# City of Davis / UC Davis

## Groundwater Management Plan

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# SECTION 1
# INTRODUCTION

## 1.1 Plan Authority and Administration

On October 4, 2005, the City of Davis formally approved Resolution 05-278 directing the City of Davis Public Works Department to proceed with the development of an AB 3030 Groundwater Management Plan (GWMP or Plan). The resolution is included in Appendix A. The development of a GWMP for the City of Davis (City) and the University of California at Davis (UC Davis) is the next phase in a series of projects that focus on the sustainability of the groundwater yield and water quality of the local groundwater basin.

The California Water Code (CWC) provides the authority to adopt a groundwater management plan. The City and UC Davis are within the jurisdictional boundary of the Yolo County Flood Control and Water Conservation District (YCFCWCD). The YCFCWCD is currently developing a GWMP for areas within its jurisdiction. Under mutual agreement, the City and UC Davis GWMP was developed to address groundwater management needs specific to the City and UC Davis service areas, and these areas are not directly included or managed under the YCFCWCD GWMP. The City and UC Davis will continue to closely collaborate with YCFCWCD during plan implementation.

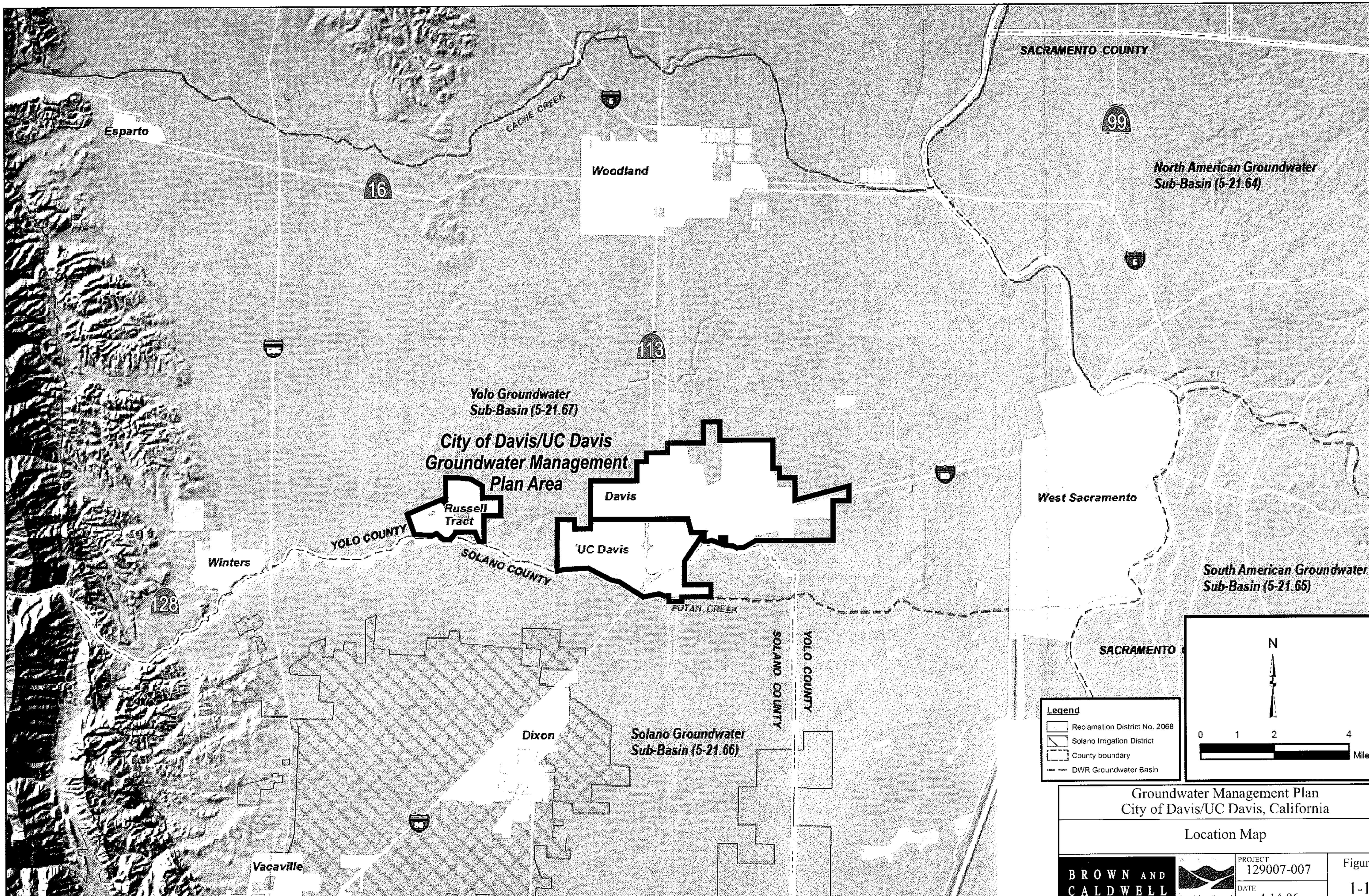
The GWMP incorporates information from the Phase I and Phase II Deep Aquifer Studies and other regional groundwater investigations into a plan for managing and monitoring the effects of groundwater utilization (Brown and Caldwell, 2005). The GWMP includes all mandatory and suggested components outlined in CWC §10750 *et seq.* and §10753.7. Compliance with these sections is required for eligibility for public funds administered by the California Department of Water Resources (DWR) for construction of groundwater projects. The statutes apply to funds authorized or appropriated after September 1, 2002. Adoption of the GWMP is not otherwise required under California law. The final Plan has been adopted by both the City and UC Davis, and filed with the DWR. Plan adoption resolutions are included in Appendix A.

The City and UC Davis have been formally partnering in groundwater management activities since 1996. In the last several years, the City and UC Davis have increased groundwater level and quality monitoring, and have worked with other entities to collect and disseminate water quality and quantity data for the Davis area. Additionally, the City and UC Davis collaborate with other entities within the region on locally-driven groundwater management activities. This GWMP documents the City and UC Davis planned groundwater management activities, and explains potential future actions to increase the effectiveness of groundwater management in the Davis area.

The area covered by the GWMP is described in Section 1.2, and Section 1.3 discusses the GWMP's objectives. The overall Plan development process, as described in the CWC, is presented in Section 1.4, and the public involvement process is described in Section 1.5. Components of the GWMP are outlined in Section 1.6.

## 1.2 Area Covered by Plan

The area covered by this Plan includes the combined City and UC Davis service areas. These service areas overlie the Yolo sub-basin and a small portion of the Solano sub-basin. The Davis/UC Davis GWMP area is shown in Figure 1-1.




Groundwater Management Plan
City of Davis/UC Davis, California

Location Map

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PROJECT 129007-007

DATE 4-14-06

Figure 1-1

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## 1.3 Plan Objectives

The GWMP goal is to maintain or enhance local groundwater quantity and quality, resulting in as reliable a groundwater supply as possible for beneficial uses and avoidance of adverse subsidence. The proposed GWMP includes all required and recommended components and all applicable voluntary components per CWC§10750 *et seq.* as described in DWR's Bulletin 118, California Groundwater – Update 2003 (DWR, 2003). Specifically, the GWMP endeavors to:

- Minimize the long-term drawdown of groundwater levels;
- Protect groundwater quality such that it remains viable for public water supply;
- Prevent adverse inelastic land surface subsidence from occurring as a result of groundwater pumping;
- Minimize changes to surface water flows and quality that directly affect groundwater levels or quality;
- Minimize the effect of groundwater pumping on surface water flows and quality in sensitive areas of Putah Creek;
- Develop, plan, and implement groundwater replenishment and cooperative management projects; and
- Work collaboratively with and understand the goals and objectives of entities engaged in groundwater management in surrounding areas.

## 1.4 Plan Development Process

There are five main steps in the development of a GWMP as defined under CWC § 10753.2 through 10753.6; these are summarized below.

Step 1- Provide public notification of a hearing on whether or not to adopt a resolution of intention to draft a GWMP and subsequently complete a hearing on whether or not to adopt a resolution of intention to draft a GWMP. Following the hearing, draft a resolution of intention to draft a GWMP.

Step 2 - Adopt a resolution of intention to draft a GWMP and publish the resolution of intention in accordance with public notification (6066 gov. code). Upon written request, provide copy of resolution of intention to interested persons. The Davis City Council adopted the resolution of intention to develop a GWMP on October 4, 2005. This resolution can be found in Appendix A. UC Davis senior administrative management authorized UC Davis staff to participate in the development and implementation of the GWMP.

Step 3 - Prepare draft GWMP within two years of resolution of intention adoption. Provide to the public a written statement describing the manner in which interested parties may participate in developing the GWMP, as discussed in Section 1.5 below. This may also include appointing a Technical Advisory Committee (TAC).

Step 4 - Provide public notification (6066 gov. code) of a hearing on whether or not to adopt the GWMP, followed by the hearing on adopting the GWMP.

Step 5 - If protests are received for less than 50 percent of the assessed value of property in the Plan area, the GWMP may be adopted within 35 days after completion of Step 4 above. If protests are received for greater than 50 percent of the assessed value of the property in the Plan area, the Plan will not be adopted.

## 1.5 Public Outreach and Education

A public involvement strategy including scheduled public and stakeholder inputs, policy establishment for notifying public/stakeholders of project meetings or plan reviews, and policy establishment for public/stakeholder input documentation was developed.

Public outreach and education are a focus of the City and UC Davis' resource and conservation goals. The City and UC Davis encourage two-way dialogue, characterized by information dissemination and requests for suggestions and feedback on both City and UC Davis activities. In addition to public outreach completed during development of the GWMP as required under CWC § 10753.2 through 10753.6, the City and UC Davis have regularly disseminated information on GWMP development as part of their ongoing public outreach effort.

The City and UC Davis have reported on GWMP development during meetings with interested stakeholders. Stakeholder groups include nearby water districts, local governments, and large private well operators near the plan area. Most Yolo County stakeholders are represented through the Water Resources Association of Yolo County (WRA) and the YCFCWCD. Individuals attending these meetings typically represent a wide range of organizations, including watershed groups, water agencies, independent groundwater users, and interest groups. Future GWMP public outreach and education will focus on GWMP implementation activities.

In particular, the GWMP team presented information on GWMP development and on the draft GWMP report at meetings of the City's Natural Resources Commission (NRC) and the WRA Technical Advisory Committee (WRA TAC), with opportunity for the public to provide comment directly to Natural Resource Commission and WRA representatives. The Notice of Intention to adopt the GWMP and the draft GWMP were also presented at Davis City Council meetings, with opportunities given for comments by stakeholders and the public. Meeting dates are listed in Table 1-1. Additional details on stakeholder involvement and interagency planning are provided in Sections 3.7 and 3.8, respectively.

**Table 1-1. Stakeholder and Public Meetings**

| Date | Meeting Group |
|---|---|
| 10/4/05 | Davis City Council |
| 11/16/05 | WRA TAC |
| 11/28/05 | Davis NRC |
| 3/27/06 | Davis NRC |
| 3/29/06 | WRA TAC |
| 5/16/06 | Davis City Council |

## 1.6 Management Plan Components

This GWMP includes the following CWC required and DWR recommended components (DWR, 2003):

- **Seven mandatory components of CWC § 10750 *et seq.*** CWC § 10750 *et seq.* requires GWMPs to include several components to be eligible for award of funding administered by DWR for the construction of groundwater projects or groundwater quality projects. These amendments to the CWC were included in Senate Bill 1938, effective January 1, 2003. The amendments apply to funding authorized or appropriated after September 1, 2003.

- **Twelve voluntary components of CWC § 10750 *et seq.*** CWC § 10750 *et seq.* includes 12 specific technical issues that could be addressed in GWMPs to manage the basin optimally and protect against adverse conditions.

- **Seven recommended components in DWR Bulletin 118-223**

Table 1-2 summarizes the CWC required and DWR recommended GWMP components pursuant to current guidance and the report section where each component is addressed.

**Table 1-2. City and UC Davis GWMP Components**

| Plan Component Description | GWMP Section |
|---|---|
| **CWC § 10750 *et seq.*, Mandatory Components** | |
| 1. Documentation of public involvement statement | 1.5 |
| 2. Establish basin management objectives | 3.2, 3.5.1 |
| 3. Monitoring and management of groundwater elevations, groundwater quality, inelastic land surface subsidence, and changes in surface water flows and quality that directly affect groundwater levels or quality or are caused by pumping | 3.4 |
| 4. Plan to involve other agencies located within groundwater basin | 3.7.1 |
| 5. Adoption of monitoring protocols by basin stakeholders | 3.4, 3.5.3 |
| 6. Map of groundwater basin showing area of agency subject to GWMP, other local agency boundaries, and groundwater basin boundary as defined in DWR Bulletin 118 | Figure 1-1 |
| 7. For agencies not overlying groundwater basins, prepare GWMP using appropriate geologic and hydrogeologic principles. | 1.2 |
| **CWC § 10750 *et seq.*, Voluntary Components** | |
| 8. Control of saline intrusion | 3.5.5 |
| 9. Identification and management of wellhead protection areas and recharge areas | 3.5.4 |
| 10. Regulation of the migration of contaminated groundwater | 3.5 |
| 11. Administration of well abandonment and well destruction program | 3.5.2 |
| 12. Mitigation of conditions of overdraft | 3.6.3 |
| 13. Replenishment of groundwater extracted by water producers | 3.6.3 |
| 14. Monitoring of groundwater levels and storage | 3.4.1 |
| 15. Facilitating conjunctive use operations | 3.6.2, 3.6.3 |
| 16. Identification of well construction policies | 3.5.1 |
| 17. Construction and operation by local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects | 3.6.4 |

**Table 1-2. City and UC Davis GWMP Components (continued)**

| Plan Component Description | GWMP Section |
|---|---|
| **CWC § 10750 *et seq.*, Mandatory Components** | |
| 18. Development of relationships with state and federal regulatory agencies | 3.7.1 |
| 19. Review of land use plans and coordination with land use planning agencies to assess activities that create reasonable risk of groundwater contamination | 3.5.2 |
| **DWR Bulletin 118 Suggested Components** | |
| 20. Manage with guidance of advisory committee | 3.6.1, 3.7.2 |
| 21. Describe area to be managed under GWMP | 1.2 |
| 22. Create link between BMOs and goals and actions of GWMP | Section 3 |
| 23. Describe GWMP monitoring program | 3.4 |
| 24. Describe integrated water management planning efforts (i.e. Yolo County IRWMP) | 3.8 |
| 25. Report on implementation of GWMP | 3.9.1 |
| 26. Evaluate GWMP periodically | 3.9.2 |

## 1.7 Groundwater Management Plan Organization

This GWMP is organized into four sections:

- Section 1 – Introduction;
- Section 2 – Water Resources (Physical) Setting;
- Section 3 – Plan Implementation; and
- Section 4 – References.

Section 2 provides an overview of existing physical conditions that should be understood and considered when developing and implementing groundwater management activities. The section includes information on topics such as precipitation, hydrology, geology, groundwater levels, groundwater quality, existing well infrastructure, and water demand and supply. The understanding of existing physical conditions helps define groundwater management needs, objectives, and actions.

Section 3 includes the major themes, or components, that will be addressed during Plan implementation. The five groundwater management components included in the Plan are groundwater monitoring, groundwater resource protection, groundwater sustainability, stakeholder involvement, and interagency water resource planning. Nested under each of these components are specific implementation actions that the City and UC Davis will be pursuing.

Section 4 includes Plan references.

# SECTION 2
# PHYSICAL SETTING

## 2.1 Introduction

The City of Davis and most of UC Davis are located in the Yolo Subbasin (Subbasin 5-21.67) of the Sacramento Valley Groundwater Basin as defined in the California DWR Bulletin 118 update (DWR, 2003). Figure 1-1 shows the location of the groundwater subbasins. The Yolo Subbasin is bounded by Cache Creek on the north; the Sacramento River on the east; Putah Creek on the south; and the Coast Range on the west (DWR, 2004).

## 2.2 Topography

Land surface elevations within the Yolo Subbasin range from approximately 0 feet along the southeastern edge to approximately 630 feet along the western edge. Except near the western edge of the basin, where land surface elevations increase with proximity to the Coast Range, the topographic relief is low. Land surface elevations within the City and UC Davis service areas range from approximately 30 to 80 feet above sea level. The Plainfield Ridge, the southern topographic expression of the Dunnigan Hills anticline, is an area of slightly elevated rolling hills located approximately four miles west of Davis. The Yolo Bypass, the flood basin of the Sacramento River, is located approximately three miles east of Davis (Figure 1-1).

## 2.3 Climate and Precipitation

The Yolo Subbasin has a Mediterranean climate with cool, wet winters and hot, dry summers. Regionally, temperature and precipitation vary with elevation, with the lower temperatures and higher precipitation occurring at higher elevations. The region is subject to wide variations in annual precipitation and experiences periodic dry periods. Summers can be hot at times with weekly periods of 100 degree Fahrenheit temperatures, which greatly increase summer irrigation requirements.

Based on the historical data obtained from the Western Regional Climate Center, average monthly temperature ranges from 45 to 75 degrees Fahrenheit. Extreme low and high daily temperatures are 12 and 116 degrees Fahrenheit, respectively.

The average annual precipitation varies from 18 inches near the eastern edge of the subbasin to 24 inches near the western edge (DWR, 2004). However, because of the low topographic relief in the eastern part of the subbasin, temperature and precipitation do not vary greatly within the City and UC Davis.

Figure 2-1 shows the annual precipitation for the Davis area for the period 1872 through 2004. Table 2-1 summarizes the annual precipitation statistics.

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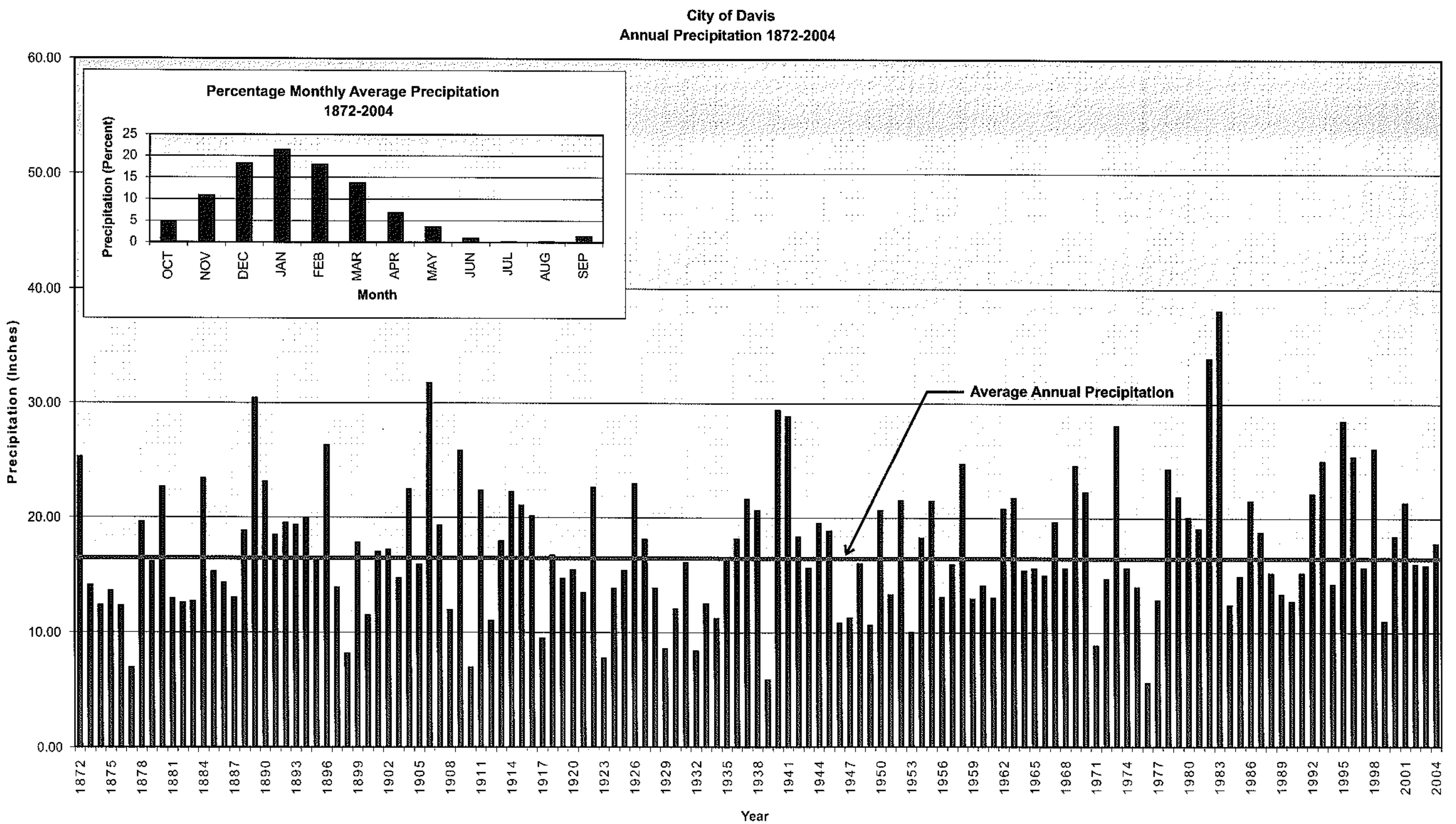


| BROWN AND CALDWELL / WEST YOST & ASSOCIATES | PROJECT 129007-007 | Groundwater Management Plan, City of Davis/UC Davis, California | Figure |
|---|---|---|---|
| | DATE 2-16-06 | Historic Precipitation | 2-1 |

**Table 2-1. Statistics for City of Davis Precipitation, 1872 through 2004**

| Statistic | Annual Precipitation, inches | Year |
|---|---|---|
| Minimum | 5.6 | 1976 |
| Maximum | 38.1 | 1983 |
| Median | 16.1 | 1931 |
| Mean | 17.4 | 1872-2004 |

Multi-year dry periods in the Davis area have included:

- 1873-1877
- 1881-1883
- 1885-1887
- 1897-1898
- 1917-1921
- 1923-1925
- 1928-1934
- 1946-1949
- 1959-1961
- 1976-1977
- 1988-1991

Figure 2-2 is an exceedance curve for Davis area precipitation data. The figure shows the frequency at which a given level of annual precipitation was met or exceeded. The curve can be used to gauge how frequently the precipitation recorded in any given year was equaled or exceeded in the past. For example, the minimum historical precipitation of 5.6 inches in 1976 was equaled or exceeded in 100 percent of all years from 1872 to 2004. The 16.1 median inches of precipitation recorded in 1931 was met or exceeded in 50 percent of past years.

## 2.4 Surface Water Hydrology

The major surface water features in the vicinity of the City and UC Davis service areas form the Yolo Subbasin's boundaries. These boundaries are Cache Creek on the north, Putah Creek on the south, and the Sacramento River on the east (Figure 1-1). Of these streams, Putah Creek is most significant because of its proximity to the City and UC Davis service areas. Putah Creek is the most southerly of the major tributaries to the Sacramento River originating in the Coast Ranges.

Putah Creek drains approximately 600 square miles beginning in the St. Helena Range south of Clear Lake. The stream flows southeasterly to Lake Berryessa, which inundated the Berryessa Valley beginning in 1959 with completion of Monticello Dam as part of the U.S. Bureau of Reclamation's Solano Project. Releases from Lake Berryessa are controlled at Lake Solano, near Winters. Flows are diverted at the Putah Diversion Dam for use in Solano Project service areas and are also released to Lower Putah Creek. Below the Putah Diversion Dam, the stream flows easterly approximately 20 miles to the Yolo Bypass and eventually discharges to Cache Slough on the Sacramento–San Joaquin River Delta.

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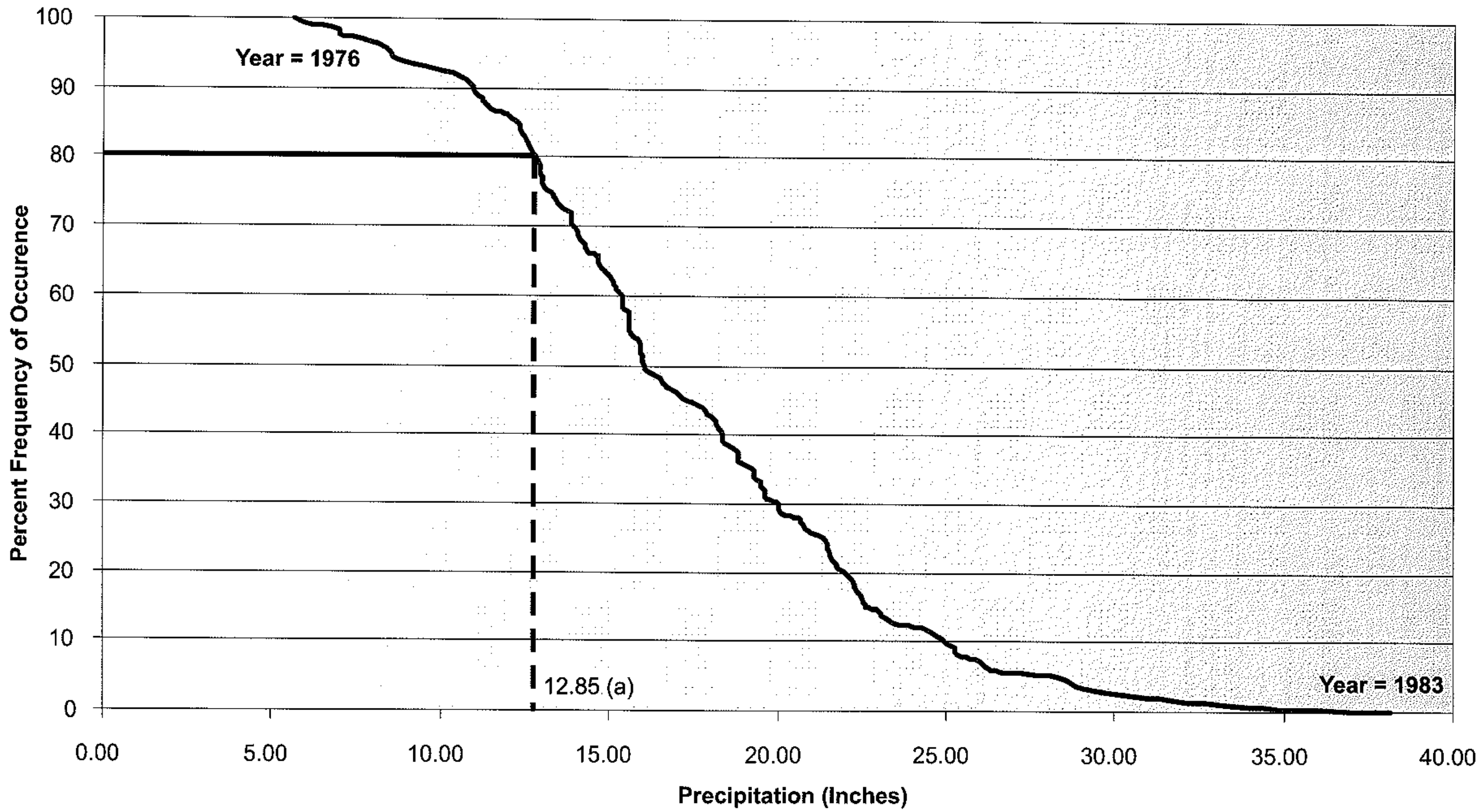



(a) Example: 80% chance of annual rainfall exceeding 12.85 inches and a 20% chance of annual rainfall less than or equal to 12.85 inches, which is one definition of a dry year in Section 3 of this plan.

| | | | |
|---|---|---|---|
| BROWN AND CALDWELL / WEST YOST & ASSOCIATES | PROJECT 129007-007 | Groundwater Management Plan, City of Davis/UC Davis, California | Figure 2-2 |
| | DATE 4-14-06 | Precipitation Exceedance Curve, 1872-2004 | |

There are no natural surface water inflows to Lower Putah Creek east of Winters, and, because the stream occupies a channel ridge, precipitation falling outside of the channel does not enter the stream (Tomasson, et. al., 1960). The stream channel forks about three miles southwest of Davis. The south fork was reportedly excavated beginning in the 1890's and follows a section line for nearly four miles (Tomasson, et. al., 1960). The former north fork, which passes through the UC Davis service area, is separated from the south fork by a flood control levee. All flow is along the south fork.

Following a series of legal actions beginning in 1990, a settlement known as the Putah Creek Accord was negotiated in 2000 to resolve disputes involving the Putah Creek Council, the City of Davis, UC Davis (Yolo parties), the Solano County Water Agency (SCWA), Solano Irrigation District (SID), Maine Prairie Water District and the Cities of Vacaville, Fairfield, Vallejo and Suisun City (Solano parties). The settlement agreement provides for instream flows required for maintenance and enhancement of aquatic and related resources in Lower Putah Creek, with provisions for reducing these flows when storage in Lake Berryessa is low. The settlement agreement also includes a process for addressing illegal surface water diversions from Putah Creek. The Yolo and Solano parties formed the Lower Putah Creek Coordinating Committee and established a streamkeeper position to implement the settlement agreement.

The settlement agreement requires SCWA and SID to maintain certain instream flows measured at the Putah Diversion Dam, the Interstate 80 Bridge over Putah Creek, and the western side of the Yolo Bypass. Releases must be sufficient to maintain flows from Old Davis Road Bridge to the western boundary of the Yolo Bypass throughout the year except in certain years when reservoir storage is low. During years of low reservoir storage, flow must be maintained to the Interstate 80 Bridge.

SCWA has established the Lower Putah Creek Riparian Water Program (PRWP) to differentiate riparian and non-riparian water downstream of the Putah Diversion Dam. SCWA defines riparian water as any water derived from precipitation or rising groundwater that would exist in Lower Putah Creek in the absence of the Solano Project. Under the PRWP, Lower Putah Creek is divided into five reaches:

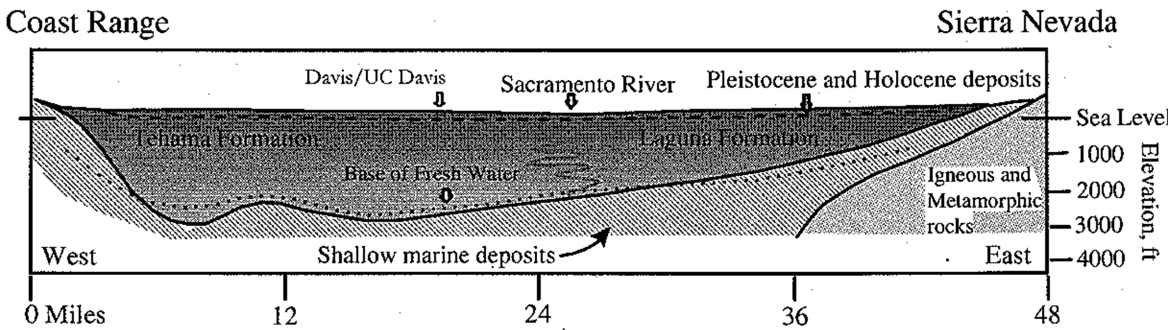
a) Putah Diversion Dam to Interstate 505 Bridge (a losing reach)
b) Interstate 505 Bridge to Stevenson Bridge (a gaining reach)
c) Stevenson Bridge to Interstate 80 Bridge (a losing reach)
d) Interstate 80 Bridge to Mace Boulevard (a losing reach)
e) Mace Boulevard to Yolo Bypass (a losing reach).

