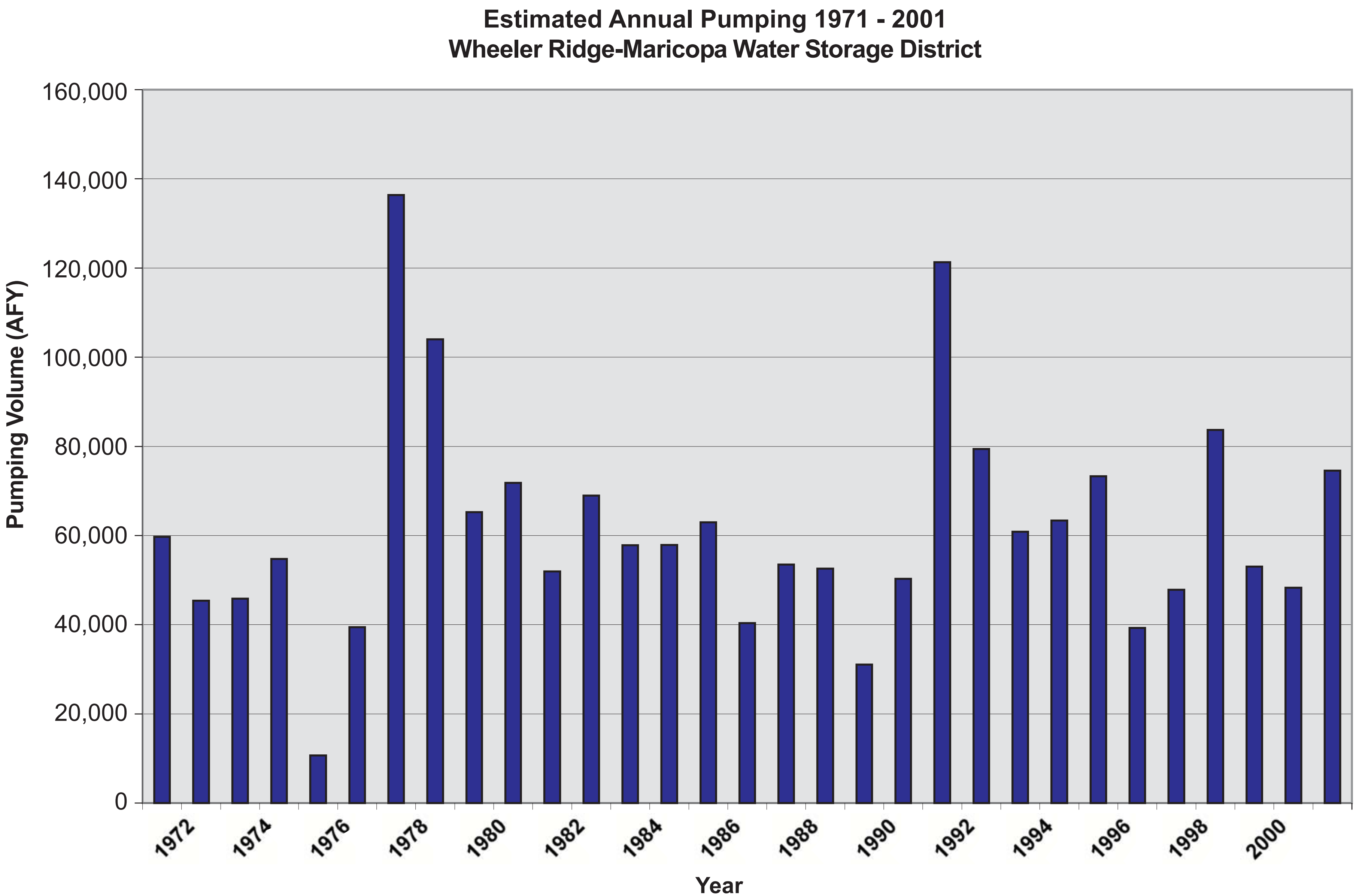
November 2007	**Figure 13**
TODD ENGINEERS Emeryville, California	**Trilinear Diagram Groundwater Variability in White Wolf Subarea**