Only the reach from Interstate 505 Bridge to below Stevenson Bridge is gaining due to groundwater seepage into the creek. The gaining characteristics may be attributable to geologic factors related to the Dunnigan Hills Anticline and Plainfield Ridge. Along all other reaches, seepage occurs from the creek to the underlying aquifer. The net stream loss or gain is the net total of groundwater seepage, precipitation, and evapotranspiration under the PRWP. Groundwater elevation measurements are used to calculate seepage to or from Putah Creek.

## 2.5 Hydrogeology

The Sacramento Valley in the vicinity of City and UC Davis is filled by a thick sequence of marine sedimentary rock of Late Jurassic (159 million years [my] before present) to Eocene (34 my) age, unconformably overlain by a sequence of continental sedimentary deposits of Pliocene (5 my) and younger age Pliestocene and Holocene deposits (Harwood and Helley, 1987).

A generalized geologic cross section for the Sacramento Valley is shown in Figure 2-3.

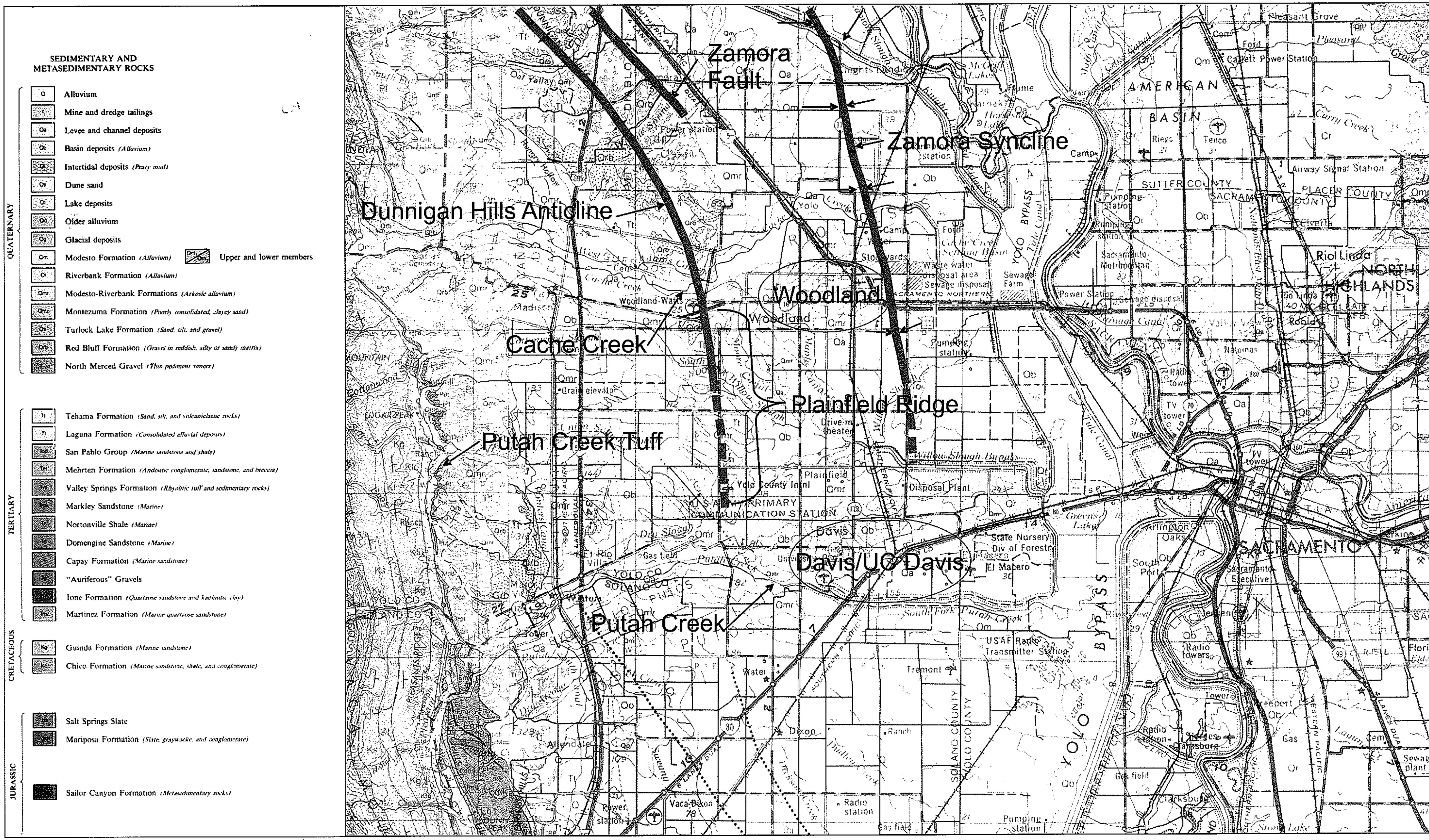



Source: California Department of Water Resources, 1978

**Figure 2-3. Sacramento Valley Geologic Cross Section**

The older, deeper marine rocks contain saline water. The freshwater aquifers in the vicinity of City and UC Davis occur in the overlying continental sedimentary deposits. Figure 2-4 is a geologic map encompassing the City, UC Davis, and vicinity showing the major types of exposed sedimentary deposits and important structural features in the area (CGS, 1981). Figure 2-5 is a geologic column that provides a conceptual overview of the freshwater portion of the aquifer in the Davis area.

Shallow groundwater in the Davis area generally occurs under unconfined conditions in the recent Holocene stream channel deposits (DWR, 1978). At greater depths, groundwater occurs under mostly semiconfined to confined conditions in a heterogeneous aquifer system, composed of predominantly fine-grained sediments enclosing discontinuous lenses of sand and gravel. The aquifer properties, including hydraulic conductivity, vertical leakance and degree of confinement are dependent on the properties of the fine grained units (Williamson, et. al., 1989; Bertoldi, et. al., 1991). The geologic formations comprising the freshwater aquifer are discussed from oldest to youngest in the following sections.




N

Not to scale.

References:

California Geological Survey, 1981, Geologic Map of the Sacramento Quadrangle, compiled by D.L. Wagner, C.W. Jennings, T.L. Bedrossian and E.J. Bortugno, 1:250,000, second printing 1987.

California Geological Survey, 1982, Geologic Map of the Santa Rosa Quadrangle, compiled by D.L. Wagner and E.J. Bortugno, 1:250,000, second printing 1999.

Harwood, D.S. and E.J. Helley, 1987, U.S. Geological Survey Professional Paper 1359, Late Cenozoic Tectonism of the Sacramento Valley

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City of Davis/UC Davis, California

Geologic Map

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DATE 3-17-06

Figure 2-4

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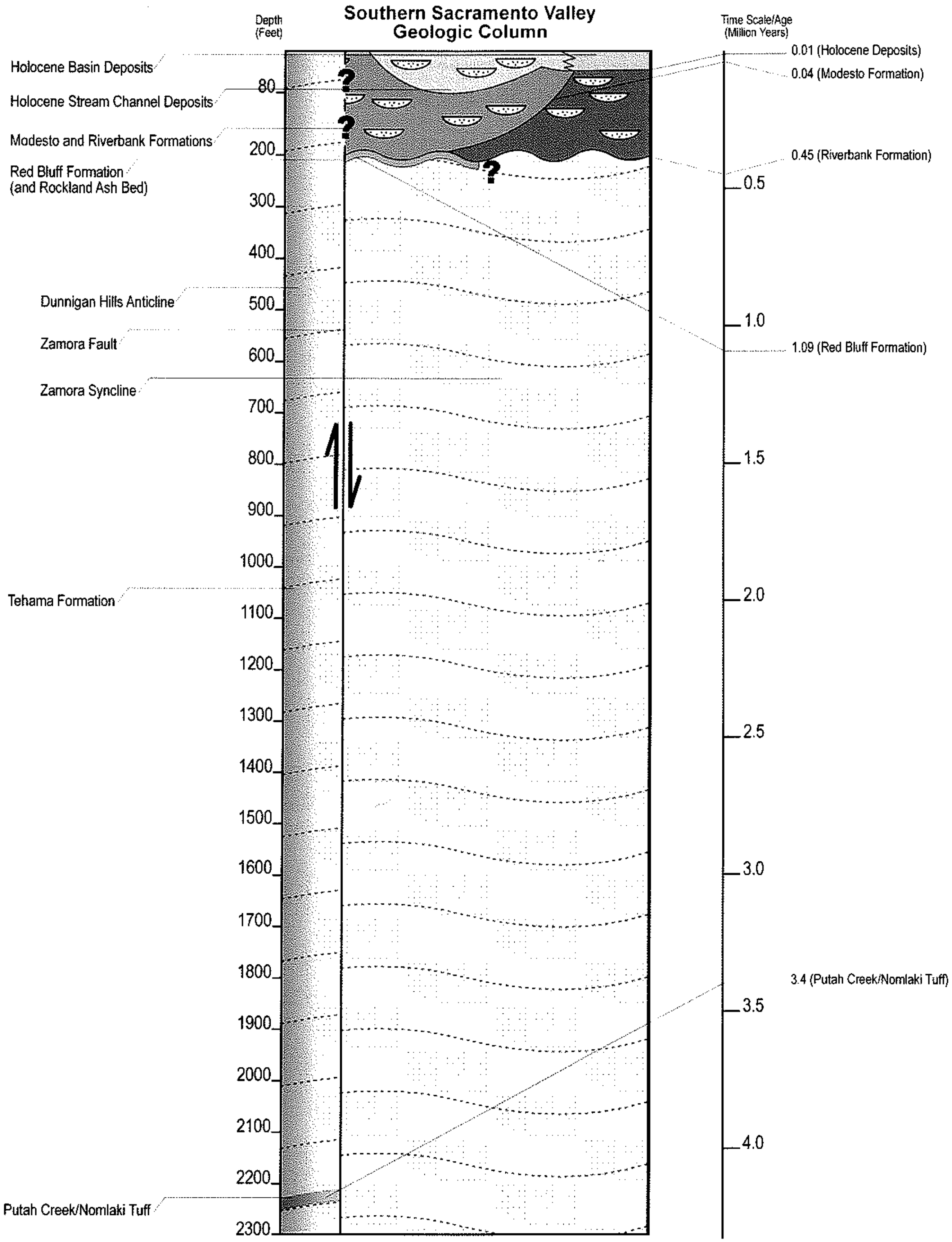


(Approximate Base of Freshwater: 2,800 Feet)

| | | | |
|---|---|---|---|
| BROWN AND CALDWELL / WEST YOST & ASSOCIATES | PROJECT 129007-007 | Groundwater Management Plan<br>City of Davis/UC Davis, California | Figure<br>2-5 |
| | DATE 3-9-06 | Conceptual Geologic Column<br>of the Sacramento Valley | |

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### 2.5.1 Tehama Formation

The Tehama Formation (Figure 2-5) forms the oldest, deepest and thickest part of the freshwater aquifer in the Davis area. The Tehama Formation consists of up to 2,500 feet of moderately compacted silt, clay, and silty fine sand enclosing thin, discontinuous lenses of sand and gravel, silt and gravel deposited in a fluvial (river-borne) environment. In outcrop, the Tehama Formation consists of pale green, gray, and tan sandstone and siltstone with lenses of crossbedded pebble and cobble conglomerates. Based on the mineralogy of surface exposures, the sediments were derived from erosion of the Coast Ranges and Klamath Mountains (Russell, 1931; DWR, 1978, 2004; Helley and Harwood, 1985). The sediments were distributed by ancestral east-flowing Coast Range drainages, and deposited into the Sacramento Valley, which, at that time, was similar but considerably wider than it is today (Olmsted and Davis, 1961). The overall south-flowing drainage of the Sacramento Valley also distributed and reworked these deposits, as evidenced by the crossbedding seen in the coarser layers of the formation and sourcing of some sediments from the north (Olmsted and Davis, 1961).

The Tehama Formation is exposed at the land surface over extensive areas on the eastern flank of the Coast Range including the Dunnigan Hills and English Hills. Smaller outcrops are present on the Plainfield Ridge. The Tehama Formation is buried beneath younger sediments in most other areas of the Sacramento Valley (Figure 2-4).

The age of the Tehama Formation is constrained by volcanic rock units, which can be time-correlated with rock units deposited near the base and slightly above the top of the Tehama Formation. The Putah Creek/Nomlaki Tuff, which is located near the base of the Tehama Formation has a radiometrically determined age of 3.4 my (Evernden et. al, 1964; Harwood and Helley, 1987). The Putah Creek Tuff is exposed at the land surface in the Capay Hills northwest of the Davis area (Figure 2-4). Figure 2-5 shows the estimated stratigraphic position of the Putah Creek/Nomlaki Tuff in the subsurface, based on the total thickness of the Tehama Formation. The Tehama Formation is unconformably overlain by a thin gravel pediment known as the Red Bluff Formation (Figures 2-4 and 2-5). The age of the Red Bluff Formation is constrained to be 0.45 to 1.09 my by the radiometrically determined ages of the Rockland ash bed and the Deer Creek basalt, respectively (Harwood, et. al., 1981; Harwood and Helley, 1987).

The Tehama Formation is the primary water-bearing stratigraphic unit in the area. The permeability of the Tehama Formation is highly variable but generally less than the overlying Quaternary alluvium. Because of the relatively large thickness, wells can yield up to several thousand gallons per minute (gpm) (DWR, 2004). The majority of irrigation and public supply wells in the Davis area are completed in the Tehama Formation (DWR, 2004).

### 2.5.2 Riverbank and Modesto Formations

Wells penetrating the sand and gravel units of the Riverbank and Modesto Formations produce up to about 1,000 gpm (DWR, 2004). The majority of the small domestic wells in the Davis area are completed in the Riverbank and Modesto Formations (DWR, 2004).

The Tehama and Red Bluff Formations are unconformably overlain by the late Pleistocene age Riverbank and Modesto Formations. These formations consist of up to 200 feet of loose to moderately compacted silt, silty clay, sand and gravel deposited in alluvial depositional environments during periods of world-wide glaciation (Lettis, 1988; Weissmann, et. al., 2002; DWR, 2004). In the Davis area, the Riverbank and Modesto Formation are not directly related to glacial activity, because glaciers were generally not present in the Coast Ranges. Instead, the formations were deposited in response to changes in base level and increased precipitation during the glacial periods.

Figure 2-4 shows the distribution of the Riverbank and Modesto Formation in the Davis area. The formations are exposed at the land surface along the channels of Cache and Putah Creeks, and along the fringes of the Dunnigan Hills and Coast Range, where they form a series of coalescing alluvial fans, emanating from the mouths of the creeks.

The age of the Riverbank Formation ranges from 0.13 to 0.45 my and corresponds to the Illinoisan and older glacial stages. The age of the Modesto Formation ranges from approximately 0.01 to 0.042 my and correlates to the Wisconsin glacial stage.

### 2.5.3 Holocene Stream Channel and Basin Deposits

According to DWR, Holocene stream channel deposits form a shallow aquifer of moderate to high permeability, but with limited capacity due to the relatively restricted lateral and vertical extents of the deposits. Some of the shallower domestic wells in the Davis area may be screened in Holocene stream channel deposits (DWR, 2004). Because of their low permeability, limited extent, and generally poor water quality, Holocene flood basin deposits are typically not used for groundwater production (DWR, 2004). Figure 2-4 shows the distribution of stream channel and basin deposits in the Davis area.

Holocene stream channel and basin deposits are the youngest sediments in the region, with ages of 10,000 years or less. The stream channel deposits consist of up to 80-foot sections of unconsolidated clay, silt, sand and gravel reworked from older formations by streams.

Holocene flood basin deposits are very young near-surface deposits formed during flood events when streams overtopped their natural levees flooding the surrounding area. As the floodwater spread, the current velocity decreased, resulting in deposition of silts, clays and fine sands.

### 2.5.4 General Structure

Tectonism related to changing dynamics of the north-northwest trending San Andreas fault plate boundary along the California coast continued to uplift and deform the Coast Ranges after the deposition of the Tehama Formation (Dickenson and Snyder, 1979; Harwood and Helley, 1987). The formation was uplifted and regionally tilted to the east, and the western edge of the formation was partially eroded, leaving it exposed on the lower east flank of the Coast Ranges. Stresses related to the San Andreas fault system extended to the western margin of the Sacramento Valley after the initial uplift that tilted the formation eastward. These stresses created a set of broad folds expressed geographically as the Dunnigan Hills (Harwood and Helley, 1987) (Figure 2-4). Other structural features are located in the subsurface.

The significant structural features in the Davis area are the Zamora fault, the Dunnigan Hills anticline (Plainfield Ridge), and the Zamora syncline (Figure 2-4). These structural features affect rock units at least as young as the Red Bluff Formation, which indicates that the structural deformation was occurring as recently as 1.09 my – the youngest age of the Red Bluff Formation – and may be continuing at present (Harwood and Helley, 1987).

Folds

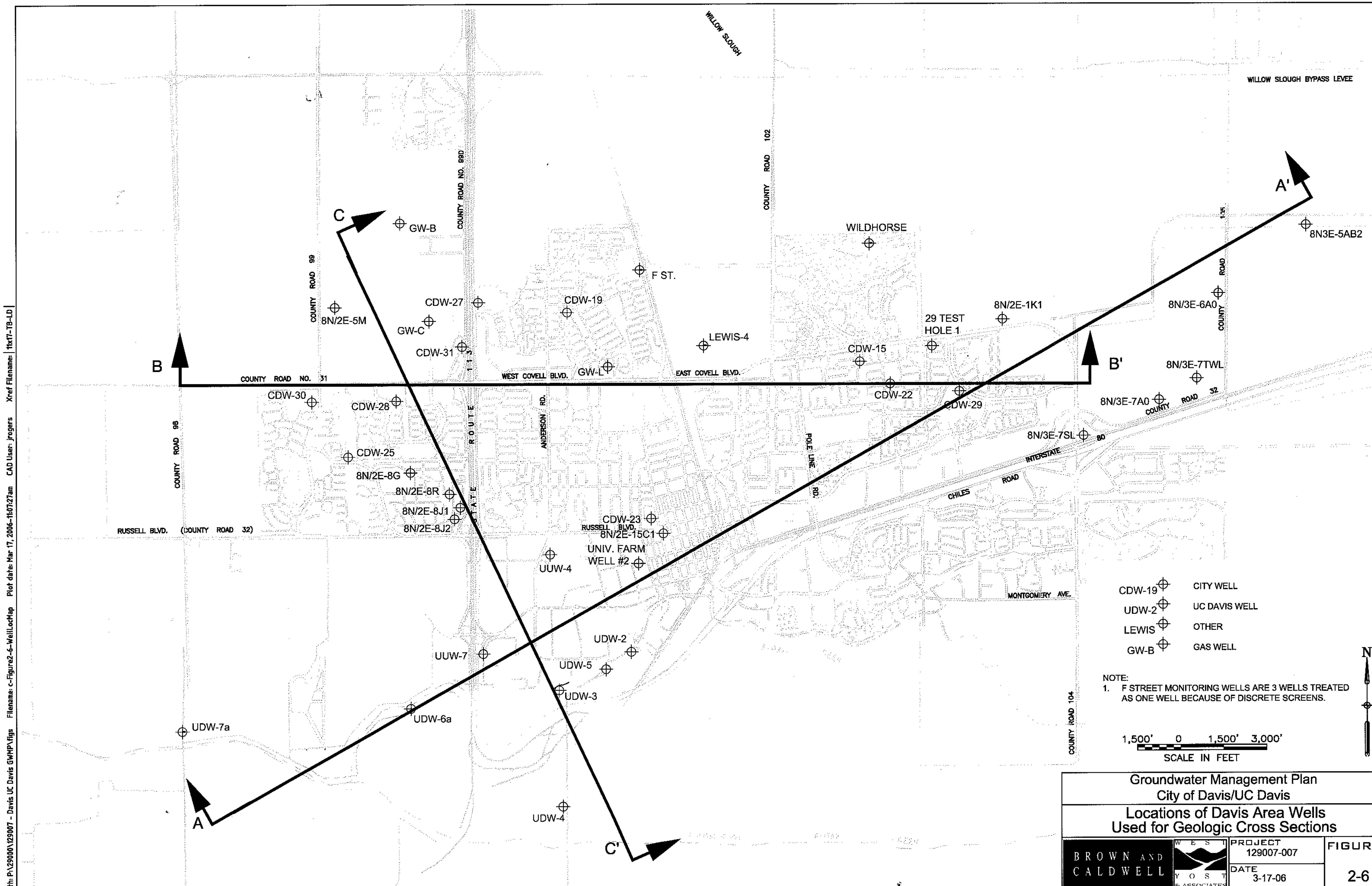
The Dunnigan Hills are the topographic expression of a doubly plunging anticline, a fold in which the central axis is raised relative to the limbs (Figures 2-3, 2-4 and 2-5). The axis of the Dunnigan Hills anticline is oriented northwest and plunges beneath the land surface on both ends of the structure. To the south-southeast the anticline is subtly expressed as the Plainfield Ridge, the alignment of low hills that project into the south-central portion of Yolo County along the western margins of Woodland and Davis (Harris and Brewster, 2005).

The Zamora syncline is a similar structural feature, except that the fold axis is lowered relative to the limbs of the fold and is not doubly plunging. The Zamora syncline is located in the subsurface east of the Dunnigan Hills and Zamora fault (Figure 2-5). The axis of the syncline passes beneath the east side of the City of Davis. The Zamora syncline has no topographic expression, which means that the thickness of post-Cretaceous sediments, including the Tehama Formation, is greater along the axis of the syncline than on the limbs (Figure 2-5). This means that the aquifer thickness is greatest along the axis of the syncline.

Folds may also affect groundwater conditions because the folds cause the elevation of geologic units to vary from place to place. This has two effects. First, since the Dunnigan Hills anticline is expressed at the land surface, erosion of the Tehama Formation has exposed older, lower sections of the formation along axis of the fold. Thus, the folds may affect recharge characteristics where the Tehama Formation is exposed at the land surface or is in contact with overlying formations that transmit recharging water. Second, the Tehama Formation sediments were typically aligned along bedding planes during deposition of the sediments, resulting in higher permeability along than across bedding planes. Typically, this results in a maximum permeability horizontally and a minimum permeability vertically. Subsequent folding of the bedding planes causes a reorientation of the direction of maximum and minimum permeability, which could tend to affect groundwater directions and rates of flow.

### 2.5.5 Davis Area Detailed Hydrogeologic Cross-Sections

Geologic cross sections were developed for the Davis area based on the Hydrogeologic Conceptualization Report (LSCE; 2003, 2005), Phase I Deep Aquifer Study cross-sections, and a detailed evaluation of water well and gas well logs in the north Davis area (Brown and Caldwell and West Yost & Associates, 2005). The section lines are shown in Figure 2-6. The cross sections including the sand sequence boundaries as defined by LSCE (2005) are shown in Figures 2-7, 2-8, and 2-9.




Groundwater Management Plan
City of Davis/UC Davis

Locations of Davis Area Wells
Used for Geologic Cross Sections

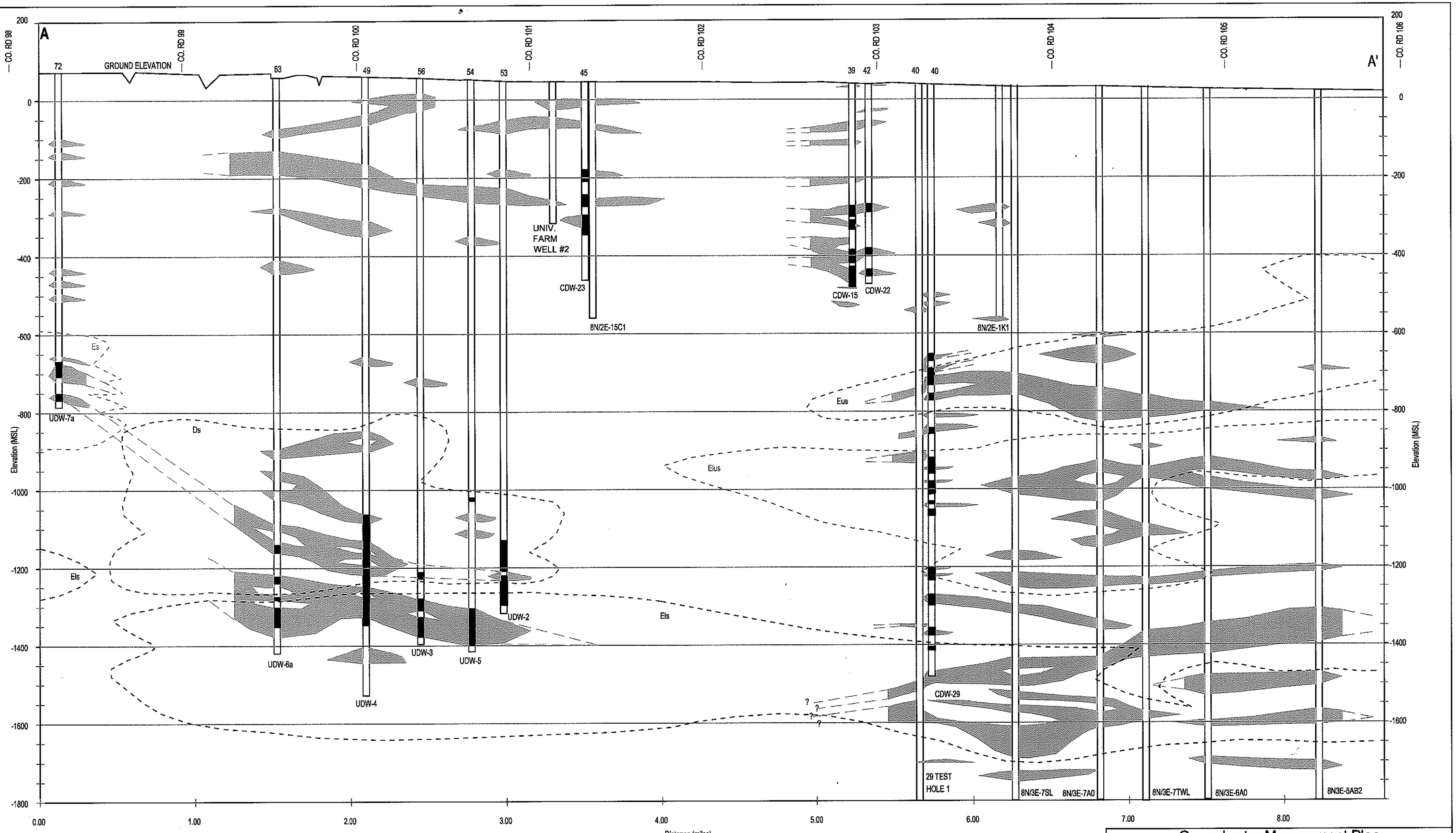
BROWN AND CALDWELL | WEST YOST & ASSOCIATES

PROJECT 129007-007

DATE 3-17-06

FIGURE 2-6

Path: P:\29000\129007 - Davis UC Davis GWMP\figs Filename: c-Figure2-6-WellLocMap Plot date: Mar 17, 2006-11:07:27am CAD User: jrogers Xref Filename: 11x17-TB-LD




| | | | |
|---|---|---|---|
| CDW- | CITY OF DAVIS WELL | ■ | WELL SCREENS |
| UDW- | UCD DOMESTIC WELL | | SAND AND GRAVEL |
| UUW- | UCD UTILITY WELL | - - - | SAND SEQUENCE, LSCE 2005 |

Groundwater Management Plan
City of Davis/UC Davis

Cross-section A-A'
Sand and Gravel Layers

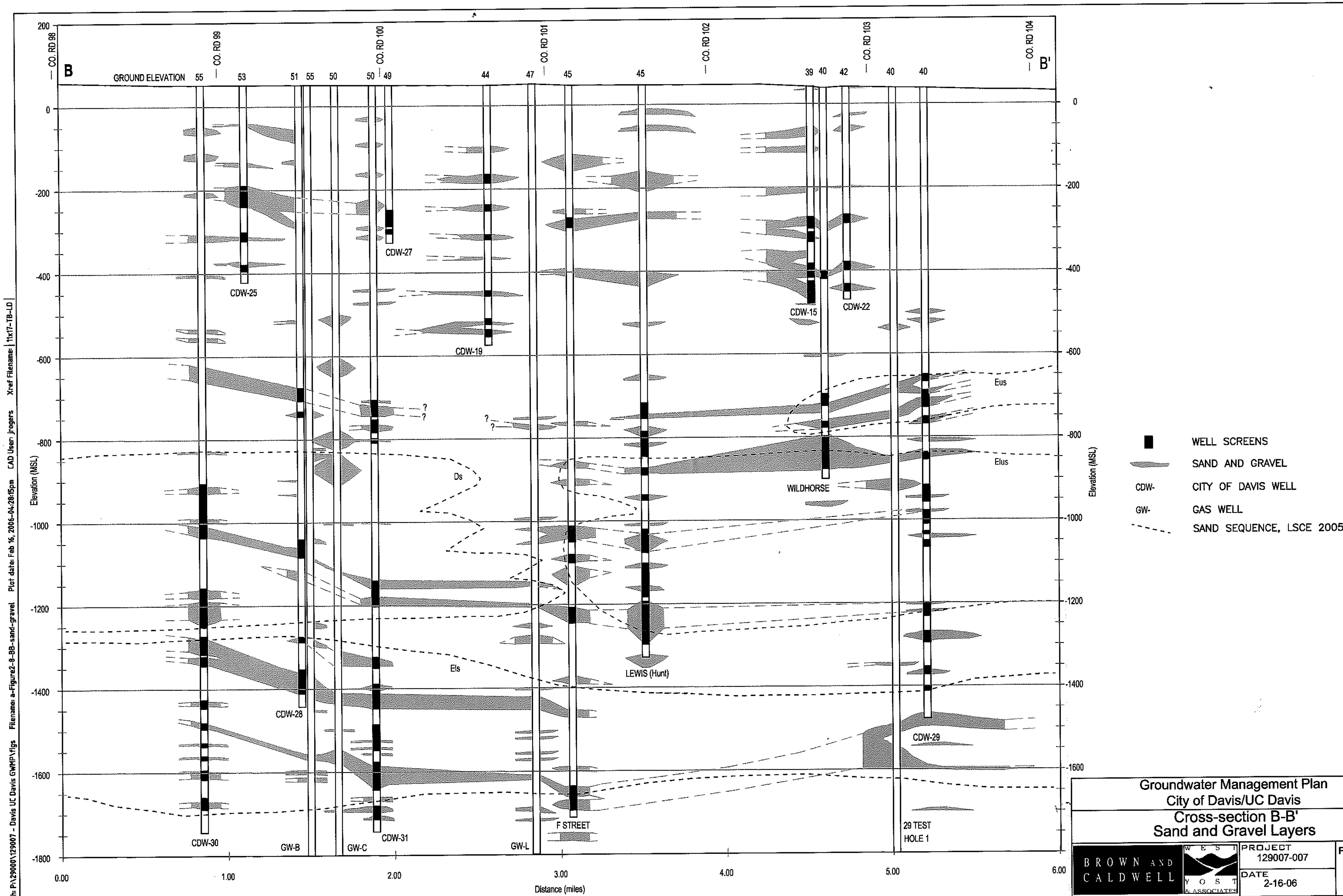
BROWN AND CALDWELL

WEST YOST & ASSOCIATES

PROJECT 129007-007

DATE 2-16-06

FIGURE 2-7

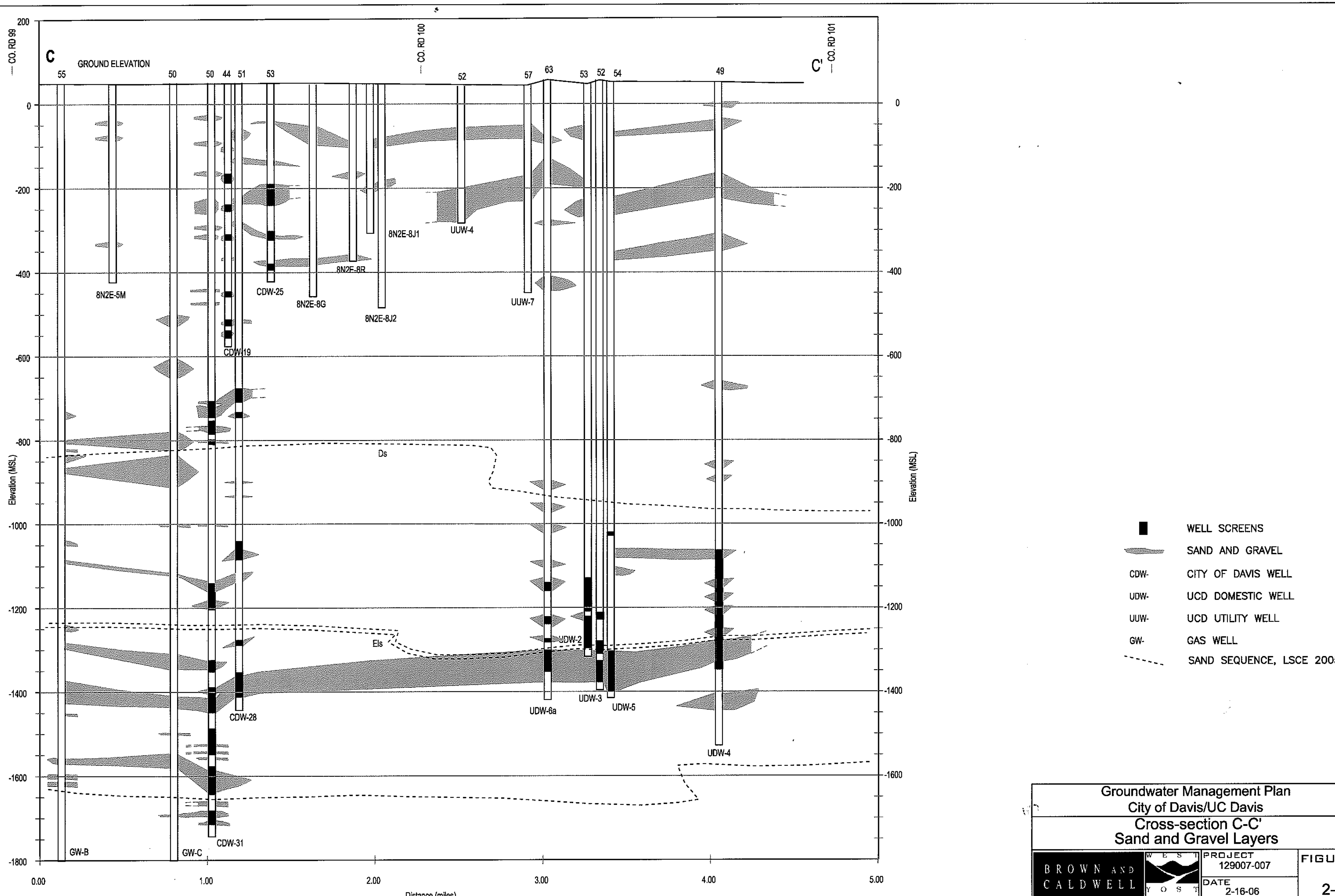



Groundwater Management Plan
City of Davis/UC Davis

Cross-section B-B'
Sand and Gravel Layers

BROWN AND CALDWELL | WEST YOST & ASSOCIATES

| PROJECT | FIGURE |
| --- | --- |
| 129007-007 | |
| DATE 2-16-06 | 2-8 |




Groundwater Management Plan
City of Davis/UC Davis

Cross-section C-C'
Sand and Gravel Layers

BROWN AND CALDWELL | WEST YOST & ASSOCIATES

PROJECT 129007-007
DATE 2-16-06

FIGURE 2-9

### 2.5.6 Soils

According to DWR (1978), which summarizes work performed by the United States Geological Survey (Bertoldi, 1974), most soils in the Davis area are either 1) "soils containing hardpan or other consolidated horizons that restrict the vertical flow of water, including soils over bedrock", such as in the Dunnigan Hills and other areas in which the Tehama Formation is exposed; or 2) "soils containing clay in sufficient quantities to impede the vertical flow of water", such as occur in most of the lands within the Davis area. Exceptions to this generalization are the soils in the vicinity of Putah and Cache Creeks, which have "few barriers to the vertical flow of water." Areas containing soils with few barriers to vertical flow are more likely to be the recharge areas for underlying aquifers

### 2.5.7 Groundwater Levels

Groundwater elevation measurements have been recorded in the Davis area for over 50 years and are available through the DWR Water Data Library at http://wdl.water.ca.gov. Representative hydrographs for shallow and intermediate depth wells in the Davis Area are shown on Figures 2-10 and 2-11. The figures show that groundwater elevations declined through the 1950s and 1960s. Groundwater elevations increased thereafter, in response to regional water supply projects implemented by SCWA (Lake Berryessa) and YCFCWCD (Indian Valley Reservoir).

In addition to the groundwater elevation changes resulting from variation in land and water use practices over time, the hydrographs also show that groundwater elevations have fluctuated in response to changes in precipitation. As noted in Section 2.2, the area experienced multiple years of below normal precipitation in 1976 through 1977 and 1988 through 1991. These periods are apparent in the hydrographs (Figure 2-10 and 2-11). Groundwater elevations in the falls of 1977 and 1992 were near the historical minima recorded in the mid 1960s. The maximum groundwater elevation measurements were recorded in spring 1983, the same year that the maximum annual precipitation was recorded (Figures 2-1 and 2-2).

Groundwater elevation contour maps depicting the range of groundwater elevations in the Davis area are shown on Figures 2-12 through 2-15. Near minimum groundwater elevations exemplified by fall 1964 and fall 1976 are shown on Figure 2-12 and 2-13. Figure 2-14 shows the maximum groundwater elevations measured in spring 1983, and Figure 2-15 shows recent groundwater elevations measured in fall 2003. Fall 2003 had near average precipitation (Figures 2-1 and 2-2).

### 2.5.8 Groundwater Movement

Generally, groundwater flow is from the margins of the Sacramento Valley toward the Sacramento River and then southward towards the Sacramento-San Joaquin Delta. Locally, near the losing stretches of Putah Creek east of the Plainfield Ridge, groundwater flow is northeast or southeast away from the creek. Groundwater pumping in several areas has created cones of depression that disrupt the broad groundwater flow patterns. Historically, groundwater elevations in the region have ranged from roughly -40 feet to 50 feet above mean sea level (msl).

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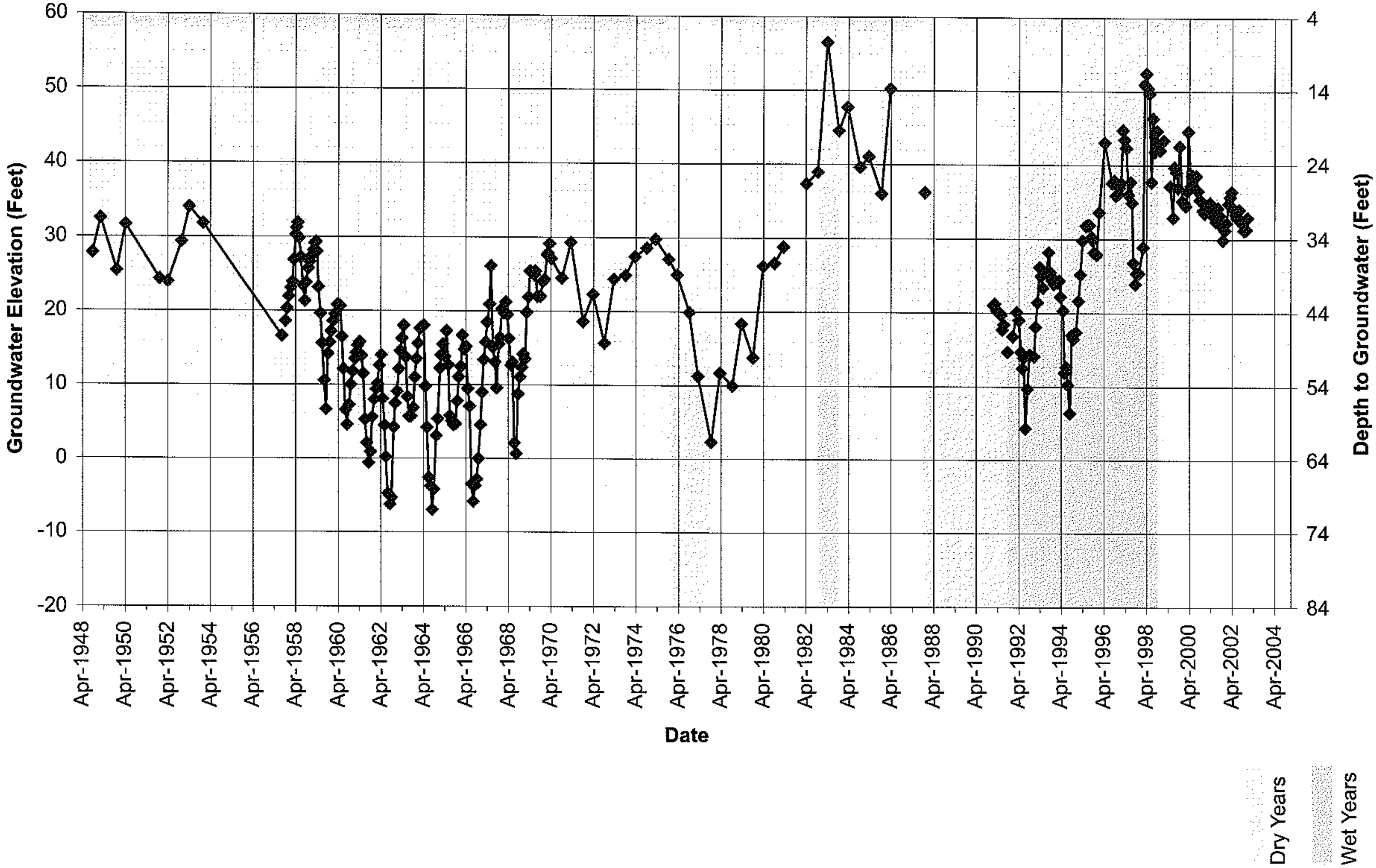


| BROWN AND CALDWELL / WEST YOST & ASSOCIATES | PROJECT 129007-007 | Groundwater Management Plan, City of Davis/UC Davis, California | Figure |
|---|---|---|---|
| | DATE 2-16-06 | Hydrograph of Department of Water Resources Well No. 08N01E12R003M, Elevation 64 feet | 2-10 |

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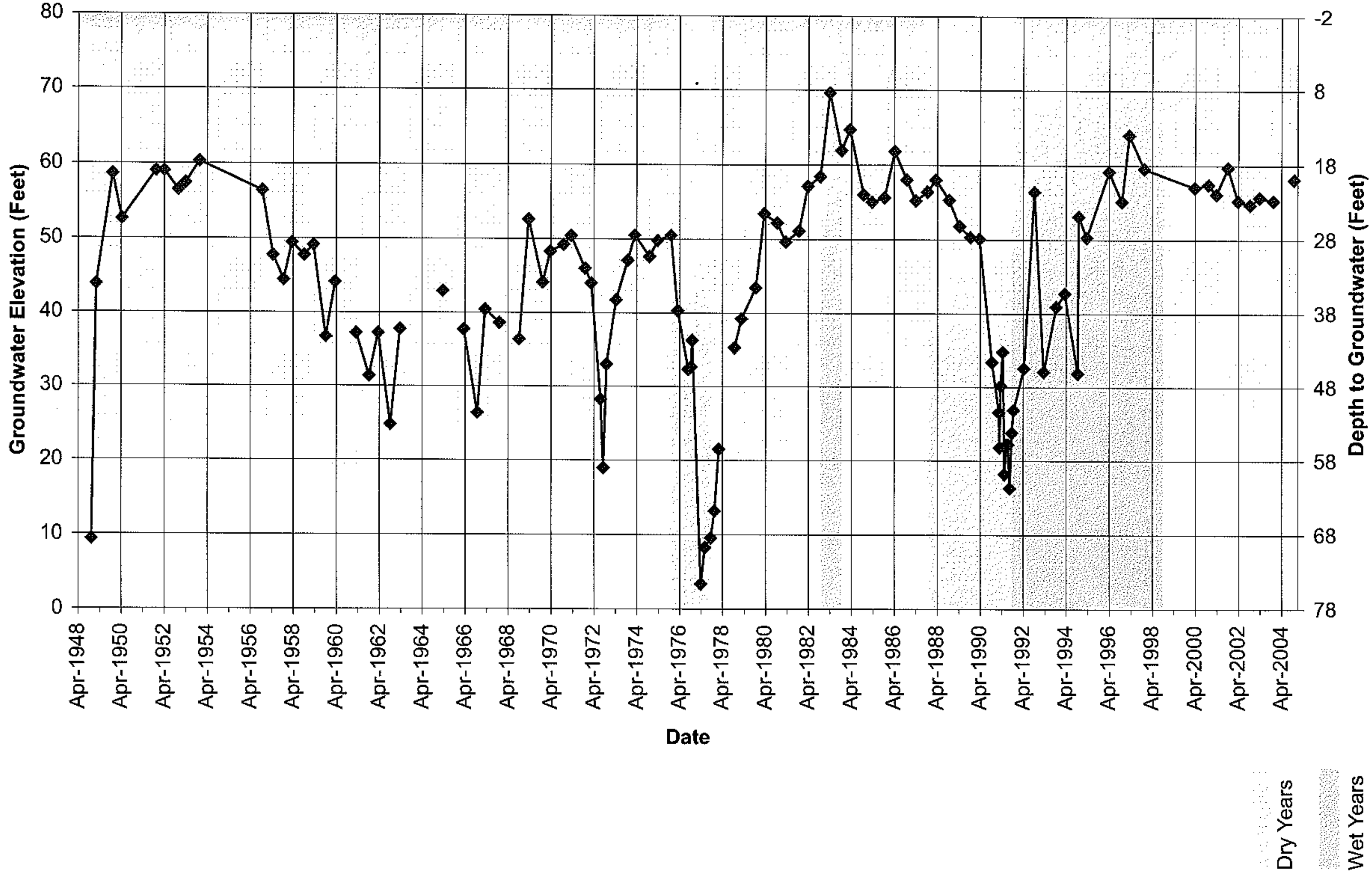
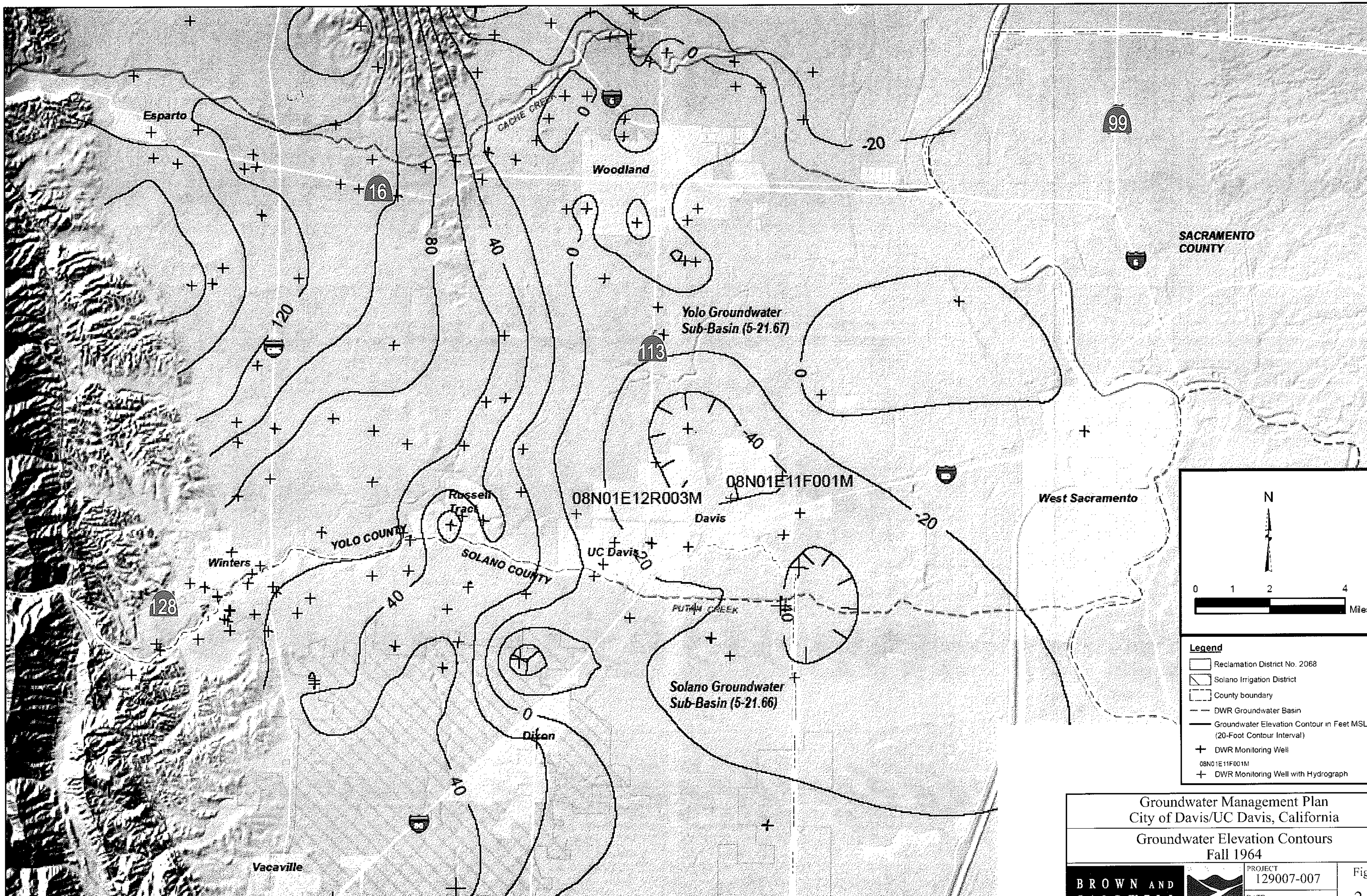



| BROWN AND CALDWELL / WEST YOST & ASSOCIATES | PROJECT 129007-007 | Groundwater Management Plan, City of Davis/UC Davis, California | Figure |
|---|---|---|---|
| | DATE 2-16-06 | Hydrograph of Department of Water Resources Well No. 08N01E11F001M, Elevation 78 feet | 2-11 |




Groundwater Management Plan
City of Davis/UC Davis, California

Groundwater Elevation Contours
Fall 1964

BROWN AND CALDWELL

PROJECT 129007-007

DATE 3-16-06

Figure 2-12

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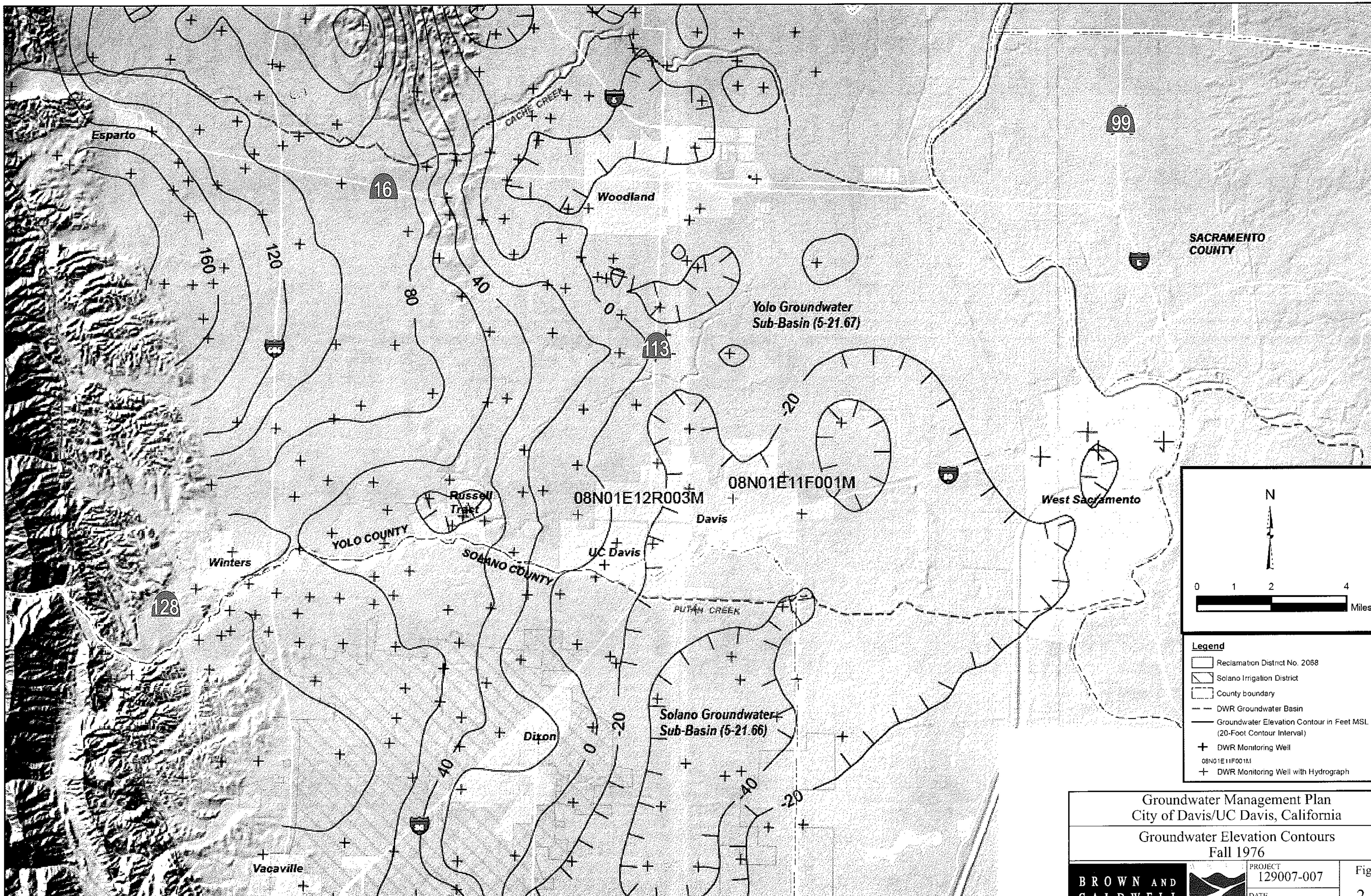


Groundwater Management Plan
City of Davis/UC Davis, California

Groundwater Elevation Contours
Fall 1976

BROWN AND CALDWELL

| PROJECT 129007-007 | Figure |
|---|---|
| DATE 3-16-06 | 2-13 |

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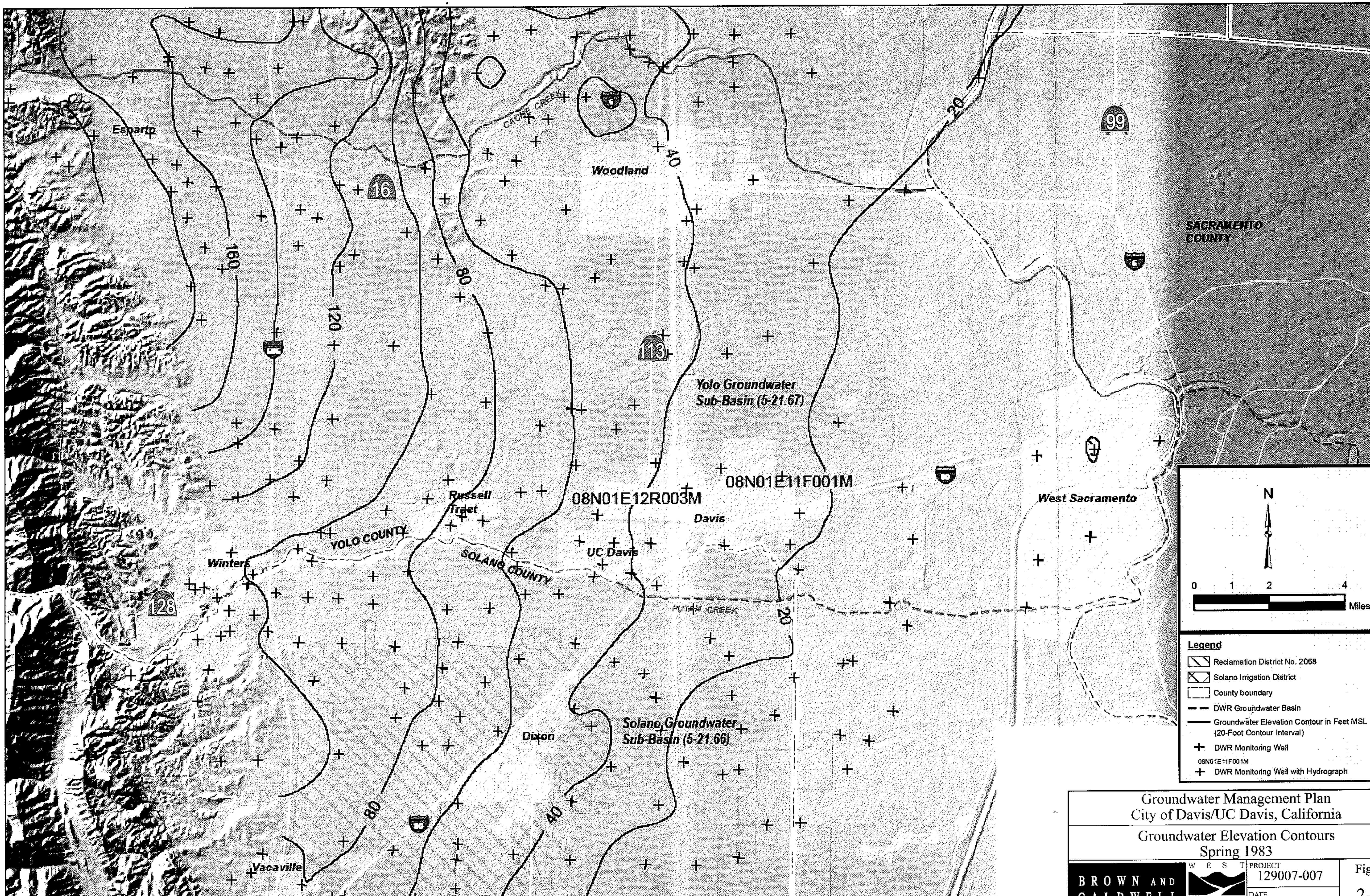


Groundwater Management Plan
City of Davis/UC Davis, California

Groundwater Elevation Contours
Spring 1983

BROWN AND CALDWELL | WEST YOST & ASSOCIATES

PROJECT 129007-007

DATE 3-16-06

Figure 2-14

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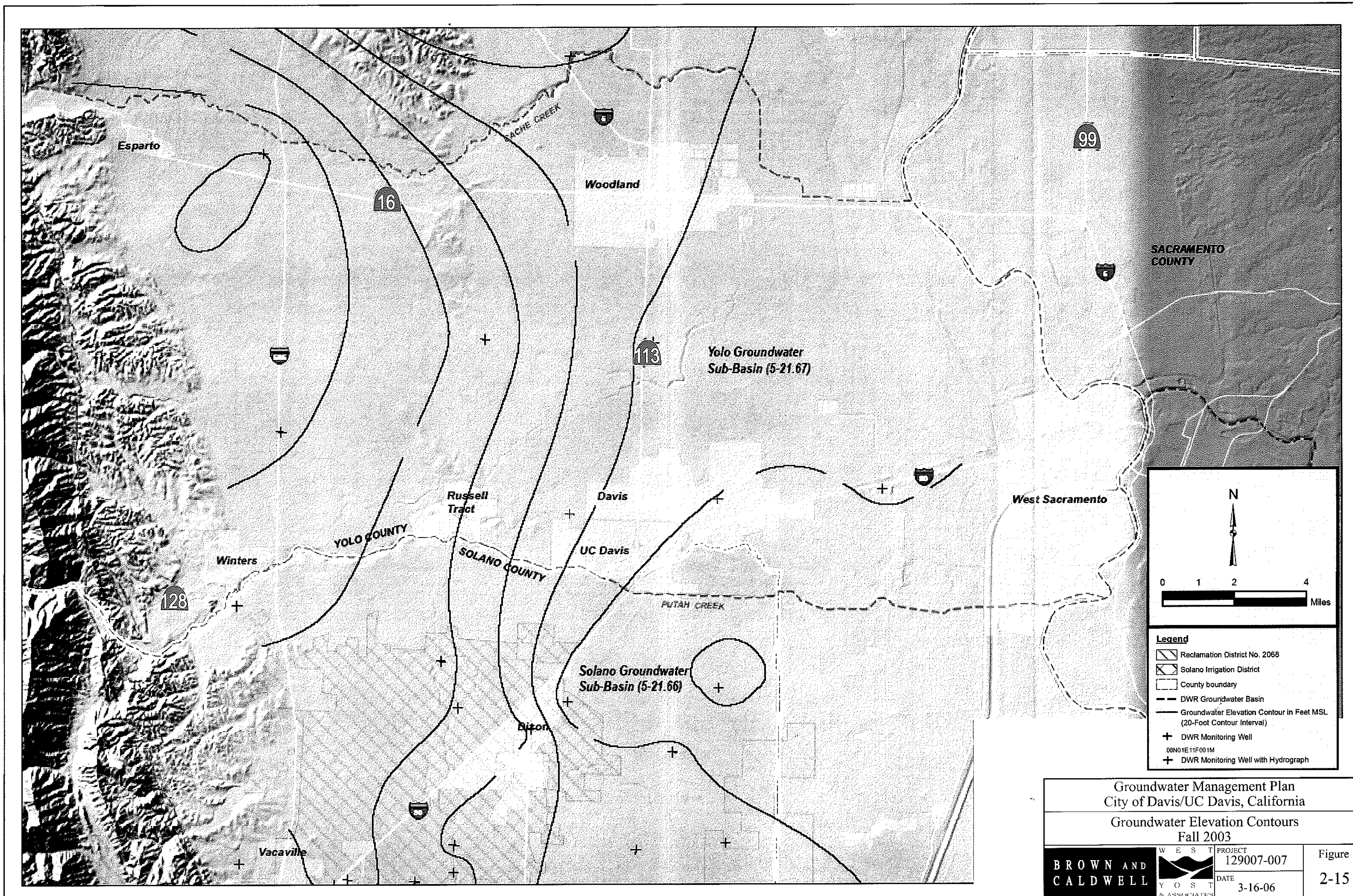


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### 2.5.9 Groundwater in Storage

In the vicinity of Davis and UC Davis, the base of fresh groundwater occurs at a depth of approximately 2,800 feet below mean sea level, implying that the fresh water aquifer is about 2,800 feet thick (DWR, 1978). However, it has only been practical thus far to construct wells less than 2,000 feet deep. The total amount of water contained to a depth of 2,000 feet in the 11,600 acre plan area (excluding Russell Tract) is over 2 million acre-feet. The useful amount of water in storage is probably somewhat less than the amount contained within the top 100 feet of the aquifer system, which is estimated to be approximately 120,000 acre-feet assuming a specific yield of 10%.