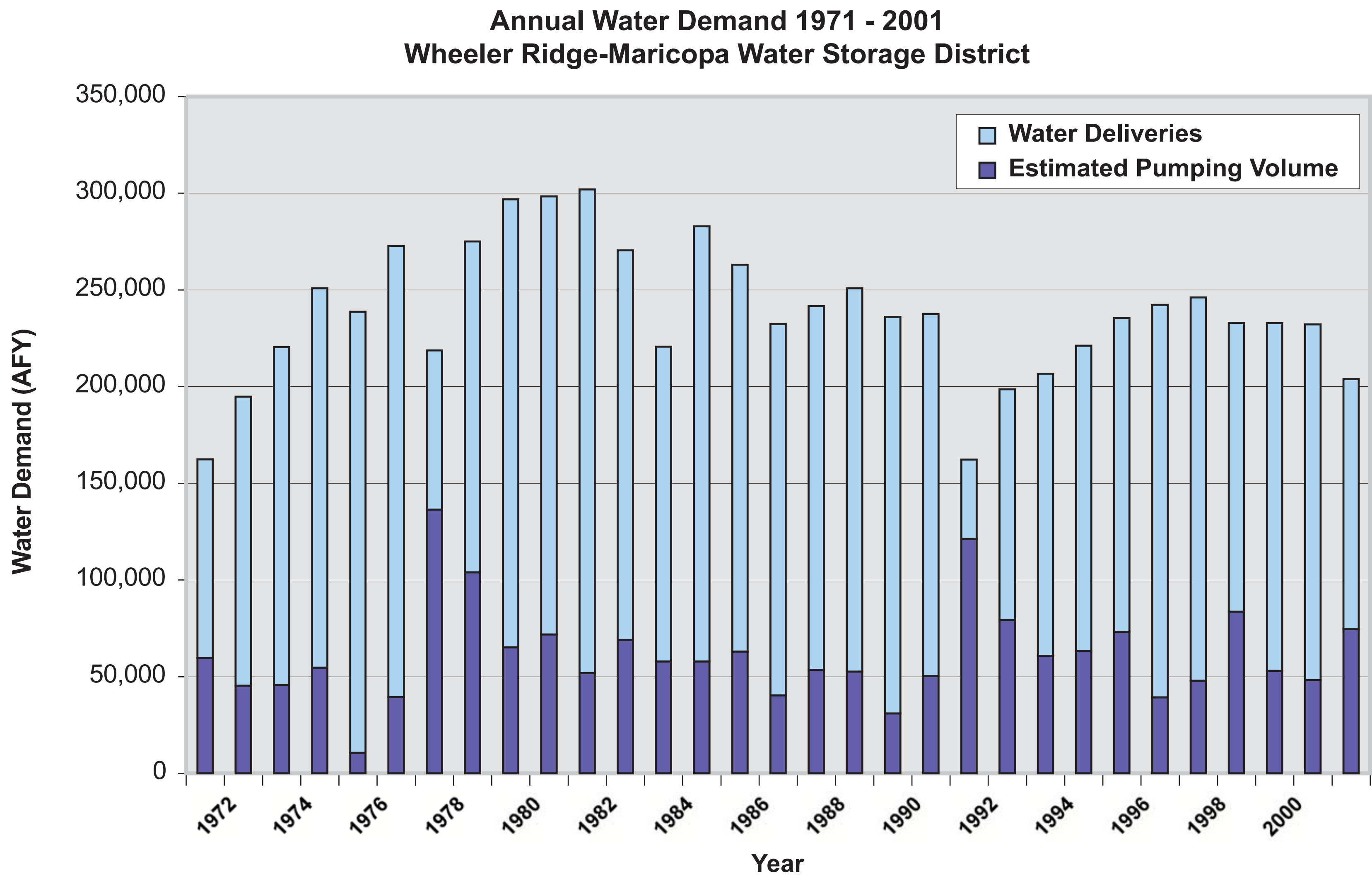
November 2007

TODD ENGINEERS
Emeryville, California

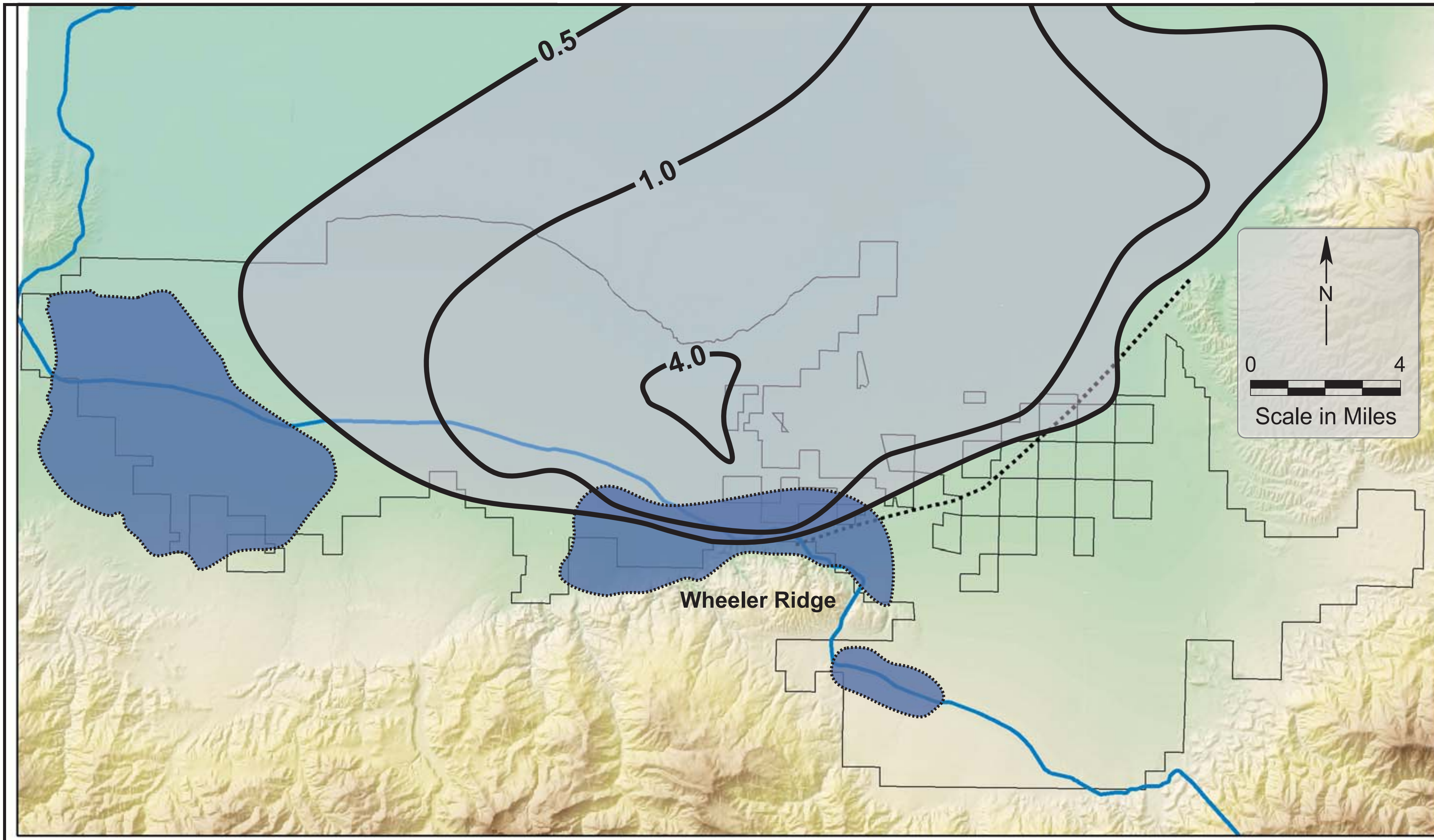
Figure 14
WRMWSD Distribution System



November 2007	**Figure 15**
TODD ENGINEERS Emeryville, California	**Estimated Annual Pumping**



November 2007	**Figure 16** **Pumping and Surface Water Deliveries**
TODD ENGINEERS Emeryville, California	



—0.5— Lines of equal subsidence due to groundwater widthdrawal, in feet

Area of subsidence due to groundwater widthdrawal (approximate)

Area subject to hydrocompaction (approximate)

Source: Lofgren, 1975.