### 2.5.10 Groundwater Quality

Major groundwater production zones in the Davis area have traditionally been divided into the "Intermediate Aquifer" and "Deep Aquifer" based on general water chemistry, even though both are geologically part of the larger Tehama Formation. The "Intermediate Aquifer" begins at about 200 feet below ground surface, transitioning to the "Deep Aquifer" at about 700 feet below ground surface. A substantial sequence of fine-grained material (roughly 100 to 150 feet thick) separates the "Intermediate Aquifer" from the underlying "Deep Aquifer" water-producing zones. Groundwater mineral quality is characterized as calcium-magnesium bicarbonate in the "Intermediate Aquifer" and sodium bicarbonate in the "Deep Aquifer". Groundwater from the "Deep Aquifer" is more desirable for household use, having low concentrations of nitrate and selenium, and moderate hardness. Groundwater from the "Intermediate Aquifer" is more desirable for irrigation, having lower relative concentrations of sodium, but high hardness. Elevated concentrations of selenium and total dissolved solids in water from the "Intermediate Aquifer" also make compliance with increasingly stringent wastewater discharge requirements more difficult. Boron is found throughout all zones at concentrations that can have some adverse effects when used for irrigation of sensitive plants. Arsenic concentrations are relatively higher in some of the "Deep Aquifer" zones than in other zones, though still generally below drinking water limits. A comparison of water quality trends versus depth and direction is shown in Table 2-2.

Because of the better acceptability for household use, new drinking water supply wells for Davis and UC Davis are completed into the "Deep Aquifer". Water quality will be monitored in the future to determine if and when recharge from shallower sources is reaching deep wells. More information about water quality monitoring is in Section 3.4. A desire for improved water quality has been one of the driving forces behind the pursuit of higher quality supplemental surface water supplies.

**Table 2-2. Summary of Relative Water Quality Results and Implications**

| Parameter | Intermediate Aquifer (< 700' bgs) | Portion of Deep Aquifer: Shallow (700'-900' bgs)[a] | Portion of Deep Aquifer: Middle (900'-1300' bgs)[a] | Portion of Deep Aquifer: Deep (> 1300' bgs)[a] | Intermediate Aquifer: Directional Trend | Intermediate Aquifer: Time Trend | Deep Aquifer: Directional Trend | Deep Aquifer: Time Trend |
|---|---|---|---|---|---|---|---|---|
| Arsenic | Low | Low | High | Moderate | None | None | Mildly towards E | None |
| Boron | High | Moderate | Moderate | Moderate | Higher towards NE | None | Higher N-NE | None |
| Chromium | Mod. to high | Moderate | Low | Low | None | None | None | None |
| Manganese | Low | Moderate | Moderate | Low | None | None | None | None |
| Nitrate-N | Mod. to high | Low | Low | Low | Higher towards W | Increasing | None | Possible gradual increase |
| Selenium | High | Moderate | Low | Low | None | None | None | Possible gradual increase |
| Sodium | Moderate | High | High | High | None | None | None | None |
| Total Salinity | High | Low | Low | Mod. low | None | None | Higher towards N | None |
| Hardness | High | Moderate | Moderate | Moderate | None | None | None | None |
| $^{14}C$ Age | Moderate | Old | Oldest | Old | Older towards NE | Decreasing | Older towards NE | None |

a) Depth zones are approximate and change from west to east.
Source: Phase II Deep Aquifer Study (Brown and Caldwell and West Yost Associates, 2005).

### 2.5.11 Land Subsidence

Land subsidence due to groundwater withdrawal is triggered by decreases in pore pressure in a confined aquifer system containing compressible clay layers. If this effective stress exceeds the maximum stress to which the aquifer skeleton has been subjected in the past, the clay layers will undergo permanent compaction.

The risk of significant impacts from differential land subsidence depends on a complex array of variables including: the degree of new groundwater development, land use, the mineral composition of the clays, and consolidation history of the aquifer skeleton.

Significant land subsidence has been documented in Solano and Yolo Counties over the years, especially in areas that rely solely on groundwater supplies. Land subsidence of up to 5.4 feet is documented over the past few decades in a north-south trending zone that extends from Zamora to Dixon (Ikehara, 1994). Down-well television surveys have been used to document well casings damaged by land subsidence over this same zone. A comparison of damaged and undamaged wells in the main area of subsidence showed similar amounts of compressible sediments and that the damaged wells were those in which the greatest declines in head had occurred after well installation (Borchers, et. al., 1998). Recent studies have verified that subsidence is continuing to occur in the Yolo County portion of this zone (Frame, 2005).

Figure 2-16 shows the preliminary results of repeat surveys of the Yolo County Subsidence Monitoring Network conducted in 1999 and 2005. Based on these preliminary results using Global Positioning System (GPS) survey measurements, 3.1 inches of subsidence have occurred at the UC Davis Continuously Operating Reference Station (CORS) and 0.8 inches at Conaway Ranch 10 miles northeast of Davis (Figure 2-16). This equates to an average rate of subsidence of about 0.5 inches per year at the UC Davis CORS. These rates measured by the subsidence surveys are significantly higher than the 0.03 inches per year average rate recorded at the Conaway Ranch extensometer, which is a high accuracy mechanical device that measures subsidence down to its completion depth at about 600 feet. The higher rates calculated from the repeat elevation surveys suggests that some of the land subsidence may be occurring due to compaction of geologic materials at depths greater than the completion depth of the extensometer, and some of the observed subsidence could be caused by factors other than groundwater withdrawal. Possible factors are withdrawal of gas and saline water from deep gas production zones, natural tectonic subsidence, and GPS raw data interpretation issues. Additional information is contained in the final recommendations report from the 2005 survey, which is contained in Appendix B.

During the 1976-1977 drought, more groundwater than surface water was used for agricultural irrigation in the Sacramento Valley. Drilling and pump contractors reported that in the summer of 1977 many wells were discovered to have broken casings, and the demand for new and replacement wells could barely be met, most likely as a result of subsidence (Borchers, et. al., 1998).

## 2.6 Groundwater Well Infrastructure

Groundwater has been the only source of drinking water supplies and the principal source of irrigation water supply in the GWMP area. The sizes and depths of wells range from small, shallow wells for individual residences to large wells completed into the "Deep Aquifer" for municipal domestic supplies. The locations of major groundwater production wells in the plan area are shown in Figure 2-17.

### 2.6.1 City of Davis Water Supply Facilities

The City has a single, potable water system which supplies domestic and irrigation water for residents and businesses. The City relies solely on groundwater to meet all its water demands. Its water supply system consists of 21 wells, distribution pipelines and storage tanks, whose characteristics are summarized in the following sections.

#### Wells

The locations of the City's 21 wells are shown in Figure 2-17. Of the 21 wells, 17 are screened in the intermediate aquifer at depths between approximately 200 and 600 feet. Newer wells 28, 29, 30, and 31 are completed in the deep aquifer at total depths ranging from 1,500 to 1,800 feet. Deep aquifer well 29 was given a low operating priority beginning in 2002 because of water quality issues. An investigation into the source of the problem is ongoing. Due to increasingly stringent water quality regulations and other water quality concerns, the City has begun shifting groundwater pumping from the intermediate to the deep aquifer. Two additional deep wells are presently being planned to replace capacity lost to intermediate-aquifer wells being removed from service (Brown & Caldwell, 2006).

Figure 2-18 is a schematic diagram showing the active City wells, and includes well depths, screened intervals, pump setting depths, and suction pipe depths, where applicable. A summary of active City wells is shown in Table 2-3.

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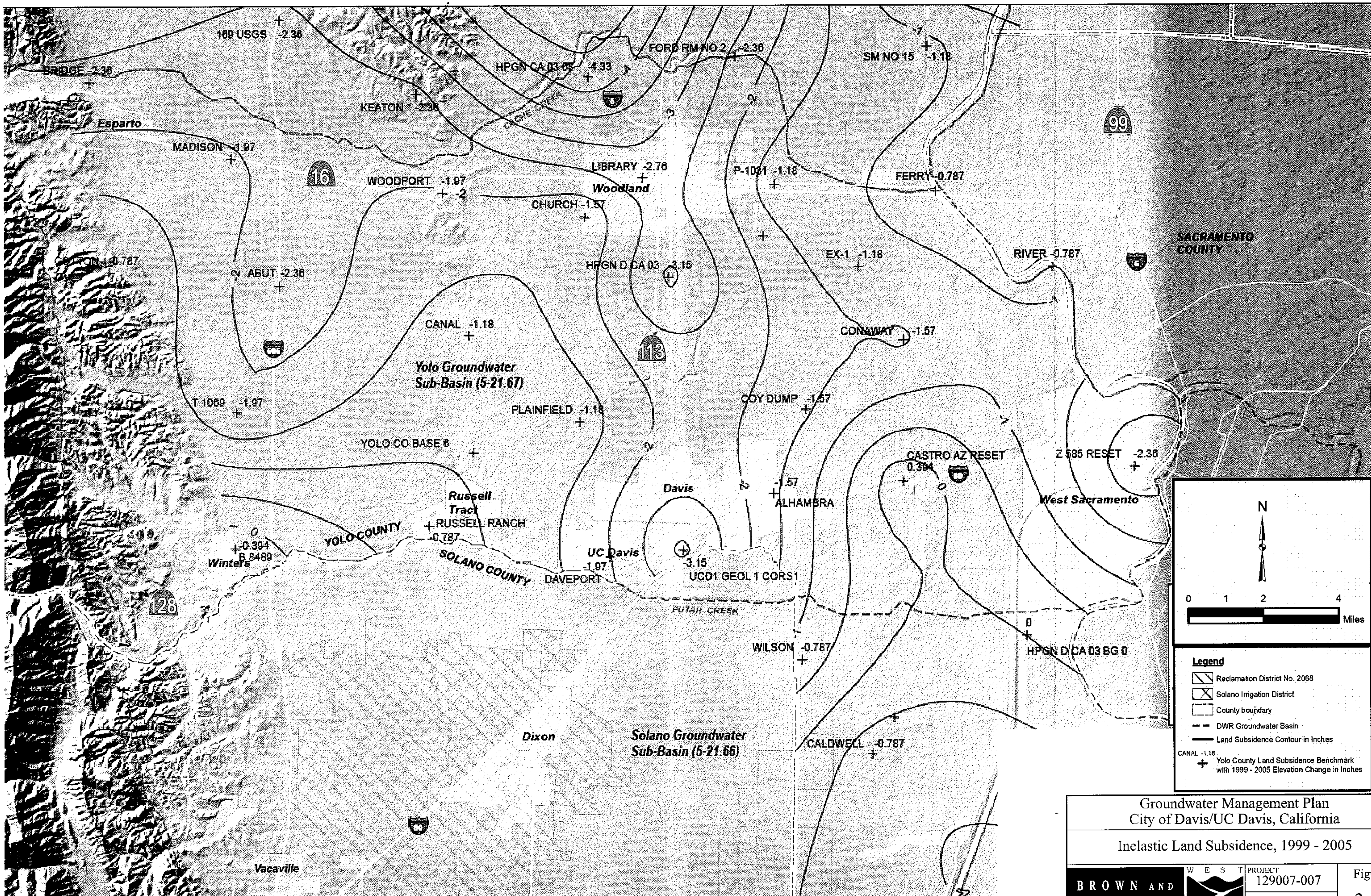


Groundwater Management Plan
City of Davis/UC Davis, California

Inelastic Land Subsidence, 1999 - 2005

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PROJECT 129007-007
DATE 3-16-06

Figure 2-16

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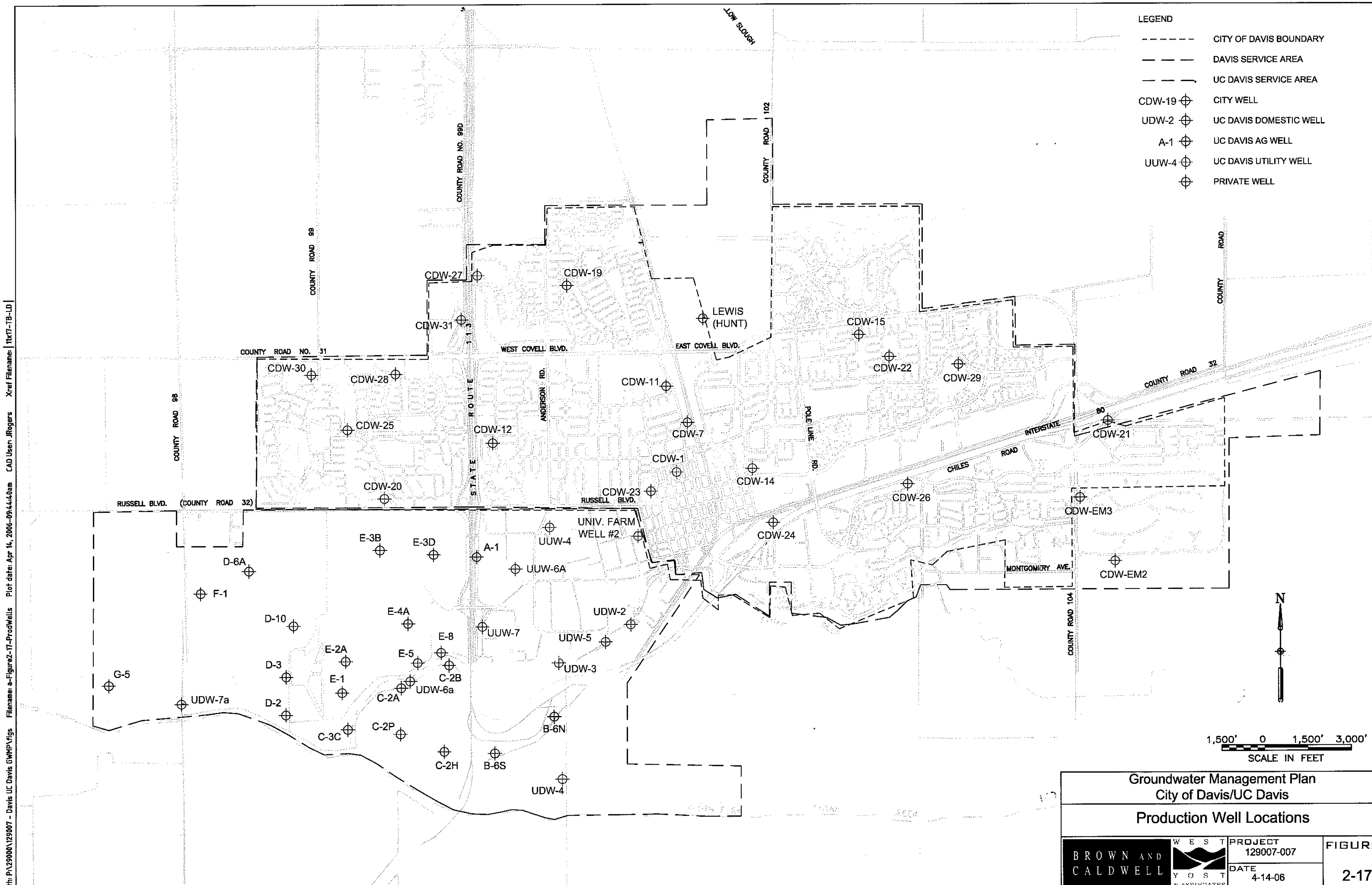


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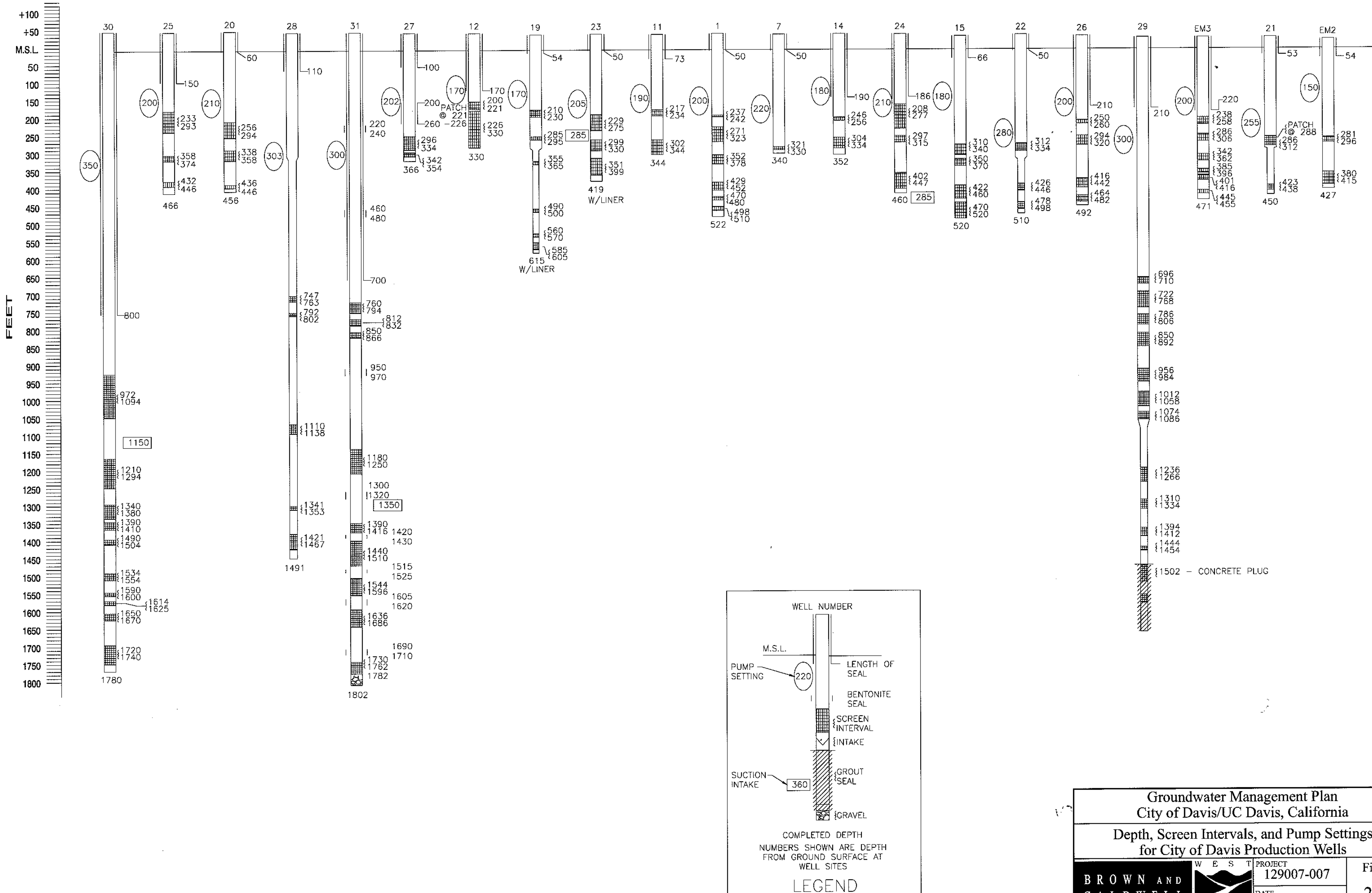


Source: Brown and Caldwell, Phase II Deep Aquifer Study, 2005

Groundwater Management Plan
City of Davis/UC Davis, California

Depth, Screen Intervals, and Pump Settings for City of Davis Production Wells

| | | | |
|---|---|---|---|
| BROWN AND CALDWELL | WEST YOST & ASSOCIATES | PROJECT 129007-007 | Figure |
| | | DATE 3-7-06 | 2-18 |

**Table 2-3. City of Davis Well Information**

| Well | Date Drilled[c] | Depth, feet | Pump Setting, feet | Suction Intake Depth, feet | Well Pumping Capacity, gpm[a] | Pump, HP[b] |
|---|---|---|---|---|---|---|
| CDW-1 | 1982 | 522 | 200 | - | 1,000 | 75 |
| CDW-7 | 1952 | 390 | 220 | - | 1,200 | 100 |
| CDW-11 | 1961 | 344 | 190 | - | 1,225 | 100 |
| CDW-12 | 1961 | 330 | 170 | - | 920 | 125 |
| CDW-14 | 1970 | 352 | 180 | - | 1,100 | Gas |
| CDW-15 | 1965 | 520 | 180 | - | 1,250 | 100 |
| CDW-19 | 1973 | 615 | 170 | 285 | 1,300 | 100 |
| CDW-20 | 1976 | 456 | 210 | - | 1,150 | 125 |
| CDW-21 | 1977 | 450 | 255 | - | 1,300 | 100 |
| CDW-22 | 1977 | 510 | 280 | - | 1,750 | 125 |
| CDW-23 | 1980 | 419 | 205 | - | 1,900 | 150 |
| CDW-24 | 1982 | 460 | 210 | 285 | 2,200 | 150 |
| CDW-25 | 1987 | 466 | 200 | - | 1,250 | 100 |
| CDW-26 | 1987 | 492 | 200 | - | 1,600 | 125 |
| CDW-27 | 1989 | 366 | 202 | - | 1,250 | 125 |
| CDW-28 | 1991 | 1,491 | 303 | - | 850 | 75 |
| CDW-29 | 1997 | 1,502 | 300 | | 1400 | 150 |
| CDW-30 | 2001 | 1,780 | 350 | 1,150 | 2,500 | 300 |
| CDW-31 | 2001 | 1,802 | 300 | 1,350 | 2,500 | 300 |
| CDW-EM2 | 1969 | 427 | 150 | | 1500 | 100 |
| CDW-EM3 | 1991 | 471 | 200 | - | 1,280 | 125 |
| Total | | | | | 30,425 | |

(a) Gallons per minute
(b)Horsepower
(c) Typical well life is 30-50 years

The City's active wells range in age from four to more than 50 years old. Since 1987, the City has removed six intermediate depth wells from service due to age, poor water quality, production, and/or operational and maintenance problems. The City is currently proposing the addition of two new deep wells to replace wells that have been taken out of service. All active wells (Table 2-3), are available to supply water to the system. The City's average annual well production since 2000 has been approximately 4,800 million gallons (MG). This value includes years in which wells that are currently offline were in use, and years in which several current wells were not yet in service.

Of the presently active wells, Well 14, powered by an internal combustion engine, is primarily designated for emergency use. Well 31 is not available to meet peak demands due to water distribution system limitations when other nearby wells are running, and is used to fill the West Area Storage Tank. Well CDW-EM2 is run infrequently. Wells Nos. 7 and EM2 are likely candidates for retirement due to their age and other problems associated with their use. Well CDW-12 may be retired because of high chromium concentrations.

Distribution and Storage

The distribution system consists of about 175 miles of water mains and serves over 15,300 customer connections. Ductile iron and cast iron are the most common piping materials. There is some asbestos-cement pipe, mostly located in the El Macero area. The majority of the system is in good condition and is less than 30 years old. There are approximately 10 miles of water mains in the older parts of the system in Central Davis that are more than 80 years old, which are being replaced over the next 10 years (West Yost & Associates, 2002).

The hydraulic grade line of the water system is primarily determined by the water level in the 200,000 gallon elevated storage tank near Elmwood Drive and Eighth Street. The water level typically varies between 95 and 115 feet above ground level, maintaining system pressures between 40 and 50 pounds per square inch (psi) under most demand conditions. A four million gallon ground-based storage reservoir on John Jones Road, adjacent to Sutter Davis Hospital, was completed in July 2002 (FS, 2002).

### 2.6.2 UC Davis Water Supply Facilities

UC Davis currently relies solely on groundwater for its entire potable and landscape irrigation water supplies. UC Davis water facilities include separate domestic, landscape irrigation, and agricultural irrigation water systems. Water for domestic and laboratory use and for heating, cooling, and other "industrial" uses on campus is supplied from the deep aquifer by the domestic water system. The landscape irrigation ("utility") system supplies groundwater from the intermediate aquifer for campus landscape and turf irrigation. The agricultural irrigation facilities supply groundwater for irrigation both in the research area west of the main campus and for the Russell Tract, located approximately 5 miles west of the campus.

Domestic Supply System

The UC Davis domestic water service area encompasses a total of approximately 3,700 acres (Figure 2-15) and provides water to more than 38,000 persons, including approximately 27,000 students and 11,000 faculty and staff. The water supply system consists of wells, distribution pipelines and storage tanks.

UC Davis operates six wells exclusively for domestic water supply. All of the wells are completed in the deep aquifer, between 800 and 1,500 feet below ground surface. The wells are located along the east and southeast sides of the UC Davis service area as shown on Figure 2-15. A summary of domestic well construction and capacity is presented in Table 2-4. Total pumping capacity of the domestic system is 5,290 gpm, based on pump tests conducted during the winter of 1999.

## Table 2-4. UC Davis Domestic Water Wells

| Well | Date Drilled | Depth, feet | Pump Setting, feet | Suction Intake Depth, feet | Yield[a], gpm | Pump Motor, HP[b] | Status |
|---|---|---|---|---|---|---|---|
| UDW-2 | 1952 | 1,368 | 190 | 210 | 370 | 30 | Active |
| UDW-3 | 1952 | 1,450 | 240 | 255 | 890 | 50 | Active |
| UDW-4 | 1971 | 1,430 | (c) | (c) | 820 | 200 | Active |
| UDW-5 | 1969 | 1,470 | 300 | 317 | 1,280 | 100 | Active |
| UDW-6A | 1988 | 1,470 | 240 | 247 | 1,160 | 125[d] | Active/Seasonal |
| UDW-7A | 1995 | 800 | 180 | 184 | 770 | 100[d] | Active |

(a) Gallons per minute, based on most recent pump tests conducted in winter 1999.
(b) Horsepower
(c) No information available
(d) Submersible pump

The domestic water system pipelines (about 50,000 linear feet) range from 6 to 14 inches in diameter and are composed of a variety of materials including asbestos-cement, cast iron, ductile iron, concrete coated steel and polyvinyl chloride (PVC). The majority of the pipeline material in the domestic system is asbestos-cement. There are two standby interties between the domestic water system and the City water system.

Wells UDW-2, UDW-3, and UDW-5 deliver water directly to an underground storage reservoir. These three wells are controlled automatically by a level monitor in the reservoir. As the water level drops, the wells are brought in service successively to maintain capacity. Wells UDW-4, UDW-6A, and UDW-7A discharge directly into the distribution system.

The UC Davis domestic water system currently has three storage reservoirs. An elevated steel storage tank, with a capacity of 200,000 gallons, is located near the intersection of Old Davis Road and California Avenue, and is the primary control on pressure in the distribution system. A 1.5 MG underground reservoir and booster pump station which receives groundwater from is located adjacent to the elevated tank. The booster pump serves to maintain the level in the elevated tank. A 300,000-gallon storage reservoir and a 1,500 gpm booster pump station are located west of the UC Davis Airport and serve to provide fire protection for the west campus area.

Utility Water System

Six utility wells completed in the intermediate aquifer provide groundwater for campus landscape and turf irrigation. Well construction and capacity information is presented in Table 2-5. The utility water system has interties to the domestic water system at Wells UUW-5 and UUW-6A to provide backup for the domestic system. The domestic water system is protected with backflow prevention devices at both locations.

**Table 2-5. UC Davis Utility Wells**

| Well | Date Drilled | Depth, ft | Pump Setting, feet | Suction Intake Depth, feet | Yield, gpm[(a)] | Pump HP |
|---|---|---|---|---|---|---|
| UUW2 | 1945 | 324 | (c) | (c) | 750 | 75 |
| UUW3 | 1909 | 321 | (c) | (c) | 680 | 75 |
| UUW4 | 1938 | 326 | (c) | (c) | 660 | 30 |
| UUW5[(b)] | 1968 | 470 | 160 | 175 | 1,100 | 100 |
| UUW6A[(b)] | 1994 | 290 | (c) | (c) | 1,030 | 100 |
| UUW7A | 1951 | 414 | 160 | 178 | 1,150 | 100 |
| Total | | | | | 5,370 | |

(a) Gallons per minute, based on 1999 pump tests.
(b) Intertie to Domestic system
(c) No information available

Agricultural Irrigation System

UC Davis maintains 20 irrigation wells in the UC Davis service area on and adjacent to the campus (Figure 2-17). An additional 13 wells are located on the so-called Russell Tract (Figure 1-1). All are completed at depths corresponding to the intermediate aquifer zone. The available information for these wells is summarized in Table 2-6.

**Table 2-6. UC Davis Agricultural Irrigation Wells**

| Well | Location | Date Drilled | Depth |
|---|---|---|---|
| UCD G6 | Davis | 1931 | 400 |
| UCD F1 | Davis | 1955 | 220 |
| UCD E8 | Davis | 1972 | 517 |
| UCD E5 | Davis | 1956 | 344 |
| UCD E4A | Davis | 1956 | 340 |
| UCD E3D | Davis | 1972 | 455 |
| UCD E3B | Davis | 1952 | 250 |
| UCD E2A | Davis | 1948 | 250 |
| UCD E1 | Davis | 1993 | 270 |
| UCD D6A | Davis | 1936 | 416 |
| UCD D3 | Davis | 1936 | 382 |
| UCD D2 | Davis | 1946 | 532 |
| UCD D10 | Davis | 1939 | 520 |
| UCD C2H | Davis | 1932 | 244 |
| UCD C2F | Davis | 1932 | 224 |
| UCD C2B | Davis | 1932 | 264 |
| UCD C2A | Davis | 1932 | 250 |
| UCD B6S | Davis | 1972 | 500 |
| UCD B6N | Davis | 1964 | 635 |
| UCD A1 | Davis | 1952 | 300 |
| RUS R2W | Russell Tract | 1978 | 739 |

**Table 2-6. UC Davis Agricultural Irrigation Wells (continued)**

| Well | Location | Date Drilled | Depth |
|---|---|---|---|
| RUS R2E | Russell Tract | 1947 | 385 |
| RUS R1E | Russell Tract | 1947 | 391 |
| RUS P3 | Russell Tract | 1959 | 672 |
| RUS P2 | Russell Tract | 1954 | 450 |
| RUS P1 | Russell Tract | 1959 | 512 |
| RUS M5 | Russell Tract | 1947 | 495 |
| RUS L2 | Russell Tract | 1948 | 425 |
| RUS K3 | Russell Tract | 1980 | 760 |
| RUS J3 | Russell Tract | 1992 | 399 |
| RUS J2 | Russell Tract | Unknown | Unknown |
| RUS H1 | Russell Tract | Unknown | Unknown |
| RUS J1 | Russell Tract | Unknown | Unknown |

### 2.6.3 Private Wells

The Wildhorse Golf Club, located north of Covell Boulevard and east of County Road 102, maintains a landscape irrigation well. The well is completed at a depth of 940 feet, in the upper portion of the "Deep Aquifer."

A well (Lewis-4) located on the former Hunt-Wesson cannery property, now owned by Lewis Properties, is completed at a depth of 1,370 feet. Lewis-4 is currently being replaced by a new deep well under construction (Lewis-5).

Known intermediate/shallow depth private wells located within the City's service area include:

- El Macero Golf Course
- Davis Cemetery
- Stonegate
- Lake Alhambra
- Andco
- East Eighth St.
- Drummond Lane

## 2.7 Water Demand and Supply

Domestic water demands have been generally increasing in the GWMP area as population has increased, and groundwater supply capacity has been incrementally added to meet the demand.

### 2.7.1 City of Davis Historical and Projected Demands

The historical and projected water demands for the City of Davis are shown on Figure 2-19. The historical water demands in water year 2000 and 2004 were 12,174 and 15,098 acre feet (ac-ft), respectively. The annual rate of increase from past water years 2000 through 2004 was approximately 5.4 percent. New water demands have increased along with population growth; however, per capita water demands have leveled off at between 10-15 percent less than the historic average, most likely due to the conversion to metered rates and other conservation programs.

The City of Davis Public Works Department estimates that the City will grow at a 1.2 percent annual rate through 2030. This corresponds to a demand projection of 20,588 ac-ft for the year 2030.

### 2.7.2 UC Davis Demands

UC Davis groundwater demands fall in three categories: domestic water supply, utility water supply and agricultural water supply. Each of these categories is discussed in the following sections.

#### Domestic Groundwater Demands

Nearly every campus facility receives domestic water. The domestic water use falls in three general categories:

- Buildings;
- Cooling Towers and Boilers; and
- Irrigation Areas (not served by the utility water system).

The total number of existing buildings relying on the domestic water system is 911. Building water use is for human consumption, research and building mechanical systems. The domestic water system provides cooling and boiler water to the Central Heating and Cooling Plant (CHCP), the Thermal Energy Storage facility (TES), the California National Primate Research Center (Primate Center), and other local cooling towers located in individual buildings. The domestic water system also provides water for fire protection at all but two hydrants.

Domestic water is also used for landscape irrigation where utility water lines are not available. The landscape irrigation needs of West and South Campus are currently served by the domestic water system because the utility water system does not extend to these areas.

Water production records have been available since 1968. Figure 2-20 shows that there was a general trend of increasing water consumption from 1968 through 1976, and then consumption dropped off dramatically. The sharp decline in consumption was most likely attributed to a concerted water conservation effort that began as a result of the 1976 - 1977 drought.

Information on future development projects that will increase demands on the UC Davis domestic water system was obtained from the following sources:

- Ten-year Capital Improvement Plan 2004/5 to 2013/14 by the UC Davis Office of Management and Planning, January 2005;
- Master Project List for Utility Forecasting, May 2005 Update, UC Davis; and
- Discussions with UC Davis Staff.

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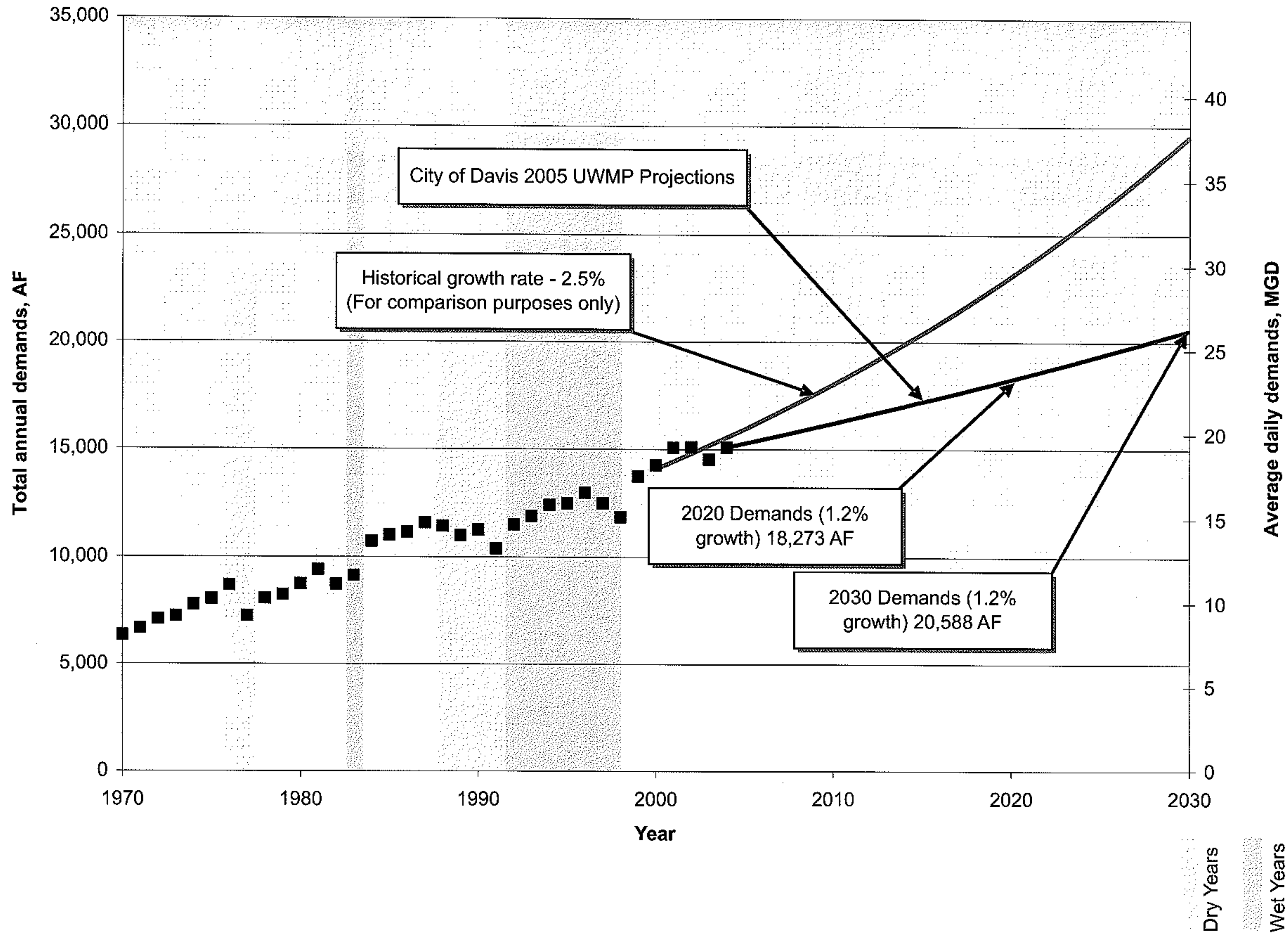


| BROWN AND CALDWELL | WEST YOST & ASSOCIATES | PROJECT 129007-007 | Groundwater Management Plan, City of Davis/UC Davis, California | Figure |
|---|---|---|---|---|
| | | DATE 2-17-06 | Historical and Projected Annual Water Demands | 2-19 |

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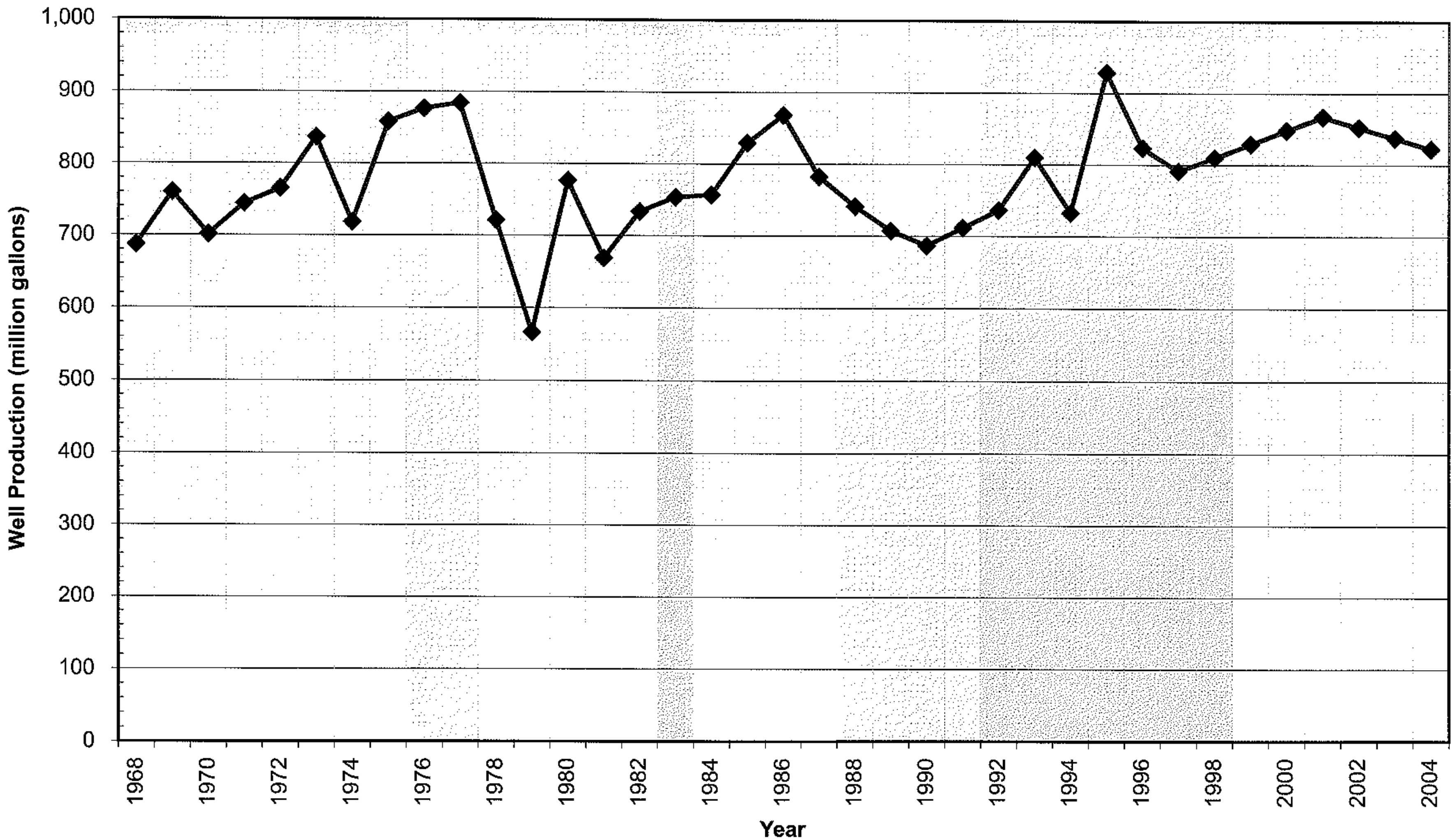



Note: Data for 1998-2000, 2002, and 2004 interpolated using data provided by UC Davis

| | | | |
|---|---|---|---|
| BROWN AND CALDWELL / WEST YOST & ASSOCIATES | PROJECT 129007-007 | Groundwater Management Plan, City of Davis/UC Davis, California | Figure |
| | DATE 3-7-06 | UC Davis Domestic Well Production | 2-20 |

Figure 2-21 summarizes the historical and projected annual water demands for the UC Davis domestic water system.

Utility Groundwater Demands

Utility water is designated primarily for the nonagricultural irrigation of approximately 300 acres of landscaped areas, and some greenhouses. Most irrigated areas in Central Campus are served by the utility water system. Landscape irrigation demands in South and West campus are served by the domestic water system because the utility water distribution system does not extend beyond Central Campus.

Annual utility water production records have been available since 1968 and indicate substantial fluctuations from year to year as shown on Figure 2-22. There has been a general increase in water demand from 1968 to 1989. Since then water demand has declined approximately 39 percent from peak levels in 1989 to 1990 primarily because of changes in landscape planting and watering practices.

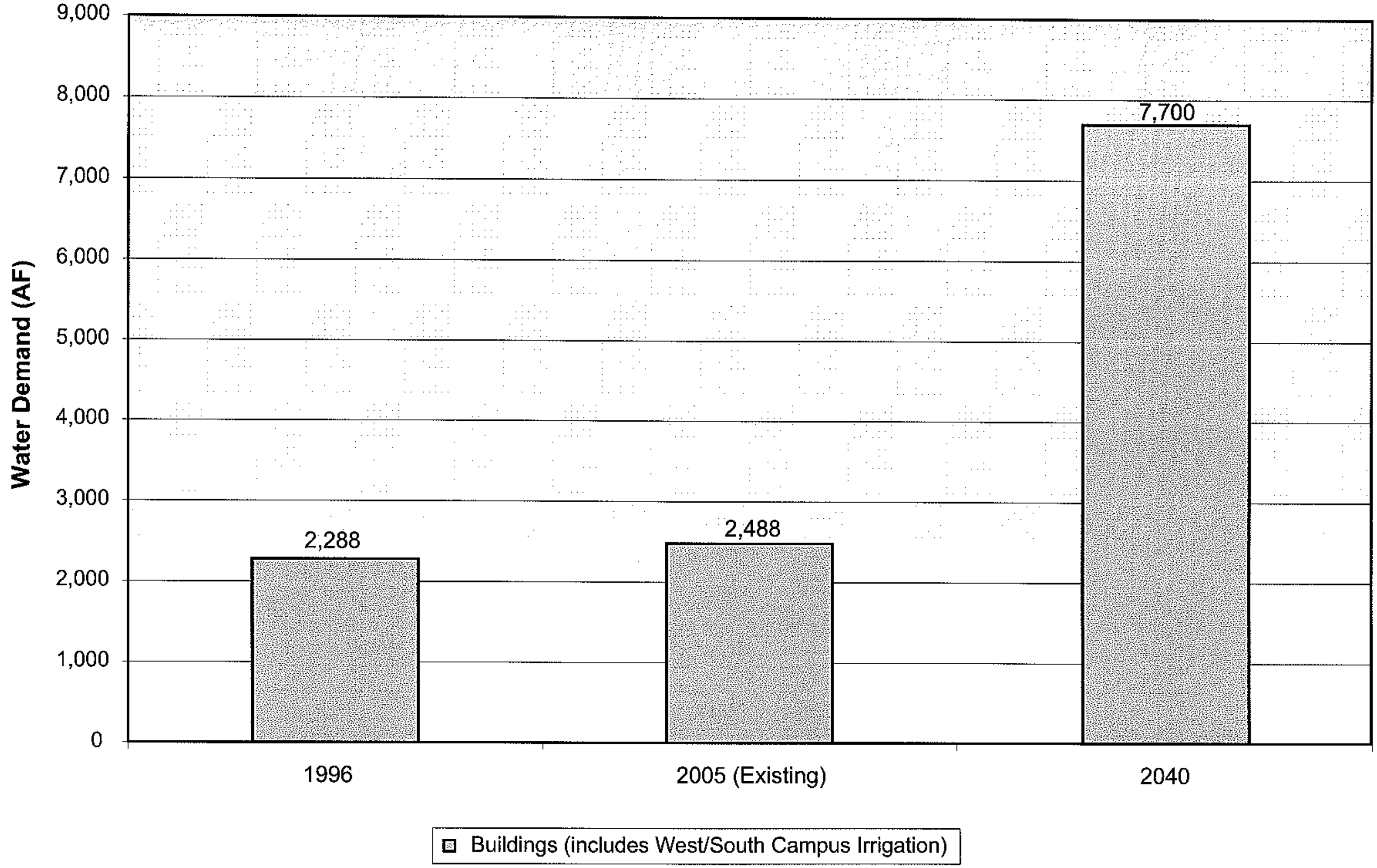
Information on future development projects that will increase demands on the UC Davis utility water system was obtained from the following sources:

- Ten-year Capital Improvement Plan 2004/5 to 2013/14 by the UC Davis Office of Management and Planning, January 2005;
- Master Project List for Utility Forecasting, May 2005 Update, UC Davis; and
- Discussions with UC Davis Staff.

Future development projects in Central Campus will result in approximately 12 additional acres to be irrigated from the utility water system. The projected demands utility water demands are shown on Figure 2-23.

Agricultural Groundwater Demands

Groundwater is used for agricultural supply in the western part of the UC Davis service area and in the Russell Tract (Figure 1-1). The total metered pumping between January 1994 and November 2005 was 21,191 acre-feet. This is equivalent to an average pumping of approximately 1,800 acre-feet per year.

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| | | |
|---|---|---|
| PROJECT 129007-007 | Groundwater Management Plan, City of Davis/UC Davis, California | Figure 2-21 |
| DATE 3-7-06 | UC Davis Historical and Projected Annual Domestic Water Demands | |

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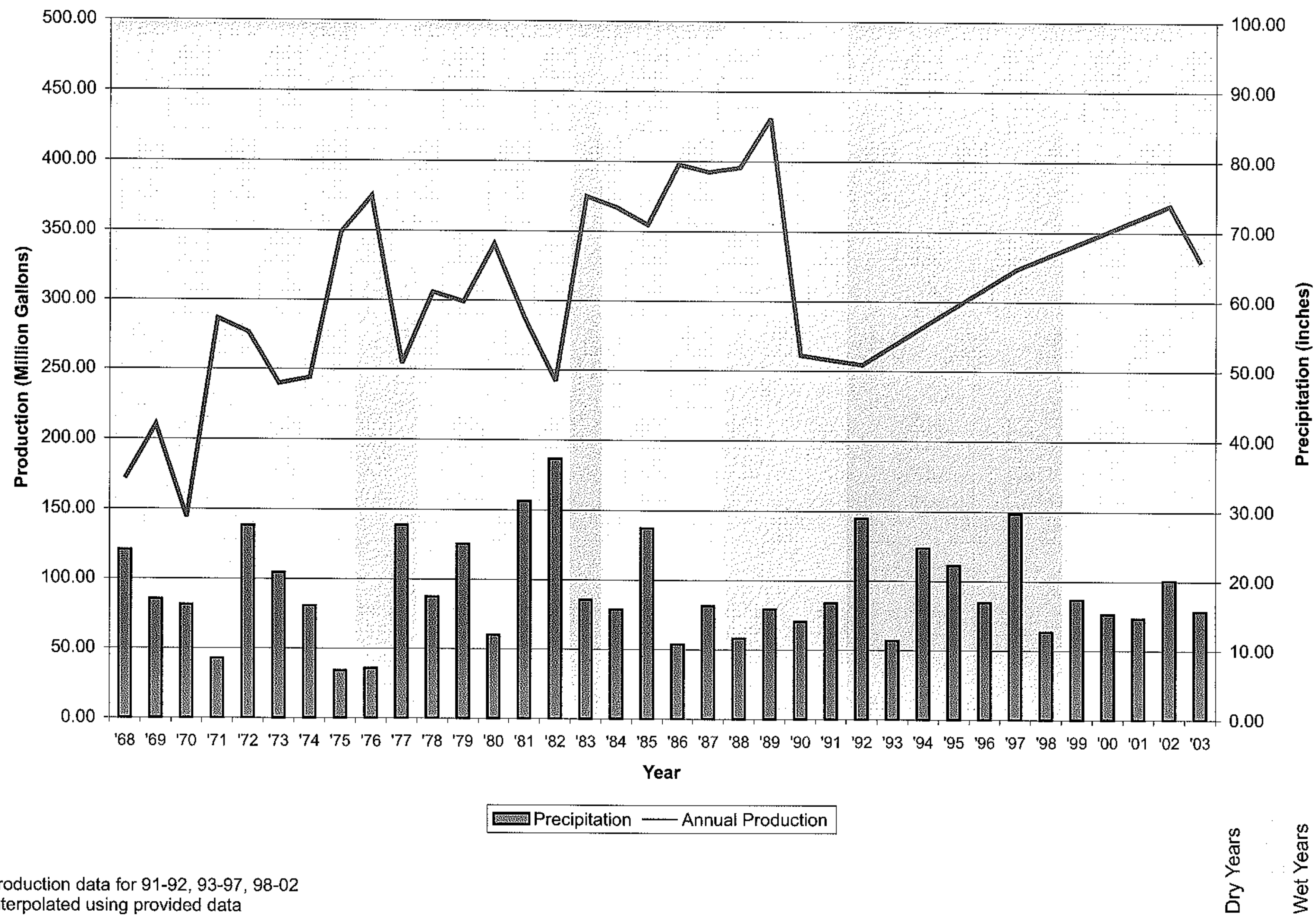
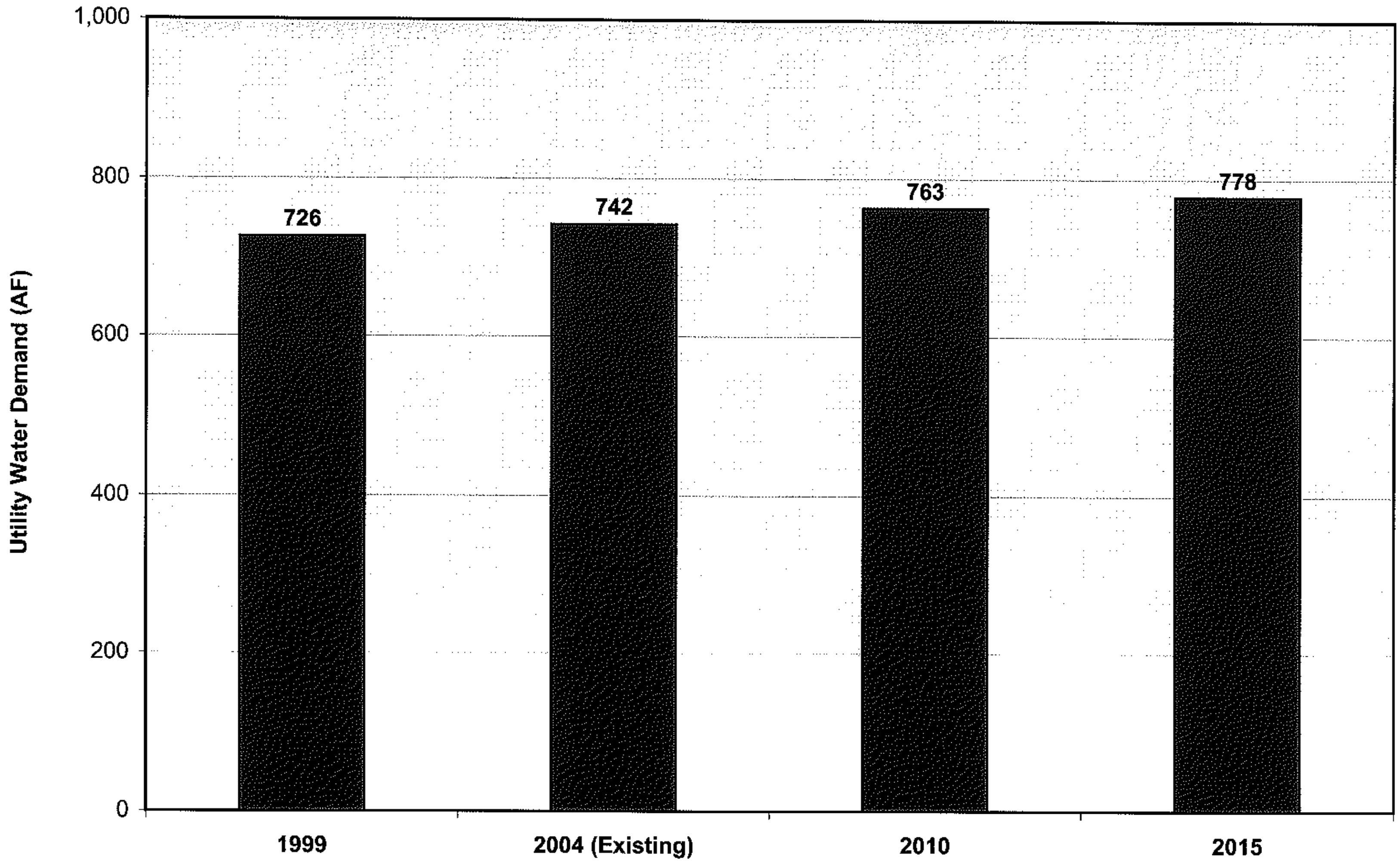



Note: Production data for 91-92, 93-97, 98-02 interpolated using provided data

| BROWN AND CALDWELL / WEST YOST & ASSOCIATES | PROJECT 129007-007 | Groundwater Management Plan, City of Davis/UC Davis, California | Figure |
|---|---|---|---|
| | DATE 2-17-06 | UC Davis Utility Water System Annual Production 1968-2004 | 2-22 |

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|---|---|---|---|
| BROWN AND CALDWELL / WEST YOST & ASSOCIATES | PROJECT 129007-007 | Groundwater Management Plan, City of Davis/UC Davis, California | Figure |
| | DATE 2-17-06 | UC Davis Historical and Projected Annual Utility Water Demands | 2-23 |

# SECTION 3
# PLAN IMPLEMENTATION

The City and UC Davis are already performing many of the groundwater management activities associated with a Groundwater Management Plan. Through plan development and implementation, the City and UC Davis are formalizing their common groundwater management goal, objectives, and plan components that elaborate on both current actions and planned future actions under the GWMP. As other neighboring entities are also engaged in groundwater management within the basin, the GWMP documents local conditions and management objectives that assist in facilitating the understanding and collaborative management among all groundwater users.

## 3.1 Groundwater Management Goal

The GWMP goal is to maintain or enhance local groundwater quantity and quality, resulting in a reliable groundwater supply for beneficial uses and avoidance of adverse subsidence. The goal will be met through the pursuit, accomplishment, and maintenance of the GWMP objectives which have been developed as a framework to coordinate and integrate basin management activities by the City, UC Davis, and adjacent groundwater management entities based on the provision of CWC §10750 *et seq*. It should be noted that even if a reliable groundwater supply is maintained as envisioned, the amount of available groundwater with desirable quality may not be adequate to meet future needs.

## 3.2 Groundwater Management Objectives

During GWMP development, the City and UC Davis considered and agreed upon qualitative and quantitative groundwater management objectives that complement and reinforce the GWMP goal. The qualitative objectives detail the common vision for groundwater management shared by both implementing entities.

The quantitative objectives are measurable objectives, commonly referred to as basin management objectives (BMOs), which establish numeric objectives for groundwater level, groundwater quality, and inelastic land subsidence. The quantitative objectives, or BMOs, are the desired physical conditions that are needed to satisfy the qualitative management objectives and the overarching plan goal.

The following sections 3.2.1 and 3.2.2 describe both the qualitative and quantitative groundwater management objectives, respectively.

### 3.2.1 Qualitative Objectives

To meet the GWMP goal, the City and UC Davis have adopted seven specific groundwater management objectives. The objectives include the following:

- Minimize the long-term drawdown of groundwater levels;
- Protect groundwater quality such that it remains viable for public water supply;
- Prevent adverse inelastic land surface subsidence from occurring as a result of groundwater pumping;

- Minimize changes to surface water flows and quality that directly affect groundwater levels or quality;
- Minimize the effect of groundwater pumping on surface water flows and quality in sensitive areas of Putah Creek;
- Develop, plan, and implement groundwater replenishment and cooperative management projects; and
- Work collaboratively with and understand the goals and objectives of entities engaged in groundwater management in surrounding areas.

### 3.2.2 Quantitative Objectives

The quantitative groundwater management objectives, or BMOs, were developed to meet local needs as reflected in the GWMP goal and qualitative objectives. The BMOs, detailed in Section 3.5.1, reflect local groundwater conditions necessary for reliable groundwater supply for beneficial uses and avoidance of adverse subsidence. A key to successful groundwater management using BMOs is the participation in BMO development by local entities with the authority, responsibility, and knowledge needed to reflect local groundwater management needs. BMOs are not intended to serve as a method of protection against the groundwater management activities by entities beyond the GWMP area.

The BMO process can be subdivided into four distinct phases, which are discussed in detail in the following paragraphs and include:

- Planning;
- Implementation;
- Management; and
- Resolution

*BMO Planning Phase:* This phase of BMO development was incorporated into the GWMP development process and includes the establishment of a GWMP Working Group and public input process. The GWMP Working Group consists of representatives from the City and UC Davis. As the annual volume of groundwater produced within the Plan area is primarily associated with the City and UC Davis pumping, there is minor potential for conflict within the Plan area with groundwater extraction by other public or private entities utilizing groundwater.

*BMO Implementation Phase:* This phase of BMO development was also incorporated into the GWMP development process and includes the establishment of an advisory committee, monitoring elements, the monitoring program, and the quantitative management objectives. The GWMP Working Group served as the advisory committee during the BMO implementation phase. The Working Group developed the monitoring elements, monitoring program, and associated BMOs. The results of the BMO implementation phase are detailed in Section 3.5.1.

*BMO Management Phase:* The management BMO phase is the enduring aspect of the BMO program. It is an integral part of the GWMP implementation and includes data collection, data evaluation, reevaluation of the monitoring program, reevaluation of the quantitative management objectives, and determination of the need for resolution activities if BMOs are exceeded. GWMP components, discussed in Sections 3.3 and 3.4, have been developed for data collection and evaluation. Periodic re-evaluation of the monitoring program and quantitative BMOs, as well as assessment the need for resolution activities, is included in the GWMP implementation activities.

*BMO Resolution Phase:* This BMO phase centers on the responsibility and process for resolution in response to an observed exceedance of an established BMO. This phase could include a technical investigation and recommendation, pursuit of a mutually agreeable solution, and recommendation of action to appropriate decision-making bodies when an agreeable solution cannot be reached. The specifics of this BMO phase are not addressed in the GWMP; however, they will be considered during GWMP implementation.

## 3.3 GWMP Components

As introduced in Section 1.6 and summarized in Table 1-2, a number of mandatory, recommended, and voluntary components constitute the GWMP content. These components have been grouped into five general categories, as shown in Figure 3-1. The components are discussed, with proposed GWMP implementation actions under the following five headings:

- Groundwater Monitoring;
- Groundwater Resource Protection;
- Groundwater Sustainability;
- Stakeholder Involvement; and
- Interagency Water Resource Planning.

Activities identified for plan implementation are designed to help the City and UC Davis achieve and continually meet the GWMP qualitative objectives and allow for assessment of performance against quantitative BMOs.

## 3.4 Groundwater Monitoring

The City and UC Davis have coordinated their monitoring efforts to provide more extensive and consistent data. These data, in turn, enable better analysis of groundwater conditions and trends, supporting development and implementation of BMOs associated with:

- Groundwater elevations;
- Water quality; and
- Inelastic land subsidence monitoring.

Monitoring issues and methodology are presented in this section. Evaluation of monitoring data for achievement of BMOs is discussed later in Section 3.5.

The YCFCWCD is currently implementing a groundwater monitoring program throughout Yolo County. A major goal of that program is to establish a groundwater quality monitoring network utilizing the wells monitored by the District for groundwater levels. The coordinated monitoring program implemented by the City and UC Davis as part of this GWMP will provide a complementary groundwater monitoring program to the YCFCWCD effort.