November 2007

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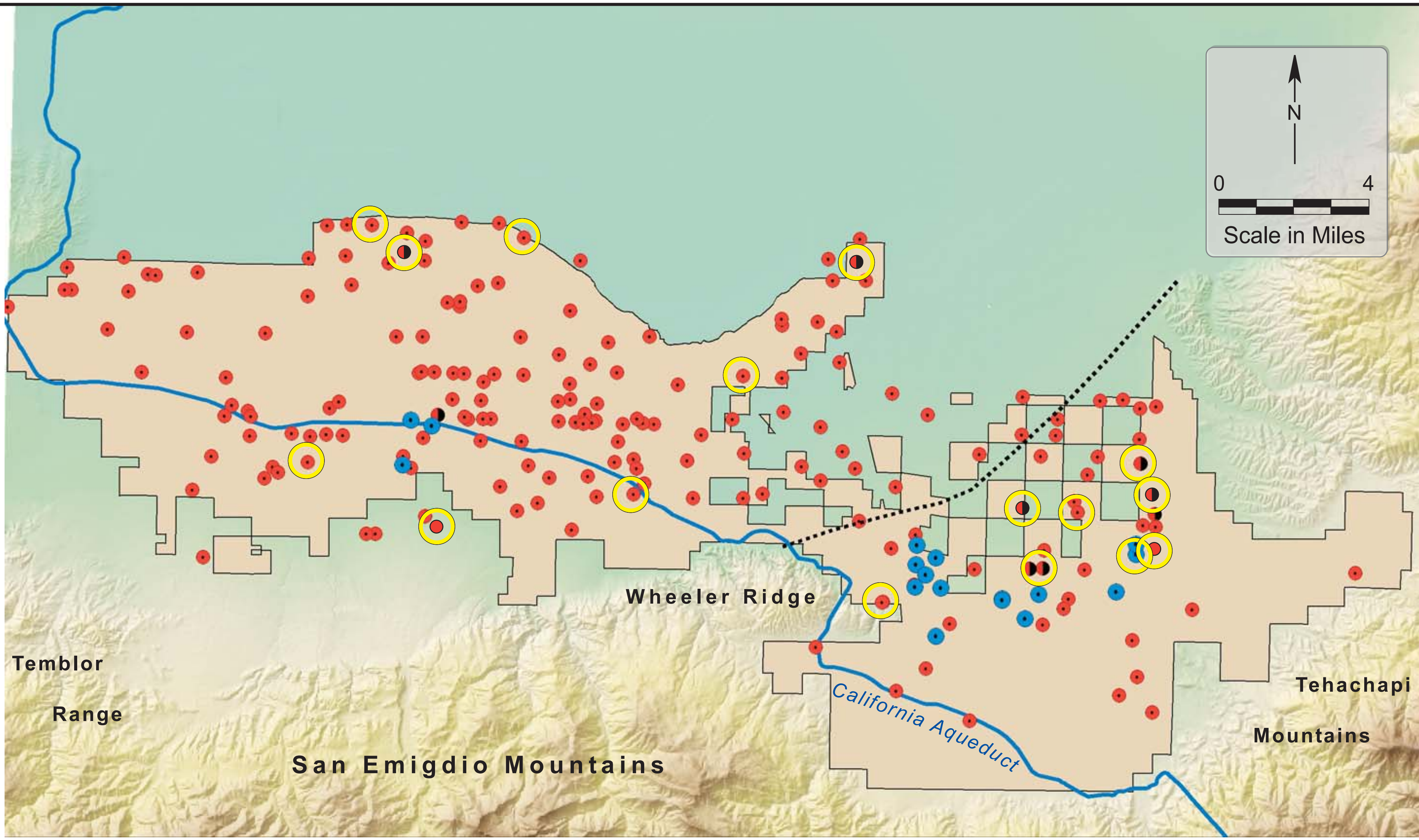
Emeryville, California

Figure 17
Areas of Subsidence and Hydrocompaction



LEGEND

- District Water Level Monitoring Locations (Historical and Current)
- District and other Agency Monitoring Locations
- District Production Wells
- District Water Quality Monitoring Locations (Current including alternate locations)

November 2007

TODD ENGINEERS
Emeryville, California

Figure 18
WRMWSD Monitoring Network

Appendix A

Notice of Public Hearing

The BAKERSFIELD CALIFORNIAN
P.O. BOX 440
BAKERSFIELD, CA 93302

PROOF OF PUBLICATION

RECEIVED
MAR - 8 2006
WR-MWSD

Ad Number	5257702	**PO #**	PUBLIC HEAI
Edition	TBC	**Run Times**	2
Class Code	2620	Legal Notices	
Start Date	2/22/06	**Stop Date**	3/1/06
Run Date(s)	02/22, 03/01		
Billing Lines	66	**Inches**	2.75
Total Cost	241.28	**Account**	1WHE05

WHEELER RIDGE-MARICOPA WATER
12109 HIGHWAY 166

BAKERSFIELD CA 93313-9630

Billing Address WHEELER RIDGE-MARICOPA WATER
12109 HIGHWAY 166

BAKERSFIELD CA 93313-9630

Solicitor I.D.: C010

--

STATE OF CALIFORNIA
COUNTY OF KERN

I AM A CITIZEN OF THE UNITED STATES AND A RESIDENT OF THE COUNTY AFORESAID: I AM OVER THE AGE OF EIGHTEEN YEARS, AND NOT A PARTY TO OR INTERESTED IN THE ABOVE ENTITLED MATTER. I AM THE ASSISTANT PRINCIPAL CLERK OF THE PRINTER OF THE BAKERSFIELD CALIFORNIAN, A NEWSPAPER OF GENERAL CIRCULATION, PRINTED AND PUBLISHED DAILY IN THE CITY OF BAKERSFIELD COUNTY OF KERN,

AND WHICH NEWSPAPER HAS BEEN ADJUDGED A NEWSPAPER OF GENERAL CIRCULATION BY THE SUPERIOR COURT OF THE COUNTY OF KERN, STATE OF CALIFORNIA, UNDER DATE OF FEBRUARY 5, 1952, CASE NUMBER 57610; THAT THE NOTICE, OF WHICH THE ANNEXED IS A PRINTED COPY, HAS BEEN PUBLISHED IN EACH REGULAR AND ENTIRE ISSUE OF SAID NEWSPAPER AND NOT IN ANY SUPPLEMENT THEREOF ON THE FOLLOWING DATES, TO WIT:

02/22, 03/01

ALL IN THE YEAR 2006

I CERTIFY (OR DECLARE) UNDER PENALTY OF PERJURY THAT THE FOREGOING IS TRUE AND CORRECT.

Cathy Wynne

DATED AT BAKERSFIELD CALIFORNIA
3-1-06

First Text
WHEELER RIDGEMARICOPA WATER STORAGE DI:

Ad Number 5257702

WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT PUBLIC NOTICE
NOTICE OF PUBLIC HEARING

NOTICE IS HEREBY GIVEN that at 9:00 am on March 15, 2006, at 12109 Highway 166, Bakersfield, California, a public hearing will be held to discuss whether or not the Wheeler Ridge-Maricopa Water Storage District (District) should adopt a resolution of intention to draft a groundwater management plan. Part 2.75 of Division 6 of the California Water Code permits the adoption and implementation of groundwater management plans to encourage authorized local agencies to manage groundwater resources within their service areas. The District encompasses approximately 147,000 acres of land in Kern County at the extreme southern end of the San Joaquin Valley south of the City of Bakersfield. A precise description of the boundaries of the Wheeler Ridge-Maricopa Water Storage District is available at the District office. Landowners within the District and other interested parties are invited to attend the hearing. Copies of the proposed resolution and other relevant written materials will be available for review by the public at the hearing or may be obtained in advance at the District office at the above address. Opportunity for public questions and input will be provided at the hearing. In compliance with Water Code 10753.4 (b), landowners and other interested parties who wish to participate in developing the groundwater management plan may do so by attending the hearing and indicating their interest, or by submitting a written letter to the Engineer-Manager, William A. Taube, Wheeler Ridge-Maricopa Water Storage District, 12109 Maricopa Highway, Bakersfield, California, 93313.