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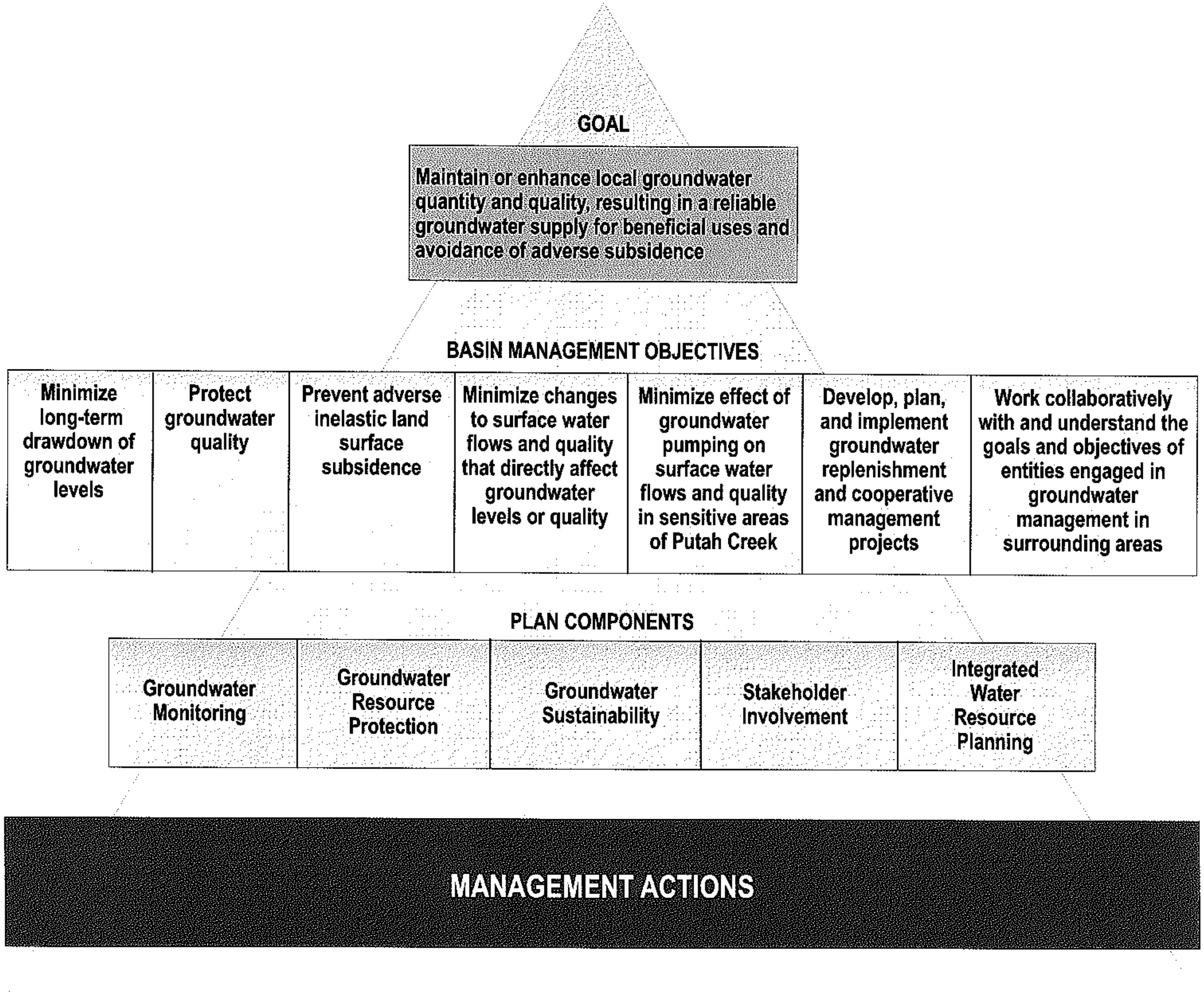


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| BROWN AND CALDWELL / WEST YOST & ASSOCIATES | PROJECT 129007-007 | Groundwater Management Plan, City of Davis/UC Davis, California | Figure |
| | DATE 3-9-06 | Groundwater Management Components | 3-1 |

### 3.4.1 Groundwater Elevation Monitoring

Monthly water level monitoring is currently practiced by the City. Static water level stabilization periods (measurement time after pump shut-off) have been a minimum of one hour since 1992 and were a minimum of 15 minutes prior to 1992. The City's newer wells have automated water level monitoring transducers connected to the City SCADA system and can provide water level monitoring at whatever frequency is desired. The City will continue monthly water level monitoring for all of its wells.

UC Davis currently monitors groundwater levels on a semi-annual basis, using static water stabilization period of approximately 24 hours. While semi-annual monitoring can provide data for the evaluation of long term trends, it is inadequate for evaluating seasonal trends and for comparing water levels to production. UC Davis is instituting quarterly monitoring of groundwater levels for its domestic and utility wells in 2006. UC Davis will be adding automatic water level monitoring to wells UDW-4, UDW-6A, and UUW-6A by 2008.

The City and UC Davis have developed a coordinated monitoring program for well pumping, mineral quality parameters, and water levels for the City's domestic productions wells and UC Davis' domestic and utility wells. This program includes a minimum two hour stabilization period for static water level measurements. UC Davis also plans to begin obtaining monitoring data for at least one key agricultural well (D-6A). Data are entered into a combined relational database. This monitoring program is compatible with YCFCWCD formats and procedures.

A discussion of quality assurance for measurement and sampling is provided in Appendix C. Detailed purging and sampling procedures are contained in Appendix D. Well construction records are included in Appendix E. Screened zones and other relevant water production information are also included in Appendix E.

### 3.4.2 Groundwater Quality Monitoring

The main use of water quality data will be to determine compliance with applicable drinking water standards under Title 22 of the California Water Code (CWC). Additional sampling and analyses will be performed to indicate whether quantitative BMOs are being achieved.

The evaluation of water quality results needs to take into account both well construction and local hydrogeology. The City analyzes groundwater samples for nitrate and selenium every four months for most wells, more often for select wells. Sampling for most other parameters is approximately once every 16 months. UC Davis samples groundwater from deep wells for mineral and other select constituents on a 12 to 18 month frequency.

Title 22 of the CWC requires sampling of water supply wells for certain parameters related to drinking water suitability on a three year frequency. Title 22 also specifies the detection limits for those parameters. In addition to meeting the Title 22 requirements, groundwater samples taken from deep wells will be sampled and analyzed at least semi-annually for nitrate, selenium and chromium at the detection reporting limits shown below in Table 3-1.

**Table 3-1. Special Parameter Detection Limits**

| Constituent | Detection Limit |
|---|---|
| Selenium | 1.0 ug/L |
| Nitrate-Nitrogen | 0.2 mg/L (as N) |
| Total Chromium | 10 ug/L |

Deep wells will also be sampled and analyzed for oxygen-18 and deuterium isotopes every three years. These additional mineral and isotopic monitoring results will be used for comparison with "trigger levels" in quantitative BMOs, as discussed in Section 3.5.1.

Detailed Standard Operating Procedures (SOPs) will be followed for purging and sample collection in order to obtain representative data that can be compared. General procedures are contained in Appendices B and C. The sample handling SOP from the analytical lab will also be followed. Additional samples will be collected for the specific purpose of documenting the Quality Assurance/Quality Control (QA/QC) of the field sampling procedures. Field QA/QC samples provide technically and legally defensible data regarding the reproducibility and overall quality of the groundwater sample. Further discussion of QA/QC samples is contained in Appendix C.

### 3.4.3 Groundwater Supply Volume and Flow

Both the City and UC Davis monitor their wells for flow and total volume of water extracted. The City's wells have automated water flow monitoring transducers connected to the City SCADA system and can provide water flow monitoring at whatever frequency is desired. UC Davis currently monitors well production on a monthly basis. UC Davis plans to add automatic flow monitoring to all utility and domestic production wells by Year 2008. Both the City and UC Davis report groundwater production on a monthly basis.

### 3.4.4 Groundwater Data Management

A relational database was initially developed for deep wells as part of the Phase II Deep Aquifer Study for storage of well construction, water level, and water quality data (Brown and Caldwell and West Yost Associates, 2005). This database was expanded to include intermediate depth wells operated by the City and UC Davis during GWMP development. Internet-based data interface features were also upgraded as part of the groundwater management project. The database was designed for a high degree of compatibility with the countywide database recently developed for the YCFCWCD through a grant from DWR. This will enable easy sharing of data to the YCFCWCD database.

The database will be maintained by the City and used jointly by both Davis and UC Davis for data storage, retrieval, and analysis. Database specifications and details are provided in Appendix F.

### 3.4.5 Surface Water/Groundwater Interaction

The City and UC Davis are members of the Lower Putah Creek Coordinating Committee, which is a multiple stakeholder organization overseeing implementation of the 2000 Settlement Agreement governing instream flows in Lower Putah Creek (Section 2.3). SCWA is the lead agency responsible for estimating the riparian flow that would exist in the absence of the Solano Project and the necessary releases from the Putah Diversion Dam. Following the PRWP, net gains and losses to five defined reaches of Lower Putah Creek are estimated as the sum of groundwater seepage and evapotranspiration. The net gains and losses are used to estimate the riparian flow and the necessary instream releases from the Putah Diversion Dam. Current and historical groundwater elevation measurements are used to estimate the groundwater seepage. These procedures are defined in Exhibit E-3 and Attachment 1 of Exhibit E-3 of the Settlement Agreement at http://www.putahcreek.org/.

The City and UC Davis will continue to participate in the Lower Putah Creek Coordinating Committee to ensure that surface water/groundwater interactions in Lower Putah Creek continue to be adequately monitored under the Settlement Agreement and the PRWP.

3.4.6 Inelastic Land Subsidence Monitoring

The City and UC Davis are active participants in the Yolo County Subsidence Network. The Yolo County Subsidence Network was conceived in late 1998 through the cooperative efforts of:

- City of Davis;
- City of Woodland;
- California Department of Water Resources;
- California Department of Transportation;
- University of California, Davis;
- U.S. Army Corps of Engineers, Topographic Engineering Center;
- U.S. Bureau of Reclamation;
- Yolo County Planning and Public Works Department; and
- Yolo County Flood Control and Water Conservation District.

In 1999, an initial survey of a network of 50 benchmarks, including benchmarks at DWR's Zamora and Conaway Ranch extensometers, was surveyed using GPS. In a report on the initial survey, the group recommended densification of the land subsidence monitoring network in certain areas of Yolo County, including Davis. The network was resurveyed and expanded to the previously unsurveyed southeastern portion of the county in 2002.

The City and UC Davis have sponsored expansion of the network. Three subsidence monuments in the Davis and UC Davis area were installed using the specifications, plans and procedures employed in developing the Yolo County Subsidence Network. One monument each was placed at UC Davis and in west Davis in locations expected to be most susceptible to drawdown from multiple wells. A second monument was placed in west Davis approximately 2000 feet west from the first monument in west Davis. Installation included the initial Global Positioning Survey to the North American Datum of 1983 and the North American Vertical Datum of 1988, consistent with the Yolo County Subsidence Network.

A repeat survey of the expanded network was conducted in 2005. This survey showed that previously recognized land subsidence is ongoing (Section 2.6, Figure 2-16, and Appendix B). However, comparison of the rates determined from the repeat surveys and area extensometers indicates that some compaction is occurring at depths greater than the completion depths of the extensometers and some of the measured subsidence may be due to factors other than groundwater withdrawal. At present, the factors controlling the total rate of inelastic land subsidence and the consequences of this subsidence are not fully defined. Additional subsidence monitoring recommendations are contained in Appendix B.

The City and UC Davis plan to continue to actively participate in the Yolo County Subsidence Network. Repeat surveys of the network will be used to monitor for changes in the rate of subsidence and for signs that differential subsidence is occurring. The subsidence rate will be compared to groundwater production information to determine whether there is an observable correlation between the two. The City and UC Davis will also advocate for funding to allow the Yolo County Subsidence Network to compare production records from the California Division of Oil and Gas to subsidence rates for evidence of a correlation. Furthermore, the City and UC Davis will advocate for a new extensometer in the vicinity of the GWMP area. The primary goal of these efforts will be to predict future subsidence rates and the ultimate amount of subsidence due to groundwater withdrawal under anticipated future land and water use scenarios.

#### 3.4.7 Groundwater Monitoring Actions

Davis and UC Davis will take the following actions:

- Update monitoring procedures as necessary to be compatible with this monitoring program;
- UC Davis to add automatic flow monitoring to all utility and domestic wells;
- Maintain a coordinated database of monitoring data;
- Export requested data annually from the database to YCFCWCD for inclusion in the Water Resources Information Database;
- Evaluate the data annually and compare with quantitative BMO trigger levels;
- Monitor surface water / groundwater interaction on Lower Putah Creek through participation on Lower Putah Creek Coordinating Committee; and
- Continue to support triennial land subsidence surveys through the Yolo County Subsidence Network.

### 3.5 Groundwater Resource Protection

This section describes policies and measures planned to help protect groundwater resources within the City and UC Davis service areas.

#### 3.5.1 Drought Water Conservation

The local groundwater aquifer is understood to be effected by various factors. Coast Range and Valley precipitation and YCFCWCD surface water delivery are two factors that appear to directly influence groundwater levels. Years of below average precipitation and/or reduced surface water delivery from Clear Lake or Indian Valley Reservoir to YCFCWCD customers correlate to years with decreased water levels in the County and Plan area. The majority of precipitation and reservoir inflow has occurred by approximately April 15 of each year. As such, the City and UC Davis will assess annual precipitation and reservoir storage on or about April 15 of each year as an indication of expected groundwater elevation trends for the upcoming peak groundwater demand period within the Plan area. The necessity for drought water conservation programs within the City and UC Davis will be determined during years where the April 15 water-year-to-date precipitation total or YCFCWCD surface water in storage values are less than the 20th percentile of the historic values. These drought conservation trigger values are shown in Table 3-2.

**Table 3-2. Drought Conservation Action Trigger Levels**

| Item | Value |
|---|---|
| Cumulative Water Year Precipitation | 12.5[(a)] inches |
| YCFCWCD Water in Storage | 325,000 acre-feet |

(a)20th percentile total water year precipitation is 12.85 inches, estimated 12.5 inches through April 15.

### 3.5.2 Implementation of Quantitative Basin Management Objectives

An important element of groundwater resource protection is the monitoring and evaluation of the local groundwater aquifer physical characteristics. Current monitoring has generally focused on confirmation that source water quality is better than CWC Title 22 drinking water requirements and that water levels are adequate to avoid damage to pumps and associated infrastructure.

Proper groundwater aquifer management is critical because groundwater serves as the sole source of water supply for the City and UC Davis. To that end, the City and UC Davis have considered appropriate quantitative BMOs within the GWMP area associated with water level, water quality, and inelastic land subsidence. Establishment of BMOs and the associated monitoring and evaluation focus on maintaining or enhancing local groundwater quantity and quality, resulting in a reliable groundwater supply for beneficial uses and avoidance of adverse subsidence. Additional background on development of quantitative BMOs is provided on Section 3.2.2.

The development of quantitative BMOs began by considering the groundwater management goal and qualitative objectives in relation to the data and associated understanding necessary to develop appropriate quantitative BMOs. The Working Group concluded that both an adequate data set and understanding exist to support quantitative BMOs for water level and water quality. Neither an adequate historic database nor an understanding of the threshold where detrimental impacts occur associated with inelastic land subsidence or depletion currently exist. Because of this, additional data collection and evaluation is needed before a quantifiable BMO can be established for inelastic land subsidence.

BMOs have been developed by considering monitoring locations and parameters that best represent the overall conditions of the groundwater aquifer. Key well locations have been identified that best represent the groundwater aquifer relative to water level and water quality. The following subsections provide detail on the BMOs for water level, water quality, and inelastic land subsidence.

#### Water Level BMOs

Quantitative water level BMOs have been developed to measure groundwater management performance against the qualitative objectives, specifically,

- Minimizing the long-term drawdown of groundwater levels, and
- Maintaining groundwater levels to protect existing infrastructure.

Water level BMO development began by considering which combination of well locations provides information needed to represent groundwater levels, both in the aerial context and in definable vertical intervals. Section 3.4.1 provides an overview of current groundwater elevation monitoring and Section 2.6 and 2.7 describe the differentiation between the intermediate and deep production intervals within the overall Tehama formation groundwater aquifer. Potential wells for use in monitoring of the water levels is complicated by the fact that most wells currently used for monitoring water level also serve as production wells. As mentioned previously, water levels in production wells are allowed to stabilize with the well off for a period of time prior to water level measurements. In the absence of additional dedicated monitoring wells, wells have been identified as key wells for monitoring of water level elevation based on location, screen interval, accessibility, and operational patterns.

Following identification of key wells, the time of year that monitoring should be completed to best represent the aquifer status was considered. Based on discussion within the Working Group, it was agreed that both spring and summer/fall water level target elevations are needed to best manage aquifer conditions. Spring represents the time of year when groundwater elevations are at the annual maximum, based on aquifer recharge and minimal landscape irrigation water demand during the wet winter months. Summer and fall represent the time of year when groundwater levels are at the annual minimum, based on maximum groundwater extraction to satisfy water demand.

After identifying the time of year that BMO compliance monitoring will be completed, appropriate trigger levels were considered and agreed upon. Trigger levels, identifying the minimum desired groundwater elevation, were derived for both spring and summer/fall. Trigger elevations at key monitoring locations for spring BMO compliance are generally consistent with the lowest historic seasonal peak spring water elevation at key wells, or slightly lower for wells with a brief monitoring history. These seasonal peak spring water elevations represent the recovery of aquifer intervals from the previous years' pumping. If recovery water levels are below these trigger levels prior to the summer demand period, the City and UC Davis want an early season warning so resolution actions can be considered.

Trigger elevations at key monitoring locations for the summer/fall BMO compliance are representative of the static water level necessary to protect well infrastructure. The summer/fall BMO water level elevations are derived considering pump intake elevation, average operational drawdown, and the desired distance between the pump intake and the operational water level in the well.

Table 3-3 includes details the selected key wells and its trigger level. Groundwater level BMO locations are shown on Figure 3-2.

Resolution actions that will be initiated if water levels fall below a trigger level may include any or a combination of the following:

- Continued monitoring;
- Additional conservation measures and reduced groundwater pumping;
- System reoperation to redirect pumping either to another area or depth interval;
- Development of new wells to allow reduced pumping from existing wells; and
- Acceleration of surface water supply source development.

**Table 3-3. Water Level BMO Well Location and Trigger Level**

| Aquifer Interval | Well ID | Owner | Spring Recovery Levels (ft msl) | | Summer/Fall Minimum Levels (ft msl) | |
|---|---|---|---|---|---|---|
| | | | Historical Minimum | Trigger | Historical Minimum | Trigger |
| Intermediate | UCD D-6A (ag) | UC Davis | | tbd[(a)] | | tbd[(a)] |
| | F Street – S | City | 14 | 5 | -51 | -70 |
| | UUW-6A | UC Davis | 8 | 5 | -7 | -60 |
| | CDW-7 | City | -15.6 | -20 | -90 | -100 |
| | CDW-21 | City | -8.1 | -10 | -69 | -100 |
| Deep | F Street - M | City | -4.8 | -10 | -35 | -60 |
| | F Street - D | City | -3.9 | -10 | -42 | -60 |
| | CDW-30 | City | 0.8 | 0 | -104 | -140 |
| | UDW-4 | UC Davis | -15.4 | -20 | -50 | -80 |
| | UDW-6A | UC Davis | 17 | 15 | 2 | -60 |

(a) To be determined in the GWMP 5 year update after developing a monitoring record

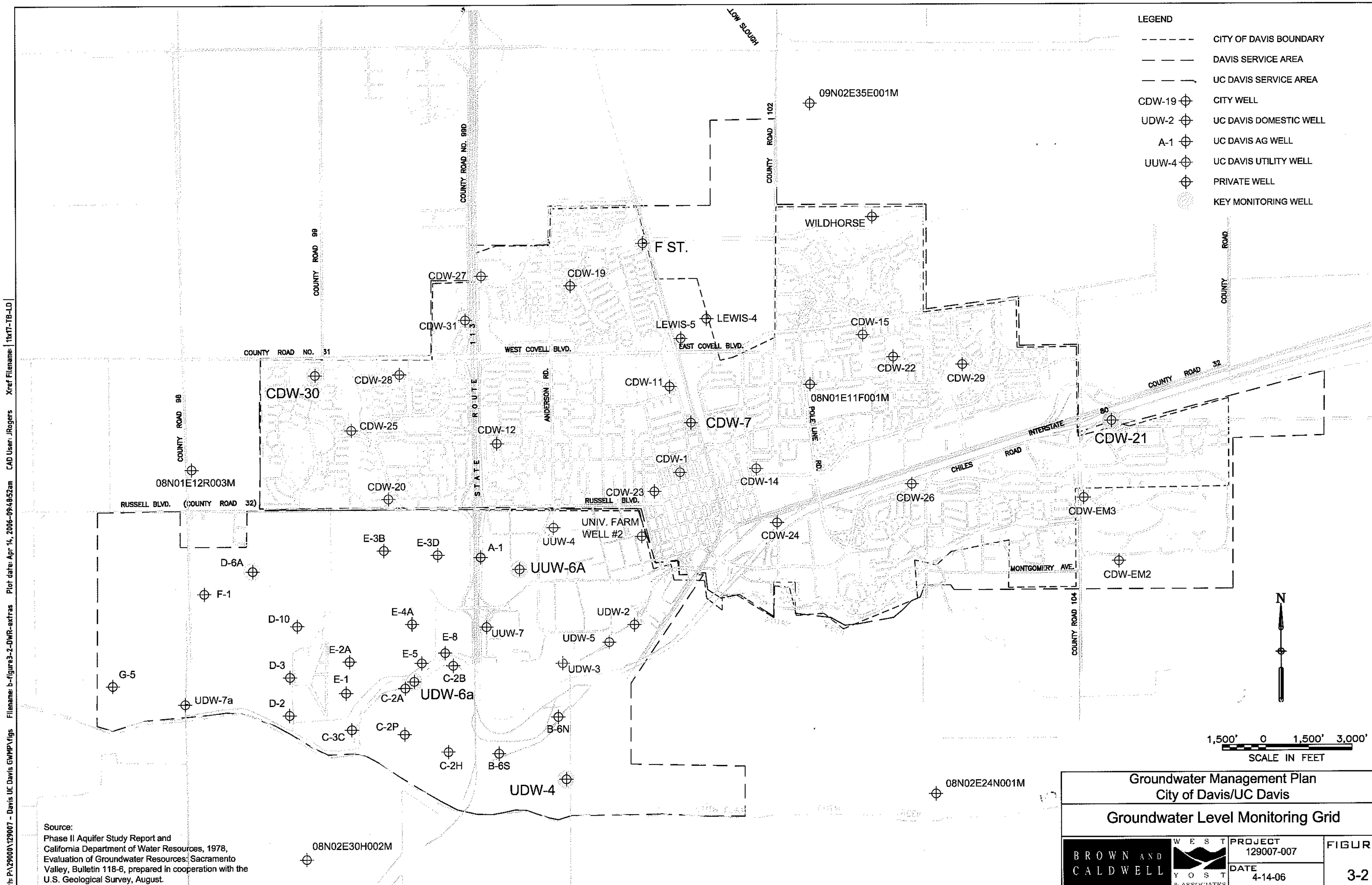
Water Quality BMO

Quantitative water quality objectives have been developed to measure groundwater management performance against the qualitative objective of protection of groundwater quality. As discussed in Section 2.6.4, the quality of the groundwater generally meets drinking water standards throughout the aquifer. However, the deeper portion of the aquifer generally has more desirable quality water when compared to the intermediate portion of the groundwater aquifer. Both the City and UC Davis will manage the aquifer in a manner that it remains a viable source of drinking water into the future. In addition, the deep aquifer will be also be managed, to the extent feasible, to preserve the higher quality water.

Based on this management philosophy, the Working Group has developed qualitative BMOs for water quality across the Plan area. As any localized change in water quality is important, the water quality monitoring network will consist of all drinking water production wells in the City and UC Davis service areas.

As discussed in Section 3.4.2, production wells are regularly monitored consistent with CWC Title 22. This monitoring is performed to demonstrate that water quality continues to meet all requirements for drinking water sources. The selection of BMO water quality parameters and trigger levels is based on criteria separate and independent from Title 22 requirements.

Parameters and trigger levels selected to function as water quality BMOs are based on their ability to represent groundwater movement within the aquifer system. The nature and distribution of the selected parameters are well defined across the service areas and vary both spatially and with depth. Because of their spatial and vertical variability, they are good indicators of groundwater movement both laterally and vertically within the aquifer system. Parameters selected for use in water quality BMOs are included in Table 3-4.




Groundwater Management Plan
City of Davis/UC Davis

Groundwater Level Monitoring Grid

BROWN AND CALDWELL | WEST YOST & ASSOCIATES | PROJECT 129007-007 | DATE 4-14-06 | FIGURE 3-2

Path: P:\29000\129007 - Davis UC Davis GWMP\Figs Filename: b-figure3-2-DWR-extras Plot date: Apr 14, 2006-09:48:52am CAD User: JRogers Xref Filename: 11x17-TB-LD

**Table 3-4. Water Quality BMO Parameters and Trigger Levels**

| Water Quality Parameter | Intermediate Aquifer Trigger Level | Deep Aquifer Trigger Level |
|---|---|---|
| Electrical Conductivity | None | >650 μmhos/cm |
| Selenium | >5 μg/L | >2 μg/L |
| Nitrate as N | >5 mg/L | >2 mg/L |
| Total Chromium | > 25 μg/L | >15 μg/L |
| $^{18}O$ Isotope | None | -7.5 $\delta^{18}O$ |

The trigger levels associated with the individual parameters have been set at levels that will indicate a change of the current concentrations typically observed. The difference in trigger level concentrations between the intermediate and deep intervals of the overall groundwater aquifer system have been established to alert the City and UC Davis of increased interaction between the two aquifers, based on the desire to maintain the higher quality in the deep portion of the aquifer. Water quality BMO monitoring locations are shown on Figure 3-3, and essentially include all active City and UC Davis domestic and utility wells. Table 3-4 includes the water quality trigger levels for both the intermediate and deep portion of the groundwater aquifer.

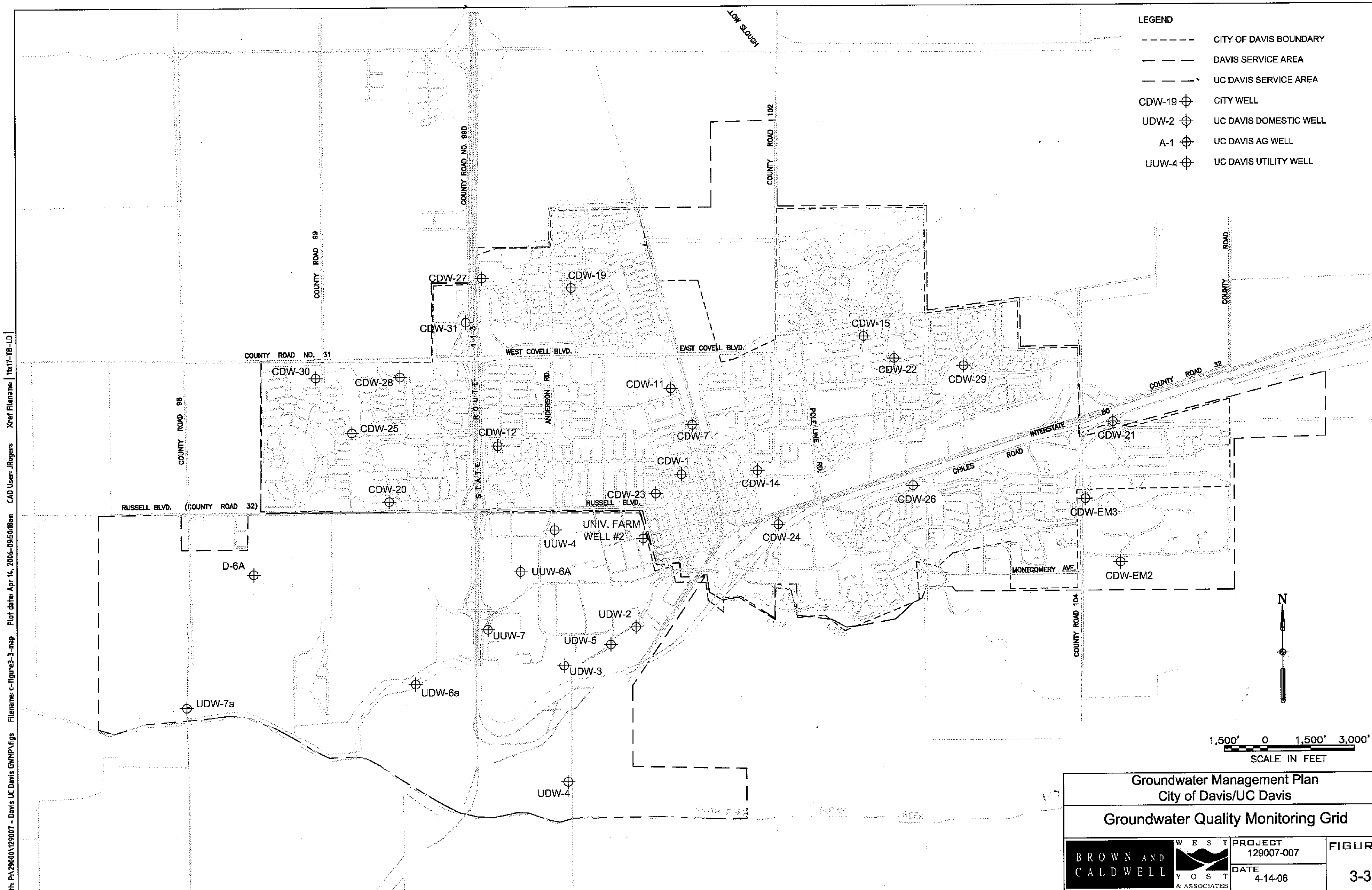
Resolution actions that will be initiated if observed quality exceeds the trigger level may include any or a combination of the following:

- Continued monitoring;
- System reoperation to redirect pumping either to another area or depth interval;
- Development of new wells;
- Acceleration of surface water supply source development; and
- Wellhead treatment where feasible.

Inelastic Land Subsidence BMO

As discussed in Section 2.6.5, inelastic land subsidence often results from consolidation of clay intervals following a reduction of aquifer pore pressure. To better understand the location, rate, and cause of land subsidence, regional land subsidence monitoring has been completed that includes the City and UD Davis GWMP area. Initial results indicate that inelastic land subsidence is occurring in the GWMP area, however there is not currently an adequate historic database nor an understanding of the threshold where significant detrimental impacts occur.

Because of this, additional data collection and evaluation is needed before a quantifiable BMO can be established for inelastic land subsidence. Monitoring of land subsidence will continue to result in an improved understanding of the subsidence rates and causes. The addition of a land subsidence BMO will be considered during the five year update based on a better understanding the rate and impacts of land subsidence.




Groundwater Management Plan
City of Davis/UC Davis

**Groundwater Quality Monitoring Grid**

BROWN AND CALDWELL | WEST YOST & ASSOCIATES

PROJECT 129007-007

DATE 4-14-06

FIGURE 3-3

Path: P:\29000\129007 - Davis UC Davis GWMP\figs Filename: c-figure3-3-map Plot date: Apr 14, 2006-09:50:18am CAD User: JRogers Xref Filename: 11x17-TB-LD

### 3.5.3 Groundwater Well Ordinances

CWC Sections 13700 through 13806 require proper construction of wells, and minimum standards for the construction of wells are specified in DWR Bulletins 74-81 and 74-90. These standards apply to all water wells, cathodic protection wells, and monitoring wells. In addition the City has adopted Ordinance 39.05.0 governing "all new and existing water wells, cathodic protection wells, heat-pump wells, test or exploratory borings, or any other nonmonitoring type of well within the jurisdictional boundaries of the City. Monitoring wells remain under full jurisdiction of the 'Water Quality Law of the County of Yolo' (chapter 8, section 6-8 of County Code). (Ord. No. 1812, § 1 (part).)".

The need for special well construction and destruction policies has not been identified within the UC Davis service area. Therefore, the construction and destruction standards put forth in CWC Section 13700 through 13806 and detailed in DWR Bulletins 74-81 and 74-90 have been adopted as the applicable standards. These standards are enforced through the well construction and destruction permitting process administrated by the Yolo County Department of Environmental Health.

### 3.5.4 Groundwater Management Program

With the development of this groundwater management plan the City and UC Davis have taken the first steps towards a formal groundwater management plan.

Currently, both agencies, along with all other Yolo Subbasin stakeholders, are members of the Water Resource Association of Yolo County. The WRA provides a forum for coordination of groundwater management program activities. The Solano Water Authority (SWA) serves a similar role in the Solano Subbasin.

### 3.5.5 Wellhead and Recharge Area Protection Measures

To date, there are no formally adopted wellhead or recharge area protection policies applicable to the City and UC Davis service areas, except for the well construction and destruction standards described in the preceding section. The City and UC Davis understand that point and non-point sources of contamination could jeopardize wells and recharge areas within their service areas.

The City and UC Davis will continue to coordinate with the Yolo County Planning Departments during evaluation of new projects in the vicinity of their service areas; the Yolo County Department of Environmental Health for permitting of any wells they construct; and the Central Valley Regional Water Quality Control Board and the California Department of Toxic Substances Control for updates on known and suspected point and non-point sources of groundwater contamination.Control of Saline Water Intrusion

Saline water intrusion into water supply aquifers has not been identified in the vicinity of the City and UC Davis service areas, and is not expected to be an issue in the future. However, the City and UC Davis have retained this element of groundwater resource protection in their GWMP in the unlikely event that groundwater quality data show increasing salinity in the future due to upwelling of deep saline water from below the Tehama formation.

### 3.5.6 Groundwater Resource Protection Actions

Davis and UC Davis will take the following actions:

- Ensure that well construction/destruction projects meet the applicable standards (City Ordinance, County Ordinance or CWC);
- Continue to cooperate with other local agencies in their groundwater management efforts;
- Endeavor to evaluate the potential for proposed projects to impact existing private wells and future wells that may be constructed by either entity;
- Consider the location of existing potential point and non-point sources of contamination when selecting well sites;
- Design wells to minimize the risk of wellhead contamination and spread of contaminants caused by pumping; and
- Continue to evaluate groundwater quality data for evidence of increasing salinity.

## 3.6 Groundwater Sustainability

The City and UC Davis are currently engaged in various activities that promote groundwater sustainability. Specific actions currently being pursued include:

- Incremental hydrogeologic investigation;
- Initial groundwater modeling;
- Support of efforts by YCFCWCD to develop additional water supply for areas north and west of this GWMP area;
- Environmental documentation for importation of surface water from the Sacramento River; and
- Construction and operation of groundwater and subsidence monitoring facilities.

### 3.6.1 Incremental Hydrogeologic Investigation

The City and UC Davis will perform detailed water quality zone sampling for any new wells constructed. They will also perform brief aquifer testing with each new well to determine how pumping impacts propagate through the aquifer system. Other testing, such as provenance (geologic source) analysis for sands and gravels, and a continuous deep core investigation are currently under consideration. These incremental hydrogeologic investigation steps will further the understanding of the aquifer system.

### 3.6.2 Groundwater Modeling

Groundwater models are a tool that can be effectively used to assess how proposed groundwater management actions or changes affect hydrologic conditions. In both the Phase I and Phase II Deep Aquifer Studies, numerical aquifer characteristics were calculated based on the results of pumping tests (West Yost & Associates, 1999; Brown and Caldwell and West Yost Associates, 2005). This also included characteristics for intermediate depth zones in the Phase I Study. These numerical characteristics were used for 2 dimensional modeling to obtain initial estimates of interference from the construction of additional deep wells.

The Integrated Ground and Surface water Model (IGSM) is currently being developed for YCFCWCD through a grant from DWR. The IGSM has been extended through the area of this GWMP to just south of Putah Creek. The IGSM is a quasi-three-dimensional water resources model that should be effective for modeling large scale groundwater conditions, especially for the shallower aquifer zones.

The City and UC Davis are exploring the possibility of developing a detailed groundwater model for the GWMP area. The previous studies and the IGSM would provide the initial basis for the model. A groundwater model could be used to:

- Evaluate interference between wells;
- Evaluate impacts of additional wells;
- Study drought impacts to City and UC Davis wells; and
- Support updates of water inventory and analysis and groundwater status reports.

Future updates could also be used to model groundwater quality and inelastic land subsidence.

### 3.6.3 Support of YCFCWCD Efforts

The YCFCWCD has proposed several projects to capture and store excess winter stream flows in Yolo County. These projects include one that would divert excess winter flows from lower Cache Creek and another that would divert and store excess winter and spring flows from the Colusa Basin Drain. These projects could provide direct and in-lieu groundwater recharge in areas north of the Davis/UC Davis groundwater management plan area. The City and UC Davis support these efforts directly through their memberships in the Yolo County WRA and the WRA Technical Advisory Committee.

### 3.6.4 Importation of Surface Water from the Sacramento River

The City of Davis, UC Davis, and the City of Woodland are jointly pursuing the diversion of water from the Sacramento River to supplement groundwater as a municipal water supply. This project has the potential to supply most of the water needed for Year 2040 target municipal water demands, with only peaking capacity provided by groundwater wells. The agencies are currently completing environmental documentation for the diversion and pipeline facilities. The agencies intend to continue this long-term effort. The Sacramento River diversion project may also be supported through the Yolo County Integrated Regional Water Management Plan (IRWMP) currently under way.

### 3.6.5 Construction and Operation of Groundwater Management Facilities

Ensuring the long-term sustainable use of the groundwater resources within the Plan area may require the planning and construction of projects that:

- Evaluate the need and potential for in-lieu groundwater recharge;
- Facilitate conjunctive use projects through improvements to recharge, extraction, and distribution infrastructure; and

- Protect groundwater quality, or remediate contaminated sites.

The Yolo County WRA is developing the IRWMP, and is considering policies, programs, and projects associated with the construction and operation of groundwater management facilities.

3.6.6 Groundwater Sustainability Actions

The City and UC Davis will take the following actions:

- Complete environmental documentation for Sacramento River diversion to eventually offset a portion of the need for groundwater pumping;
- Continue other planning actions for Sacramento River diversion;
- Support the development of a local groundwater model;
- Perform detailed zone sampling and aquifer tests at any new wells constructed by the City and UC Davis;
- Support YCFCWCD efforts to develop additional water supplies for areas north of this GWMP area; and
- Pursue funding from state agencies, federal agencies, and partnerships for groundwater sustainability activities.

## 3.7 Stakeholder Involvement

Public outreach and education are core activities of both the City and UC Davis.

The primary stakeholder outreach was through a GWMP Advisory Committee, which was formed to solicit input and guidance from major agency stakeholders. Public outreach and stakeholder input have also been encouraged through the City's Natural Resources Commission, whose mission includes providing two-way dialogue with the public and dissemination of information on water resources. The City and UC Davis have provided public outreach for the many previous projects leading up to this GWMP, including the Future Water Supply Study, Joint Water Supply Feasibility Study, and the Phase I and Phase II Deep Aquifer Studies (West Yost & Associates 1999 and 2002; Brown and Caldwell and West Yost & Associates, 2005).

Information on this project and other water resource projects is provided on the City's web site at http://www.ci.davis.ca.us/pw/water/. The City and UC Davis regularly engage in cooperative efforts with state and other local agencies. The following sections provide details on the involvement by the City and UC Davis with the water resource stakeholders.

3.7.1 Interagency and District Cooperation

Effective groundwater management requires coordination and cooperation between state, local, and federal agencies. The City and UC Davis will continue to work proactively with key agencies, local districts, and County departments, such as:

- State Water Resources Control Board (SWRCB): The SWRCB is responsible for establishing water rights and maintaining water quality standards. The SWRCB provides the framework and direction for groundwater protection efforts. The City and UC Davis have established a working relationship with the SWRCB to develop an appropriative surface water rights application that, if permitted, will allow diversion from the Sacramento River.

- California Department of Water Resources (DWR): DWR plays an important role in the management of both surface water and groundwater resources. Davis and UC Davis have worked closely with DWR Central District on a number of important studies and programs, including previous groundwater studies and land surface subsidence studies. DWR continues to support groundwater management and land surface monitoring in the Davis/UC Davis service areas. Current projects with substantial funding managed by DWR include IGSM development, the Yolo County IRWMP, and this GWMP development.

- Water Resources Association of Yolo County (WRA): The WRA is a consortium of entities authorized to provide a regional forum to coordinate and facilitate solutions to water issues in Yolo County. Davis and UC Davis are active members of the WRA along with YCFCWCD, Yolo County, and other cities and water districts.

- Yolo County Flood Control and Water Conservation District (YCFCWCD): YCFCWCD provides surface water throughout much of western and central Yolo County from water rights on Cache Creek and storage in Clear Lake and Indian Valley Reservoir. YCFCWCD has statutory authority for groundwater management throughout its original service area, which included some of the area currently served by The City and UC Davis. The City and UC Davis work collaboratively with YCFCWCD in water resource planning.

- Solano County Water Agency (SCWA) and Solano Irrigation District (SID): SCWA provides untreated water to cities and agricultural districts in Solano County from the Federal Solano Project and the North Bay Aqueduct of the State Water Project. SID is the retail water district that serves the northern portion of Solano County using surface water from SCWA and groundwater wells. Actions by the Solano water agencies could have some effects on groundwater within the Davis and UC Davis service areas and vice-versa. A representative from SID has been included on the Advisory Committee for the Davis/UC Davis GWMP to insure coordination in GWMP development.

- Reclamation District 2035 (RD 2035): RD 2035 serves surface and groundwater to the Conaway Ranch area several miles north of Davis. RD 2035 is one of the main surface water suppliers to eastern Yolo County. RD 2035 could be a potential partner in a Sacramento River water diversion project for the City and UC Davis. The City and UC Davis coordinate water resource planning with RD 2035 through joint participation in the WRA.

- City of Woodland: Although Woodland is distant enough from Davis and UC Davis that groundwater pumping interference is not anticipated, Woodland is interested in further exploration of the hydrogeology in and around its service area. Woodland participated with Davis and UC Davis in the recent Phase II Deep Aquifer Study. Woodland is also an active member in the WRA and could be a participant in a Sacramento River diversion project.

- City of West Sacramento: West Sacramento currently supplies its municipal water needs with water diverted from the Sacramento River. West Sacramento is a potential partner in a Sacramento River diversion project for Davis and UC Davis.

### 3.7.2 Advisory Committees and Stakeholders

The following local agencies were considered to be stakeholders in the management of groundwater in and around the Davis/UC Davis service areas:

- YCFCWCD
- RD 2035
- Yolo County
- WRA
- SID
- SCWA

These local agencies were discussed above in 3.7.1. In addition to these local agencies, the following advisory committees were specifically involved in the development of the GWMP and stakeholder outreach:

- Davis NRC
- WRA TAC

The City and UC Davis staff are active members of the WRA Technical Advisory Committee (TAC). The Advisory Committee for this GWMP was comprised of the WRA TAC and a member from SID. Advisory, stakeholder, and public meetings held during the GWMP development process were listed previously in Table 1-1.

### 3.7.3 Ongoing Stakeholder Involvement Actions

The City and UC Davis will take the following actions:

- Continue to work cooperatively with DWR Central District and the Division of Local Planning and Assistance (DLPA) on groundwater investigation and management activities;
- Continue to work cooperatively with YCFCWCD on groundwater management and other water resource activities;
- Be active in the WRA and responsive to the needs and requests of the WRA TAC;
- Continue to disseminate groundwater management planning information to other nearby local water districts and agencies; and
- Continue to support locally-driven stakeholder groups.

## 3.8 Integrated Water Resource Planning

The WRA expectes to complete its IRWMP in September 2006. The IRWMP will be closely coordinated with the Yolo County General Plan process that has a planning horizon of 2025. The goal of the IRWMP is to improve water resource management in five areas:

1. Water supply and drought preparedness;
2. Water quality;
3. Flood control and storm drainage;
4. Recreation; and

5. Riparian and aquatic ecosystem enhancement.

A series of community workshops are being scheduled and conducted to inform interested parties of the IRWMP, answer questions and solicit input on the IRWMP.

Drawing from data and information presented in the IRWMP document, water resource plans, technical studies, and expressed public concern, the WRA TAC has identified particular findings and issues, and in some cases needs, related to the respective water resource management categories. The groundwater related issues and guidelines for water supply are as follows:

**Issues**

1. Need to improve existing water supply quality and pursue higher quality water sources to meet current and future demands;
2. Availability of adequate water supplies during severe drought conditions;
3. Subsidence as a result of groundwater extraction; and
4. Ability of deep aquifer to sustain current and future demands.

**Guidelines**

Water Supply Reliability

1. Wellhead protection plans will be developed to maintain groundwater quality.
2. Drought protection and contingency plans will be developed to improve water supply reliability during extended droughts.
3. Data and information related to water resources and land use will be compiled, evaluated, and reported on a regular basis.

Groundwater

1. Groundwater resources will be managed on a sustainable basis to ensure sufficient amounts of high quality water for existing and future uses, and protection and enhancement of natural ecosystems.
2. Conjunctive use of surface water and groundwater will be maximized.
3. Monitoring and assessment/modeling of groundwater and surface water resources will be enhanced in concert with water supply and wastewater recycling projects.

### 3.8.1 Integrated Water Resource Planning Actions

The City and UC Davis will take the following actions:

1. Through participation in the WRA and WRA TAC, assist in the development of the IRWMP;
2. Implement plan policies, programs, and projects approved by the WRA for which funding is available; and
3. Pursue funding sources for implementation of plan policies, programs, and projects.

## 3.9 GWMP Reporting and Updating

The City and UC Davis consider the GWMP to be a living document that guides groundwater management. Plan implementation centers on the implementation actions under each of the five groundwater management components.

Section 3.3 identifies the five GWMP components. Individual plan components are described in Sections 3.4 through 3.8. Plan implementation actions are identified at the conclusion of each section. Additionally, this section concludes with Table 3-5 which summarizes implementation actions and the associated schedule. The City and UC Davis Working Group will meet periodically to assess progress toward completion of the identified implementation actions. The following sections provide additional discussion on plan implementation, reporting, and updates.

### 3.9.1 GWMP Implementation Report

The City and UC Davis will collaborate annually to develop a brief status report to document progress on GWMP implementation during the previous year and to review and confirm implementation actions for the next year. The report will discuss the status of groundwater levels, groundwater quality, and inelastic land subsidence in relation to established BMOs. Data necessary for completion of the annual report will continue to be input and managed within the combined relational database shared by the City and UC Davis.

### 3.9.2 GWMP Update

The continually evolving knowledge of subsurface conditions coupled with improved groundwater management strategies will result in the need for periodic Plan updates. The City and UC Davis will at least annually consider improvements to the groundwater management techniques, and will incorporate these improvements as they develop. BMOs may be modified in future years based on monitoring results, new information, or evolving objectives. If changes need to be made, the City and UC Davis will formalize changes to this GWMP at least once every five years.

### 3.9.3 GWMP Reporting and Updating Actions

The City and UC Davis will take the following actions:

- Work cooperatively with local stakeholders, county government, and local advisory committees to assess needed GWMP updates;
- Document BMO performance status, actions ongoing or completed, and prioritized actions for the next year; and
- Assess and modify, if necessary, BMOs based on monitoring results and management strategies.

## Table 3-5. Summary of GWMP Actions

| | Description of Action | Implementation Schedule |
|---|---|---|
| **I.** | **Groundwater Monitoring** | |
| 1 | Update monitoring procedures as necessary to be compatible with monitoring program. | As needed |
| 2 | UC Davis to add automatic flow monitoring to all active domestic and utility wells, automatic water level monitoring to select wells. | By 2008 |
| 3 | Maintain a coordinated database of monitoring data. | Ongoing |
| 4 | Export requested data annually from the database to YCFCWCD for inclusion in the Water Resources Information Database. | Annual |
| 5 | Evaluate the data annually and compare with quantitative BMO trigger levels. | Annual |
| 6 | Monitor groundwater / surface water interaction on Lower Putah Creek through participation on Lower Putah Creek Coordinating Committee. | Ongoing |
| 7 | Continue to support triennial land subsidence surveys through the Yolo County Subsidence Network. | Ongoing |
| **II.** | **Groundwater Resource Protection** | |
| 1 | Ensure that any well construction or destruction projects meet the applicable standards (City Ordinance, County Ordinance or CWC). | As needed |
| 2 | Continue to cooperate with other local agencies in groundwater management efforts. | As needed |
| 3 | Endeavor to evaluate the potential for proposed projects to impact existing private wells and future wells that may be constructed by either entity. | Ongoing |
| 4 | Consider the location of existing potential point and non-point sources of contamination when selecting well sites. | As needed |
| 5 | Design wells to minimize the risk of wellhead contamination and spread of contaminants caused by pumping. | Ongoing |
| 6 | Continue to evaluate groundwater quality data for evidence of increasing salinity | Annual |
| **III.** | **Groundwater Sustainability** | |
| 1 | Complete environmental documentation for Sacramento River diversion to eventually partially offset the need for groundwater pumping. | Pending |
| 2 | Continue other planning actions for Sacramento River diversion. | Annual |
| 3 | Support the development of a local groundwater model. | Ongoing |
| 4 | Perform detailed zone sampling and aquifer tests at any new wells constructed by the City and UC Davis. | As new wells are constructed |
| 5 | Support YCFCWCD efforts to develop additional water supply for areas north of this GWMP area. | Annual |
| 7 | Pursue funding from state agencies, federal agencies, and partnerships for groundwater sustainability activities. | Annual |
| **IV.** | **Stakeholder Involvement** | |
| 1 | Continue to work cooperatively with DWR Central District and Division of Local Planning and Assistance on groundwater investigation and management activities. | Annual |
| 2 | Continue to work cooperatively with YCFCWCD on groundwater management and other water resource activities. | Annual |
| 3 | Be active in the WRA and responsive to the needs and requests of the WRA TAC. | Ongoing |
| 4 | Continue to disseminate groundwater management planning information to other nearby local water districts and agencies. | Ongoing |
| 5 | Continue to support locally-driven stakeholder groups. | Ongoing |

## Table 3-5. Summary of GWMP Actions (continued)

| | Description of Action | Implementation Schedule |
|---|---|---|
| **V.** | **Integrated Water Resources Planning** | |
| **1** | Through participation in the WRA and WRA TAC, assist in the development of the IRWMP. | Fall 2006 |
| **2** | Implement plan policies, programs, and projects approved by the WRA for which funding is available | 2007, 2008 |
| **3** | Pursue funding sources for implementation of plan policies, programs, and projects. | Annual |
| **VI.** | **GWMP Implementation, Reporting and Updating** | |
| **1** | Work cooperatively with local stakeholders, county government, and local advisory committees to assess needed GWMP updates. | Ongoing |
| **2** | Document BMO performance status, actions ongoing or completed, and prioritized actions for the next year. | Annual |
| **3** | Assess and modify, if necessary, BMOs based on monitoring results and management strategies. | Annual |

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# APPENDIX A

## Groundwater Management Plan Resolutions

## RESOLUTION NO. 05-278, SERIES 2005

## RESOLUTION NOTICING THE INTENT OF THE CITY OF DAVIS AS THE LEAD AGENCY ON BEHALF OF UC DAVIS TO PREPARE A GROUNDWATER MANAGEMENT PLAN (GWMP) UNDER WATER CODE SECTION 10750 et seq. (AB 3030, STATS 1992) FOR THE DAVIS AREA NOT COVERED BY ANOTHER GROUNDWATER MANAGEMENT PLAN UNDER THIS AUTHORITY OR ANY OTHER AUTHORITY

WHEREAS, it is the intent of the Legislature through the passage of AB 3030 (Stats 1992) codified as Water Code Section 10750 et seq. to encourage local agencies to work cooperatively to manage groundwater resources within their jurisdictions to ensure both its safe production and quality; and

WHEREAS, the Legislature also finds and declares that the additional study of groundwater resources is necessary to better understand how to manage groundwater effectively to ensure the safe production, quality, and proper storage of groundwater in the state; and

WHEREAS, the adoption of a GWMP is encouraged, but not required by law; and

WHEREAS, any local agency, whose service area includes a groundwater basin, or a portion of a groundwater basin, that is not subject to groundwater management pursuant to other provisions of law or a court order, judgment, or decree, may, by ordinance, or by resolution if the local agency is not authorized to act by ordinance, adopt and implement a GWMP pursuant to this part within all or a portion of its service area not served by a local agency or served by a local agency whose governing body, by a majority vote, declines to exercise the authority to implement a GWMP and enters into an agreement with the local public agency pursuant to Water Code Sections 10750.7 and 10750.8; and

WHEREAS, the City of Davis is interested in the development of a GWMP, working collaboratively with UC Davis, as defined under Water Code Section 10750, et seq. for the Davis Area not covered by another GWMP; and

WHEREAS, prior to adopting a resolution of intention to draft a GWMP, Water Code Section 10753.2 requires a local agency to hold a hearing, after publication of notice pursuant to Government Code Section 6066, on whether or not to adopt a resolution of intention to draft a GWMP pursuant to this part for the purposes of implementing the plan and establishing a GWMP; and

WHEREAS, such hearing was noticed pursuant to Government Code Section 6066 and held on October 4, 2005 at 6:30 p.m. in the City of Davis Community Chambers, 23 Russell Boulevard in Davis, California; and

WHEREAS, at the conclusion of the hearing, the local agency may draft a resolution of intention to adopt a GWMP pursuant to this part for the purposes of implementing the plan and establishing a GWMP.

NOW, THEREFORE, BE IT RESOLVED that the City Council of the City of Davis does hereby agree to:

1. Adopt a Resolution of Intention to Draft a GWMP pursuant to Water Code Section 10750 et seq. for the purposes of implementing the plan and establishing a GWMP for the Davis Area.

2. Direct the City Clerk to publish the Resolution of Intention under Government Code Section 6066 pursuant to Water Code Section 10753.3(a).

3. Direct the City Manager to prepare the GWMP for the Davis Area by May 2006 in accordance with AB303 project funding contract requirements.

PASSED AND ADOPTED by the City Council of the City of Davis this 4th day of October, 2005 by the following vote:

AYES: GREENWALD, PUNTILLO, SAYLOR, SOUZA, ASMUNDSON.

NOES: NONE.

RUTH UY ASMUNDSON
Mayor

ATTEST:

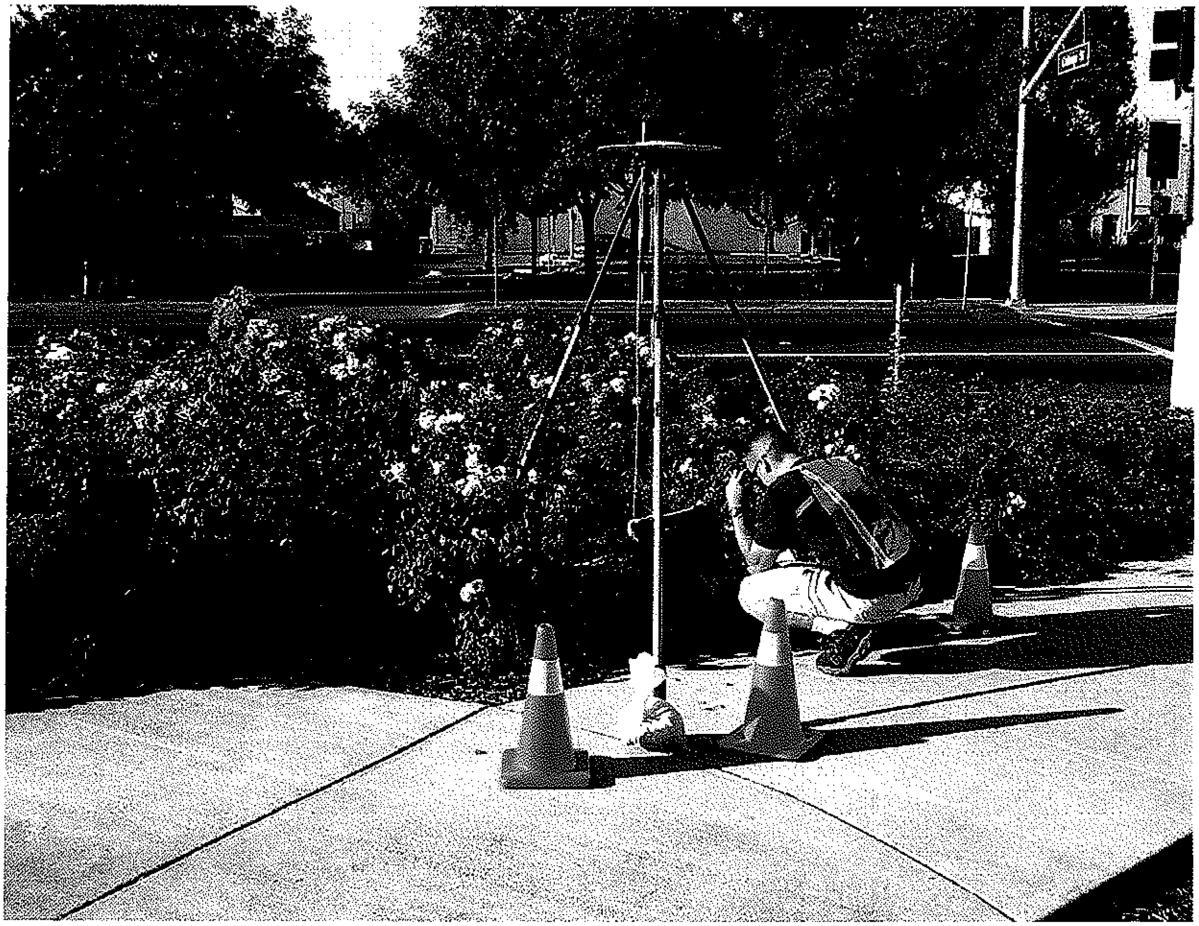
BETTE E. RACKI
City Clerk

# APPENDIX B

## 2005 Subsidence Survey Recommendations Report

# The Yolo County GPS Subsidence Network

# Recommendations and Continued Monitoring



(Photo: Station LIBRARY, in Woodland)


**Submitted by:**

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**March, 2006**

## Executive Summary

From July through September, 2005 the third set of observations of the Yolo County GPS Subsidence Network were obtained. This marks the third time the Yolo network has been observed. The original observations were obtained in 1999. The second observation of the network was obtained in 2002. In 2002 the network was expanded to include stations south of the Highway 80 corridor. Also, the City of Sacramento added several stations to the network for the 2002 observations. In the 2005 project a few new stations were added to the network.

The results of the 2005 observations validate the findings of the 2002 results. The results show continuing subsidence in the Davis to Zamora corridor. The 2005 observations also provide an opportunity to take a more in-depth look at the underlying assumptions of subsidence based on the issue of what is believed to be stability. The project incorporates a few continuously operating GPS sites. These sites provide a continuous record of ground movements, both horizontal and vertical. It is in light of these data that we may now be able to refine some of our assumptions about stability against which subsidence is measured.

The 2005 project included the addition of one station (RWF1) that is part of the Davis Deep Aquifer study, and one station (RD2068) that was established for Reclamation District 2068 in Solano County. Both were established in 2004. Including RD2068 entailed adding two additional stations (SURVEYOR and MILLAR) in order to meet the network geometry specification. These two stations were part of earlier subsidence network observations in the Sacramento/San Joaquin River Delta.

Station ellipsoid heights for the 1999, 2002 and 2005 projects, as developed by CSRC, are included in **Appendix A**.

The provisional results of the elevations (orthometric heights) for the 2005 project are included in **Appendix B.** Also included in this appendix are the values obtained from the earlier 1999 and 2002 projects along with the inter-survey subsidence values.

A map of the project showing the local network stations, cumulative subsidence contours and water source information, may be found in **Appendix C**.

The hypothetical results of continued subsidence at rates seen to date is shown for selected stations in **Appendix F**.

The report of the 1999 survey (The Yolo County Subsidence Network: Recommendations for Future Recommendations, Frame and D'Onofrio, 1999) included a series of ten recommendations. The 2002 report (The Yolo County GPS Subsidence Network: Recommendations and Continued Monitoring, Frame and D'Onofrio, 2003) added an additional two recommendations. All of these recommendations are further discussed in Section IV of this report.

## I. INTRODUCTION

This report outlines the results of the 2005 Yolo County GPS Subsidence Project. It also includes comparisons with the earlier 1999 and 2002 projects. Each of the recommendations in the 1999 and 2002 reports are addressed with updated comments. This report also includes a discussion of the subsidence findings with respect to a more thorough review of the relationship of subsidence areas to neighboring stable areas and/or subsiding areas with continuous records of earth movement.

As with the earlier 1999 and 2002 projects, the 2005 project was accomplished with cooperation from several agencies. Observation personnel were provided by the California Department of Water Resources, the cities of Woodland and Davis, the US Bureau of Reclamation, the Yolo County Planning, Resources & Public Works Department, and Frame Surveying & Mapping. GPS equipment was supplied by the University of California Davis, the US Bureau of Reclamation, and Frame Surveying & Mapping.

## II. BACKGROUND

The 2005 GPS subsidence survey is the third in the series of observations. These observations have been conducted at three year intervals, the previous observations being in 1999 and 2002. The greatest portion of the GPS network has been the same. Several new stations were added in 2002 and four additional stations were added in the 2005 survey.

The results of the 2005 survey indicate that subsidence trends throughout much of the county are continuing. The largest amount of subsidence occurs in the Zamora area, especially near the Zamora extensometer (station ZAMX) which has subsided a total of about 12 to 15 centimeters (roughly 6 inches) over the six years of the project. A map of the subsidence contours based upon the CSRC ellipsoid height analysis is provided in **Appendix C.**

It should be noted that only a very few stations in the network showed no subsidence. It should also be noted that the accuracy of the subsidence values is +/- 2 centimeters.

## III. PROJECT ISSUES

All stations observed in the 2002 project were recovered in good condition. There were four additional stations added to the network. One of the stations is part of the Davis Deep Aquifer Study (station RWF1), and one was established in 2004 for Reclamation District 2068 (station RD2068). Station RD2068 is in Solano County. Two additional stations in Solano County ( SURVEYOR and MILLAR) were added to allow for a more complete relationship with RD2068. The two additional Solano County stations were part of earlier GPS subsidence projects. Station RWF1 is inside Yolo County and required no additional station observations.