/s/Antonio S. Costamagna
Antonio S. Costamagna,
Secretary of the Board of Directors
February 15, 2006 February 22, March 1, 2006 (5257702)

Appendix B

Resolution of Intent to Prepare a Groundwater Management Plan

COPY

BEFORE THE BOARD OF DIRECTORS OF THE
WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT

IN THE MATTER OF: **RESOLUTION NO. 2006-06**

INTENTION OF THE WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT TO DRAFT A GROUNDWATER MANAGEMENT PLAN

WHEREAS, adoption of a groundwater management plan is in furtherance of the District's adopted project as approved by the landowners and consistent with the historic operations of the District; and

WHEREAS, Part 2.75 of Division 6 of the California Water Code permits the adoption and implementation of groundwater management plans to encourage authorized local agencies to manage groundwater resources within their service areas; and

WHEREAS, the Wheeler Ridge-Maricopa Water Storage District (the "District") is an authorized local agency and may therefore adopt and implement such a management plan; and

WHEREAS, a public hearing was held on March 15, 2006 to consider whether or not the District should prepare a groundwater management plan and to discuss the manner in which interested parties may participate in developing the plan; and

WHEREAS, the Board believes that groundwater resources can best be managed by local agencies in coordination with owners of lands overlying the groundwater basin; and

WHEREAS, the Board believes the adoption of a groundwater management plan will be in the best interests of the District's landowners and water users and can help meet the projected long-term water needs of the District,

NOW THEREFORE BE IT RESOLVED, by the Board of Directors as follows:
The foregoing findings are true and correct:

1. It is the intention of the District to draft a groundwater management plan in accordance with Part 2.75 of Division 6 of the California Water Code, and the District's project consultant is hereby authorized and directed to draft such a plan;
2. That this resolution shall be deemed a resolution of intention in accordance with California Water Code Section 10753.2;
3. After such a plan has been prepared, the District will conduct a second public hearing in accordance with the California Water Code Section 10753.5, et seq. to determine whether to adopt the plan;
4. That the Engineer-Manager is authorized and directed to publish this resolution of intention to draft a groundwater management plan in accordance with the provisions of California Water Code Section 10753.3 and to provide interested persons with a copy of this resolution upon written request;
5. That the Board hereby authorizes its Engineer-Manager to execute all documents and to take any other action necessary or advisable to carry out the purposes of this resolution.

ALL THE FOREGOING, being on motion of Director Cappello, seconded by Director Mullins and adopted by the following vote, to wit:

AYES:	Directors Atkinson, Cappello, Costamagna, Greenlee, Jr., Johns, Larsen, Mettler and Mullins
NOES:	None
ABSENT:	Valpredo
ABSTAINED:	None

I HEREBY CERTIFY that the foregoing resolution is the resolution of said District as duly passed and adopted by said Board of Directors on the 15th day of March 2006.

WITNESS my hand and seal of said Board of Directors this 15th day of March 2006.

____

Secretary of the Board of Directors

(Seal)

E:\2006-06-WRMGroundwater Management Plan-AB3030.wpd

Minutes of the Adjourned Meeting
of the Board of Directors of the
Wheeler Ridge-Maricopa Water Storage District
Convened at 8:30 A.M., March 15, 2006

The adjourned meeting of the Board of Directors of the Wheeler Ridge-Maricopa Water Storage District was held at the offices of the District on Wednesday, March 15, 2006 at the hour of 8:30 A.M. President Johns declared that a quorum was present and called the meeting to order.

Directors Present: Atkinson, Cappello, Costamagna, Greenlee, Jr., Johns, Larsen, Mullins and Mettler

Directors Absent: Valpredo

Others Present: Engineer-Manager, Wm. A. Taube; Assistant Engineer-Manager, Robert Kunde; Controller, Mark E. Gardner; Executive Secretary, Linda L. Hood; Staff Engineer, Tom Suggs; Attorney for the District, Ernest A. Conant of Young Wooldridge, Albert Etcheverry with Rossini Farms, and Denise Newton with PG&E.

Minutes: Motion was made by Director Cappello, seconded by Director Atkinson and unanimously carried, approving the *Minutes of the Regular Meeting of the Board of Directors of February 8, 2006* as mailed.

Treasurer's Report: Director Larsen, Treasurer for the District, presented the *Treasurer's Report for the Month of February 2006.* After review it was stated that the *Report* was in order. Upon motion of Director Costamagna, seconded by Director Mettler and carried, the *Treasurer's Report* was accepted and filed.

Accounts Payable: The accounts payable for *February 2006* was presented by Treasurer Larsen and reviewed.

It was noted the accounts payable includes the Report entitled *"Board of Directors/Management Expense Breakdown - February 2006."* This Report breaks down all Director compensation and expense reimbursement by Director and the nature of the event creating the expense. This Report has been included in the Accounts Payable and complies with requirements of newly applicable law AB1234.

Upon motion of Director Atkinson, seconded by Director Greenlee, Jr., and unanimously carried, the Board approved the accounts payable for the month of *February 2006.*

President's Report: President Johns reported that he, Vice-President Cappello, and Mr. Taube would be meeting on March 17 with a Kern County Water Agency Board Committee to discuss issues related to the Pioneer Project including the Castle & Cooke Land Exchange. After consultation with the other Directors, he directed the Budget and Finance Committee to meet with the District Auditor at 8:00 a.m. on April 3 to review the draft Audit Report.

__9:00 A.M. - Public Hearing on Intention of Wheeler Ridge-Maricopa Water Storage District to Draft a Groundwater Management Plan (AB3030)__. President Johns noted this was the time and place for a Public Hearing on this subject, and asked Mr. Suggs to review his March 9, 2006 memorandum entitled *"Notice of Intention to Prepare of a Local Groundwater Management Plan (AB3030 Plan)"*. Mr. Suggs reviewed his memorandum describing the reasons for preparing a plan, the public participation process including this Hearing, and the approximate time line for development. Mr. Suggs presented a signup list for the public to indicate their interest in participating in the plan development. President Johns then asked for comments from the public. There were none. President Johns declared the Public Hearing closed at 9:09 a.m. After further discussion, and upon motion by Director Cappello, seconded by Director Mullins and unanimously carried, the Board adopted Resolution 2006-06 in the matter of:

Intention of the Wheeler Ridge-Maricopa Water Storage District to Draft a Groundwater Management Plan

__Kern Water Bank Authority Board Meeting__: Mr. Taube reported on the March Kern Water Bank Authority (KWB) Board meeting as follows.

a. The KWB Board adopted the Fourth Amendment to the Kern Water Bank Joint Powers Authority Agreement to increase the recharge and recovery capital fees as discussed with the District Board in February, and allowing for future adjustment in such fees.
b. The KWB Board also discussed the issues of annual recovery limits, the Rosedale/Irvine Ranch banking project, and the relocation of the James Canal.

__State Water Contractors Board of Directors Meeting in Sacramento__: Mr. Taube reported the Contractor Board authorized filing of litigation challenging the Cease and Desist Order of the State Water Resources Control Board. This Order placed the entire responsibility for meeting South Delta water quality standards on the state and federal projects notwithstanding contributions to the problems by others.

__Association of California Water Agencies Energy Committee Meeting__: Mr. Kunde attended the February 23, 2006 Committee Meeting in Sacramento. He reported (a) recent analysis shows California water agencies use 10% of the state's electricity, (b) the Public Utilities Commission has ordered that demand response programs targeted at water agencies be a primary response to California electrical demand shortages, and (c) incentive payments of $100/kw/year have been proposed under a five year program. The financial incentives would be helpful in making peak load shifting reservoirs financially viable within the District. The District studied such reservoirs in 2001 but the high capital costs and unknown future electrical costs made such investments infeasible.

__Engineer-Manager's Report and 2006 Water Supply__: Mr. Taube reported the 2006 State Water Project allocation remained at 70%. He reviewed the District's February deliveries as further described in the *Engineer-Manager's Report for February 2006*. He noted the preservation of 1,401 acre-feet of 2005 District carryover into 2006 due to 2005 overdeliveries by Semitropic, and that higher than projected February deliveries resulted in 4,488 of Article 21 water deliveries in-District.

Mr. Kunde used the new overhead projection unit and screen to display and discuss information in the Board folders regarding the Northern California Eight Station Index of precipitation, the Northern, Central, and Southern Sierra snowpack, the District's *2006 Water Supply/Demand Estimate*, and the effect of the proposed EWA sale thereon.

Appendix C

Components of a Groundwater Management Plan