The City of Sacramento stations included in the 2002 survey were not observed in 2005.

There were a greater percentage of re-observations required for this project than for previous projects. All baselines (those inter-station lines indicated on the project map – see **Appendix D**) are observed at least twice. Baseline comparisons must agree within 2 centimeters. In the 2005 project over 15 percent of the baselines did not meet this criterion. All were re-observed and all ultimately met the 2 centimeter criterion.

All other activities associated with the 2005 project were routine.

Provisional coordinates (latitude, longitude and elevations) are included in **Appendix E.**

## IV. RECOMMENDATIONS AND COMMENTS

After the 1999 project was completed a series of ten recommendations was made. After the 2002 project an additional two recommendations were made. We will include two additional recommendations in **Section V. NEW RECOMMENDATIONS.**

A summary of the recommendations is immediately below, followed by more detailed information.

## Summary of Recommendations

| Recommendation | Year | Status |
|---|---|---|
| | | |
| 1. Inform the public & make data easily available | 1999<br>2002<br>2005 | Implemented for 1999 & 2002; in process for 2005. |
| 2. Annual field review of network station condition | 1999<br>2002<br>2005 | Not formally implemented. |
| 3. Pre-emptive replacement of endangered station marks | 1999<br>2002<br>2005 | Untested. |
| 4. Re-observe network every 3 years | 1999<br>2002<br>2005 | Implemented. |
| 5. Consider more frequent observations | 1999<br>2002 | Discontinued due to lack of demand. |
| 6. Network densification | 1999<br>2002<br>2005 | Limited implementation near Davis. |
| 7. Non-financial support for continued operation of UCD1 | 1999<br>2002<br>2005 | Not formally implemented. |
| 8. Establish a new CORS in the north county | 1999<br>2002 | Obsolete. |
| 9. Encourage FEMA to adopt network results | 1999<br>2002<br>2005 | Not formally implemented. Early attempt to involve FEMA met no response. |
| 10. Investigate supplemental detection technologies | 1999<br>2002<br>2005 | Not implemented due to lack of demand. |
| 11. Incorporate extensometer data | 2002<br>2005 | Implemented. |
| 12. Extend network into Solano County near Davis | 2002<br>2005 | Limited implementation in 2005. |
| 13. Review technical approach to data analysis | 2005 | In process. |
| 14. Document subsidence effects | 2005 | New. |

**Recommendation 1.** Inform public and private agencies involved in construction, utilities management, public works and related activities in the county about the network and the location of all stations. Information about the project's web site should be included in this information. (Note: As of the date of this report, the website – http://www.yarn.org/subsidence/about.html – not has not been updated. The update is pending final publication of station positions by NGS.)

As noted in the report after the 2002 observations there continues to be anecdotal information about the utility of the network, especially among the surveying community. Survey painting and flagging indicate that the network stations are being used. The County Surveyor reports that many of the stations are used and reported in Records of Survey submitted to him.

**Recommendation 2.** Task a single entity with visiting each monument in the network annually to assess the integrity of the individual monuments. Any discrepancies in the monument description and condition should be brought to the attention of the interested parties and to the National Geodetic Survey (NGS). Follow proper steps for reporting such discrepancies.

It continues to appear that no agency has accepted this responsibility. It might appear that this is unnecessary since all stations used in the 2005 survey were recovered in good condition. As the network ages experience indicates that some stations may be destroyed due to construction or other activities. It becomes more imperative that this recommendation be followed. In the absence of an agency accepting this responsibility a private entity should be considered to undertake this responsibility on a contractual basis.

**Recommendation 3.** Identify stations in imminent danger of destruction and replace them in advance, following National Geodetic Survey guidelines. (A copy of these guidelines may be obtained from the NGS California State Geodetic Advisor, Marti Ikehara – Marti.Ikehara@noaa.gov). A station destroyed before replacement represents a permanent break in the subsidence history for that station.

As indicated in Recommendation 2, above, the absence of occasional visits to each of the stations increases the possibility of stations being lost. While there is no difference in the cost of replacing a monument either before or after it is destroyed, replacing it after it has been destroyed breaks the subsidence history of the mark.

**Recommendation 4.** Re-observe the entire network in three years. Depending on the results of the re-observation, the county can better determine the time period for subsequent re-observations.

It appears that the decision to re-observe the network on a three-year cycle is acceptable to project participants. A review of the latest three-year cycle (2005 – 2002) indicates a slightly larger amount of subsidence at several of the stations than that observed in the first three year cycle (2002 – 1999). The next three year cycle should provide a more definitive overview of subsidence effects. The fact that subsidence rates over one cycle differ from those of another cycle provide additional information about the nature of subsidence. Because subsidence is a result of several factors (e.g., aquifer re-charge, amount of pumping, etc.) it tends to be a non-linear phenomenon.

**Recommendation 5.** Investigate the benefits of more frequent re-observation of particular areas of the county.

Based on the results of the 2005 survey and its comparison with the 1999 and 2002 surveys it does not appear that more frequent observations of the network will add significantly more reliable information than is provided under the current 3-year observation cycle.

**Recommendation 6.** Investigate densification of the network in areas of particular interest.

The approach made for this recommendation after the 2002 survey still seems valid. If an area of the county is deemed to need a more densified approach this can be accomplished by either GPS or a combination of GPS and terrestrial observations. In the areas of greatest subsidence this might be worthwhile. This assumes that there is a need for such densified observations. Planned construction in these areas might necessitate that this option be considered.

**Recommendation 7.** Provide continuing non-financial support for the Continuously Operating Reference Station (CORS) at the University of California, Davis. This site can be of significant value in ongoing subsidence measurement operations.

The CORS site at UC3D provides the only continuous record of land movement in the area. The following figure shows the downward (subsiding) trend of the site as well as the seasonal trends of the site. This seasonal trend seems to be symbolic of sites in subsiding areas. Efforts should be made to ensure continuous operation of the site. As long as it continues in operation it will continue to provide a piece of the framework for continued, accurate monitoring of subsidence in the county.

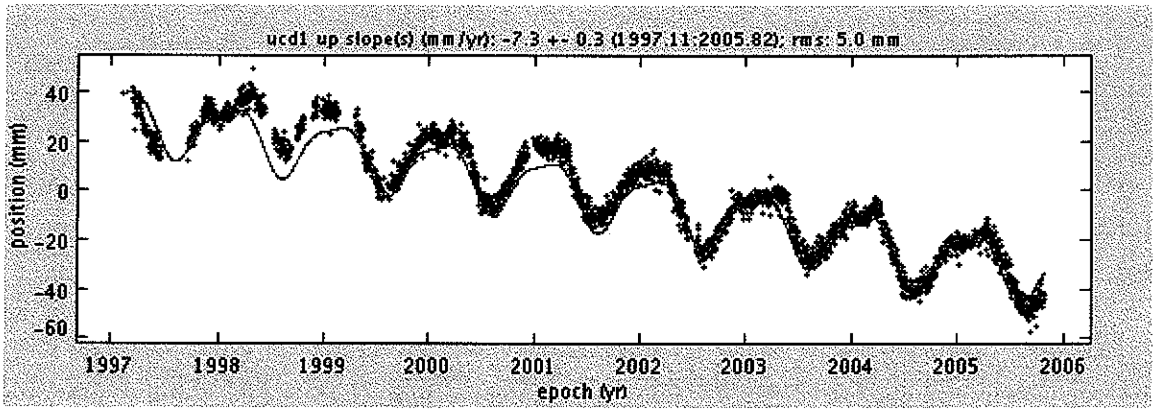



Fig. 1. UCD CORS site vertical record, 1997 through 2005.

**Recommendation 8.** Investigate the establishment of a CORS site in the north county area.

This recommendation was made prior to the establishment of the Plate Boundary Observatory (PBO) program. The PBO program includes the establishment of over 400 continuous GPS sites in California. Four of these have been established in the vicinity of Yolo County: three in the county (near Woodland, Dixon and Winters), and one to the north in Colusa County (near the city of Colusa). These should help with long term measurements of earth movement and obviate the need for a station in northern Yolo County. This recommendation will be removed from future reports unless there is a need to re-consider the need for a station in that vicinity.

There is an additional continuous tracking GPS site in the Sutter Buttes. This station has been part of the three Yolo County surveys.

**Recommendation 9.** Consider the merits of encouraging the Federal Emergency Management Agency (FEMA) to adopt the results of the project in its flood plain mapping efforts.

The county should consider following up on this recommendation with FEMA. Since accepting the results of the 1999 survey it appears that FEMA would be receptive to such a request. The 2002 City of Woodland Flood Insurance Rate Maps (FIRMs) were developed using vertical control from the 1999 Yolo project. These FIRMS indicate flood contours in both the NGVD29 and NAVD88 datums.

**Recommendation 10.** Investigate other supporting technologies as an adjunct to the GPS Subsidence Network within Yolo County.

The 2002 report suggested considering the use of either LIDAR or Synthetic Aperture Radar (SAR) technology which could provide more densified coverage of the project area. Because the accuracy of LIDAR technology is currently less than what is required for Yolo County subsidence monitoring, its application is not recommended at this time.

In the absence of any apparent interest in more densified measure of subsidence, the use of SAR is similarly not recommended at this time. SAR technology offers a potentially better alternative to LIDAR. However, the use of SAR continues to be somewhat more problematic in agricultural areas.

**Recommendation 11.** Incorporate measurements to relate the two DWR extensometers (at Zamora and Conaway ranch) to the Yolo County Subsidence network.

In July of 2005 DWR personnel took measurements relating both the Conaway and Zamora extensometers to their respective adjacent network station marks (CONAWAY and ZAMX). Continued annual measurements of this nature will simplify tracking the relationship between movement indicated by the extensometers and that indicated by the GPS measurements.

In the 2002 survey, a discrepancy was noted between the amount of subsidence indicated by the GPS results and that indicated by the Stevens chart recorders mounted on the extensometers. This trend – which is attributed to the fact that the extensometers only reflect subsidence in the upper region of the ground (716 feet at Conaway, 1003 feet at Zamora) – continues. See **Appendix H** for details.

**Recommendation 12.** Seek cooperation with the County of Solano to determine the magnitude and extent of the subsidence in the vicinity of Davis.

The addition of station RD2068 of the Davis Deep Aquifer project and two of its neighboring stations (SURVEYOR and MILLAR) in Solano will help resolve this issue. The inclusion of up to three additional stations in Solano County that were part of the San Joaquin/Sacramento Delta project would provide the necessary observations to complete this recommendation. In the absence of working with Solano County these stations could be added into the base Yolo project. The candidate stations are CURREY (PID AE9856), STORE (PID AE9852) and X 128 RESET (PID JS1613).

## V. ADDITIONAL RECOMMENDATIONS

There are now five continuous GPS sites in or near the county. Two of these stations, at UC Davis and Sutter Buttes, have been in continuous operation since 1997. They provide the potential to form a better basis for measuring and monitoring subsidence in the county. These stations are on a more or less north-south axis so might not account for an east-west bias, if any, in the GPS observations. The three additional PBO sites, especially the two in Woodland and Winters, should help resolve this issue. These stations (and the Dixon station) have not been operational long enough to provide any useful data for the current survey but should prove more beneficial in future surveys.

**Recommendation 13.** Given the longer continuous time series now available at the Sutter Buttes and UC Davis sites, and the apparent subsidence at sites previously believed to be stable, we recommend that the 2005 data be reviewed more thoroughly.

When the Yolo project was initiated in 1999, the survey results were constrained to ellipsoid height values based upon the best information available from NGS. At the time, relatively little work had been done to comprehensively analyze the data being accumulated at northern California continuous GPS monitoring sites.

For the 2005 project, CSRC reanalyzed the data from the 1999, 2002 and 2005 surveys with regard to ellipsoid heights. This analysis was informed by the analysis of data gathered continuously over the 1999-2005 period at the Sutter Buttes and UC Davis permanent GPS stations. Although some discrepancies between the CSRC and NGS values remain, the relative ellipsoid heights derived from the CSRC analysis are considered to be the most reliable indicator of cumulative subsidence at this time. The subsidence contour map (Appendix B) reflects this analysis.

The most significant discrepancies between the NGS and CSRC analyses are found toward the periphery of the county. The magnitude of the discrepancies range from 2cm to 9cm. It is important to note that both analyses show the same areas of concentrated subsidence, in particular the area centered on station ZAMX.

Once the NGS and CSRC height values are reconciled, updated values for the project station positions will be incorporated into the NGS database.

**Recommendation 14.** Establish a coordinated interagency approach to the identification and documentation of subsidence effects. This would require agencies to gather supplemental data that demonstrates the impact of subsidence upon facilities and operations. Photographs and descriptions of observed impacts (e.g., raised well pads and crushed well casings) will assist in rounding out the understanding of subsidence impacts among the project partners, non-technical officials and the general public. (See **Appendix G** for example photographs.)

## VI. CONCLUSION

With the completion of the 2005 project observations, a clearer picture of ongoing subsidence begins to emerge. The 2002 survey indicated subsidence, but the time frame between the 1999 and 2002 surveys was too short to allow definitive measures of subsidence given the myriad potential causes. The 2005 survey results, when compared with the earlier surveys, provide definitive proof of such subsidence. It begins to give a clearer picture of the amount and distribution of subsidence across the project area. As indicated in the 2002 report, the central corridor of the project is undergoing the greatest subsidence. The corridor runs north from Davis, through Woodland, north to Zamora and through to the northeast corner of the county. It is generally characterized as having little or no surface water availability and substantial groundwater pumping. The subsidence does not appear to be strictly uniform – a common characteristic of the phenomenon – but rather the result of several factors. For this reason it is recommended that continued re-observations of the network be planned on a 3-year cycle. It is recommended that other studies of ground water pumping, water usage and related issues be studied as well.

Please note that the horizontal coordinates (latitude and longitude) have changed again for all stations in the network. The county is in the area of the North American and Pacific tectonic plate boundary. This tectonic motion causes all stations in the project move northwesterly a few centimeters per year.

Respectfully submitted:

Jim Frame
Frame Surveying & Mapping

Don D'Onofrio
Geodetic Consultant

# APPENDIX A.

## CSRC NAD83 Ellipsoid Height Values from 1999, 2002 and 2005 Surveys (with differences)

| 4-CH ID | 1999 | 2002 | Change 02-99 | 2005 | Change 05-02 | Change 05-99 |
|---|---|---|---|---|---|---|
| | | | | | | |
| 0308 | -6.842 | -6.880 | -0.038 | -6.910 | -0.030 | -0.068 |
| 03BG | | -21.122 | | -21.120 | | 0.002 |
| 03DG | -6.730 | -6.759 | -0.029 | -6.762 | -0.003 | -0.032 |
| 03EH | -19.335 | -19.347 | -0.012 | -19.339 | 0.008 | -0.004 |
| 1031 | -20.402 | -20.401 | 0.001 | -20.418 | -0.017 | -0.016 |
| 1069 | 23.627 | 23.646 | -0.019 | 23.630 | -0.016 | 0.003 |
| 1075 | -15.424 | -15.424 | 0.000 | -15.425 | -0.001 | -0.001 |
| 1200 | 47.507 | 47.483 | -0.024 | 47.494 | 0.011 | -0.013 |
| 1699 | 21.812 | 21.833 | 0.021 | 21.829 | -0.004 | 0.017 |
| 2068 | | | | -19.213 | | |
| ABUT | 22.034 | 22.033 | -0.001 | 22.034 | 0.001 | 0.000 |
| ALHA | -18.089 | -18.106 | -0.017 | -18.127 | -0.011 | -0.038 |
| ANDR | | -27.837 | | -27.845 | -0.008 | |
| B849 | 8.482 | 8.459 | -0.023 | 8.482 | 0.023 | 0.000 |
| BIRD | 63.747 | 63.773 | 0.026 | 63.780 | 0.007 | 0.033 |
| BRID | 33.505 | 33.527 | 0.022 | 33.510 | -0.017 | 0.005 |
| CALD | | -25.915 | | -25.904 | 0.011 | |
| CANA | -1.250 | -1.235 | 0.015 | -1.246 | -0.011 | 0.004 |
| CAST | -25.680 | -25.690 | -0.010 | -25.680 | 0.010 | 0.000 |
| CHUR | -6.689 | -6.675 | 0.014 | -6.694 | -0.019 | -0.005 |
| CODY | -17.502 | -17.551 | -0.049 | -17.586 | -0.035 | -0.084 |
| CONA | -23.079 | -23.091 | -0.012 | -23.088 | 0.003 | -0.009 |
| COTT | 60.663 | 60.711 | 0.048 | 60.710 | -0.001 | 0.047 |
| COUR | | -23.354 | | -23.358 | -0.004 | |
| COY1 | -22.381 | -22.383 | -0.002 | -22.400 | -0.017 | -0.019 |
| CVAP | -22.180 | -22.187 | -0.007 | -22.217 | -0.030 | -0.037 |
| DAVE | -11.868 | -11.872 | -0.004 | -11.876 | -0.004 | -0.008 |
| DRAI | -17.049 | -17.053 | -0.004 | -17.050 | 0.003 | -0.001 |
| DUFO | -10.193 | -10.232 | -0.039 | -10.284 | -0.052 | -0.091 |
| EX11 | -22.835 | -22.865 | -0.030 | -22.863 | 0.002 | -0.028 |
| F859 | -16.022 | -16.028 | -0.006 | -16.066 | -0.038 | -0.044 |
| FERR | -18.509 | -18.498 | 0.011 | -18.510 | -0.012 | -0.001 |
| FORD | -12.948 | -12.953 | -0.005 | -12.989 | -0.036 | -0.041 |
| FREM | -17.820 | -17.782 | 0.038 | -17.798 | -0.016 | 0.022 |
| GAFF | | -30.304 | | -30.294 | 0.010 | |
| GW17 | 54.278 | 54.292 | 0.014 | 54.302 | 0.010 | 0.024 |
| GW32 | 82.143 | 82.169 | 0.026 | 82.140 | -0.029 | -0.003 |
| HERS | -16.223 | -16.210 | 0.013 | -16.205 | 0.005 | 0.018 |
| JIME | -17.587 | -17.586 | 0.001 | -17.586 | 0.000 | 0.001 |
| KEAT | 5.083 | 5.112 | 0.029 | 5.093 | -0.019 | 0.010 |
| LIBR | -10.801 | -10.810 | -0.009 | -10.824 | -0.014 | -0.023 |
| MADI | 16.177 | 16.170 | -0.007 | 16.196 | 0.026 | 0.019 |
| MILL | | | | -20.869 | | |
| PLAI | -11.133 | -11.142 | -0.009 | -11.124 | 0.020 | 0.011 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **RIVE** | -18.667 | -18.673 | -0.006 | -18.678 | -0.005 | -0.011 |
| **RUSS** | -1.918 | -1.899 | 0.019 | -1.916 | -0.017 | 0.002 |
| **RWF1** | | | | -16.414 | | |
| **SM15** | -23.150 | -23.128 | 0.022 | -23.161 | -0.033 | -0.011 |
| **SURV** | | | | -18.080 | | |
| **SUTB** | 617.087 | 617.078 | -0.009 | 617.070 | -0.008 | -0.017 |
| **SYCA** | -22.449 | -22.426 | 0.023 | -22.435 | -0.009 | 0.014 |
| **T462** | | -21.893 | | -21.889 | 0.004 | |
| **T849** | 5.687 | 5.702 | 0.015 | 5.684 | -0.018 | -0.003 |
| **TYND** | -20.949 | -20.936 | 0.013 | -20.965 | -0.029 | -0.016 |
| **UCD1** | 0.197 | 0.190 | -0.007 | 0.171 | -0.019 | -0.026 |
| **VINC** | 17.812 | 17.828 | 0.016 | 17.800 | -0.028 | -0.012 |
| **WILS** | | -21.685 | | -21.700 | -0.015 | |
| **WOOD** | 8.873 | 8.892 | 0.019 | 8.841 | -0.051 | -0.032 |
| **X200** | -0.315 | -0.309 | 0.006 | -0.310 | -0.001 | 0.005 |
| **YCAP** | | -1.558 | | -1.566 | -0.008 | |
| **Z585** | -24.492 | -24.521 | -0.029 | -24.520 | 0.001 | -0.028 |
| **ZAMX** | -17.289 | -17.357 | -0.068 | -17.411 | -0.054 | -0.122 |

Notes:

1. All height values are expressed in meters.

2. The 1999 height value shown for station VINCOR was calculated from the 1999 height value for station PHILLIPS (not shown). PHILLIPS was rendered unsuitable for GPS observations prior to the 2002 monitoring event. VINCOR was installed nearby, and a leveling tie made to transfer the 1999 elevation from PHILLIPS to VINCOR.

# APPENDIX B.

## FSM Provisional NAVD88 Orthometric Height Values from 1999, 2002 and 2005 Surveys (with differences)

| 4-CH ID | 1999 | 2002 | Change | 2005 | Change | Change |
|---|---|---|---|---|---|---|
| | | | 02-99 | | 05-02 | 05-99 |
| | | | | | | |
| 0308 | 23.78 | 23.73 | -0.05 | 23.67 | -0.06 | -0.11 |
| 03BG | 9.91 | 9.91 | 0.00 | 9.91 | 0.00 | 0.00 |
| 03DG | 24.13 | 24.09 | -0.04 | 24.05 | -0.04 | -0.08 |
| 03EH | 10.75 | 10.73 | -0.02 | 10.74 | 0.01 | -0.01 |
| 1031 | 10.26 | 10.26 | 0.00 | 10.23 | -0.03 | -0.03 |
| 1069 | 54.73 | 54.71 | -0.02 | 54.68 | -0.03 | -0.05 |
| 1075 | 14.90 | 14.87 | -0.03 | 14.85 | -0.02 | -0.05 |
| 1200 | 77.38 | 77.38 | 0.00 | 77.38 | 0.00 | 0.00 |
| 1699 | 52.52 | 52.50 | -0.02 | 52.46 | -0.04 | -0.06 |
| 2068 | | | | 12.42 | | |
| ABUT | 53.03 | 53.01 | -0.02 | 52.97 | -0.04 | -0.06 |
| ALHA | 12.99 | 12.97 | -0.02 | 12.95 | -0.02 | -0.04 |
| ANDR | 3.68 | 3.68 | 0.00 | 3.70 | 0.02 | -0.02 |
| B849 | 39.68 | 39.68 | 0.00 | 39.69 | 0.01 | -0.01 |
| BIRD | 94.13 | 94.11 | -0.02 | 94.08 | -0.03 | -0.05 |
| BRID | 64.21 | 64.20 | -0.01 | 64.15 | -0.05 | -0.06 |
| CALD | 5.42 | 5.42 | 0.00 | 5.43 | 0.01 | 0.01 |
| CANA | 29.80 | 29.79 | -0.01 | 29.77 | -0.02 | -0.03 |
| CAST | 5.27 | 5.27 | 0.00 | 5.28 | 0.01 | -0.01 |
| CHUR | 24.13 | 24.12 | -0.01 | 24.09 | -0.03 | -0.04 |
| CODY | 12.80 | 12.75 | -0.05 | 12.68 | -0.07 | -0.12 |
| CONA | 7.72 | 7.71 | -0.01 | 7.68 | -0.03 | -0.04 |
| COTT | 91.51 | 91.52 | 0.01 | 91.49 | -0.03 | -0.02 |
| COUR | 8.06 | 8.06 | 0.00 | 8.06 | 0.00 | 0.00 |
| COY1 | 8.56 | 8.55 | -0.01 | 8.52 | -0.03 | -0.04 |
| CVAP | 8.05 | 8.01 | -0.04 | 7.96 | -0.05 | -0.09 |
| DAVE | 19.44 | 19.39 | -0.05 | 19.39 | 0.00 | -0.05 |
| DRAI | 12.99 | 12.97 | -0.02 | 12.93 | -0.04 | -0.06 |
| DUFO | 20.31 | 20.25 | -0.06 | 20.18 | -0.07 | -0.13 |
| EX11 | 7.88 | 7.86 | -0.02 | 7.85 | -0.01 | -0.03 |
| F859 | 14.23 | 14.21 | -0.02 | 14.16 | -0.05 | -0.07 |
| FERR | 12.12 | 12.13 | 0.01 | 12.10 | -0.03 | -0.02 |
| FORD | 17.55 | 17.53 | -0.02 | 17.49 | -0.04 | -0.06 |
| FREM | 12.54 | 12.56 | 0.02 | 12.54 | -0.02 | 0.00 |
| GAFF | 0.99 | 1.00 | 0.01 | 1.02 | 0.02 | 0.03 |
| GW17 | 84.85 | 84.79 | -0.06 | 84.77 | -0.02 | -0.08 |
| GW32 | 112.58 | 112.58 | 0.00 | 112.50 | -0.08 | -0.08 |
| HERS | 13.99 | 13.97 | -0.02 | 13.94 | -0.03 | -0.05 |
| JIME | 12.30 | 12.30 | 0.00 | 12.25 | -0.05 | -0.05 |
| KEAT | 35.84 | 35.83 | -0.01 | 35.78 | -0.05 | -0.06 |
| LIBR | 19.93 | 19.90 | -0.03 | 19.86 | -0.04 | -0.07 |
| MADI | 47.03 | 47.00 | -0.03 | 46.98 | -0.02 | -0.05 |
| MILL | | | | 10.88 | | |
| PLAI | 19.99 | 19.96 | -0.03 | 19.96 | 0.00 | -0.03 |

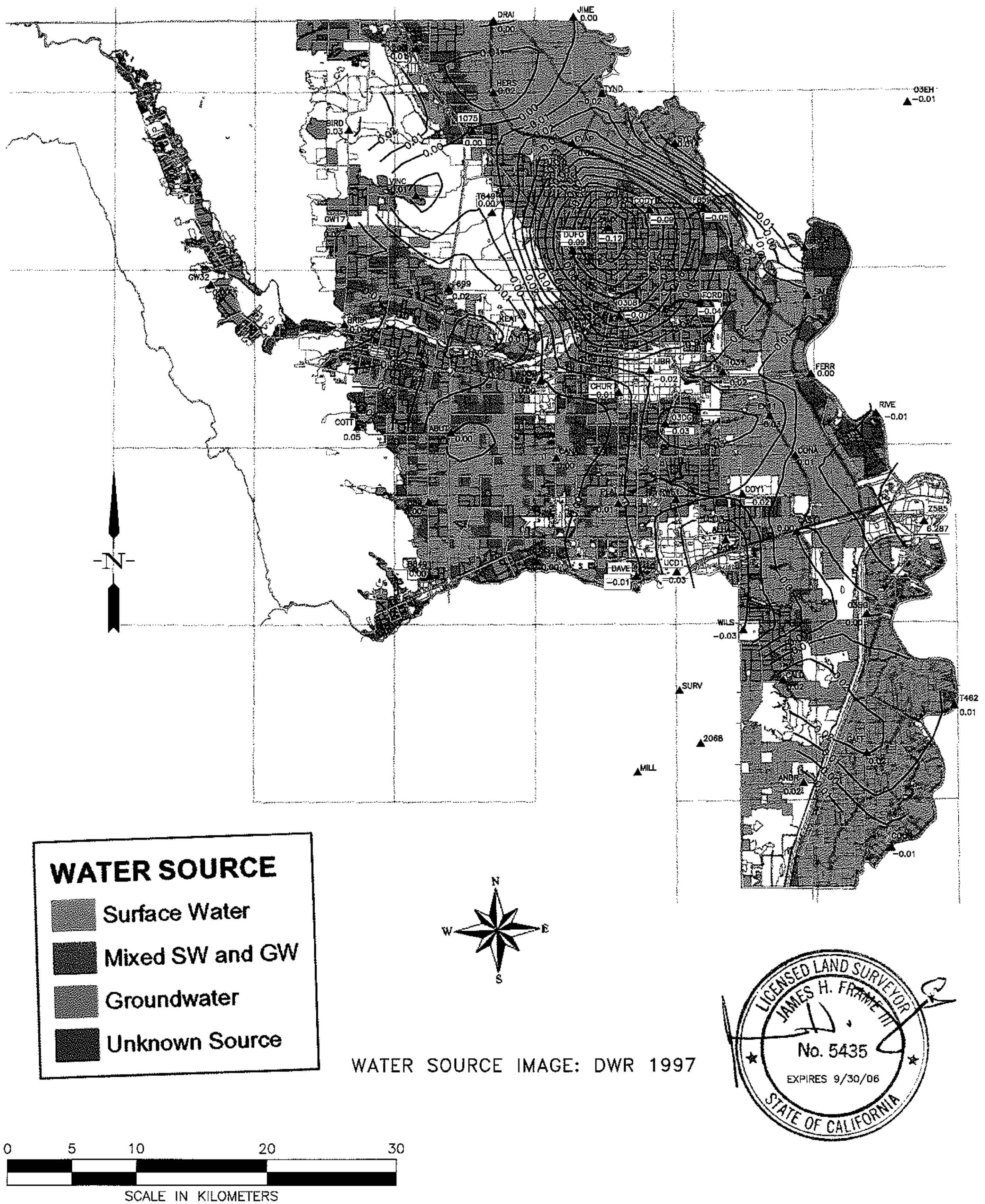
| | | | | | | |
|---|---|---|---|---|---|---|
| **RIVE** | 12.03 | 12.02 | -0.01 | 12.01 | -0.01 | -0.02 |
| **RUSS** | 29.38 | 29.37 | -0.01 | 29.36 | -0.01 | -0.02 |
| **RWF1** | | | | 14.60 | | |
| **SM15** | 7.30 | 7.33 | 0.03 | 7.27 | -0.06 | -0.03 |
| **SURV** | | | | 13.45 | | |
| **SYCA** | 7.67 | 7.66 | -0.01 | 7.65 | -0.01 | -0.02 |
| **T462** | 9.14 | 9.14 | 0.00 | 9.15 | 0.01 | 0.01 |
| **T849** | 36.20 | 36.17 | -0.03 | 36.12 | -0.05 | -0.08 |
| **TYND** | 9.10 | 9.08 | -0.02 | 9.04 | -0.04 | -0.06 |
| **UCD1** | 31.50 | 31.44 | -0.06 | 31.42 | -0.02 | -0.08 |
| **VINC** | 48.32 | 48.28 | -0.04 | 48.24 | -0.04 | -0.08 |
| **WILS** | 9.61 | 9.60 | -0.01 | 9.59 | -0.01 | -0.02 |
| **WOOD** | 39.75 | 39.74 | -0.01 | 39.70 | -0.04 | -0.05 |
| **X200** | 29.91 | 29.88 | -0.03 | 29.85 | -0.03 | -0.06 |
| **YCAP** | | 29.61 | | 29.61 | 0.00 | |
| **Z585** | 6.35 | 6.30 | -0.05 | 6.29 | -0.01 | -0.06 |
| **ZAMX** | 13.10 | 13.03 | -0.07 | 12.95 | -0.08 | -0.15 |

Notes:

1. All height values are expressed in meters.

2. The 1999 height value shown for station VINCOR was calculated from the 1999 height value for station PHILLIPS (not shown). PHILLIPS was rendered unsuitable for GPS observations prior to the 2002 monitoring event. VINCOR was installed nearby, and a leveling tie made to transfer the 1999 elevation from PHILLIPS to VINCOR.

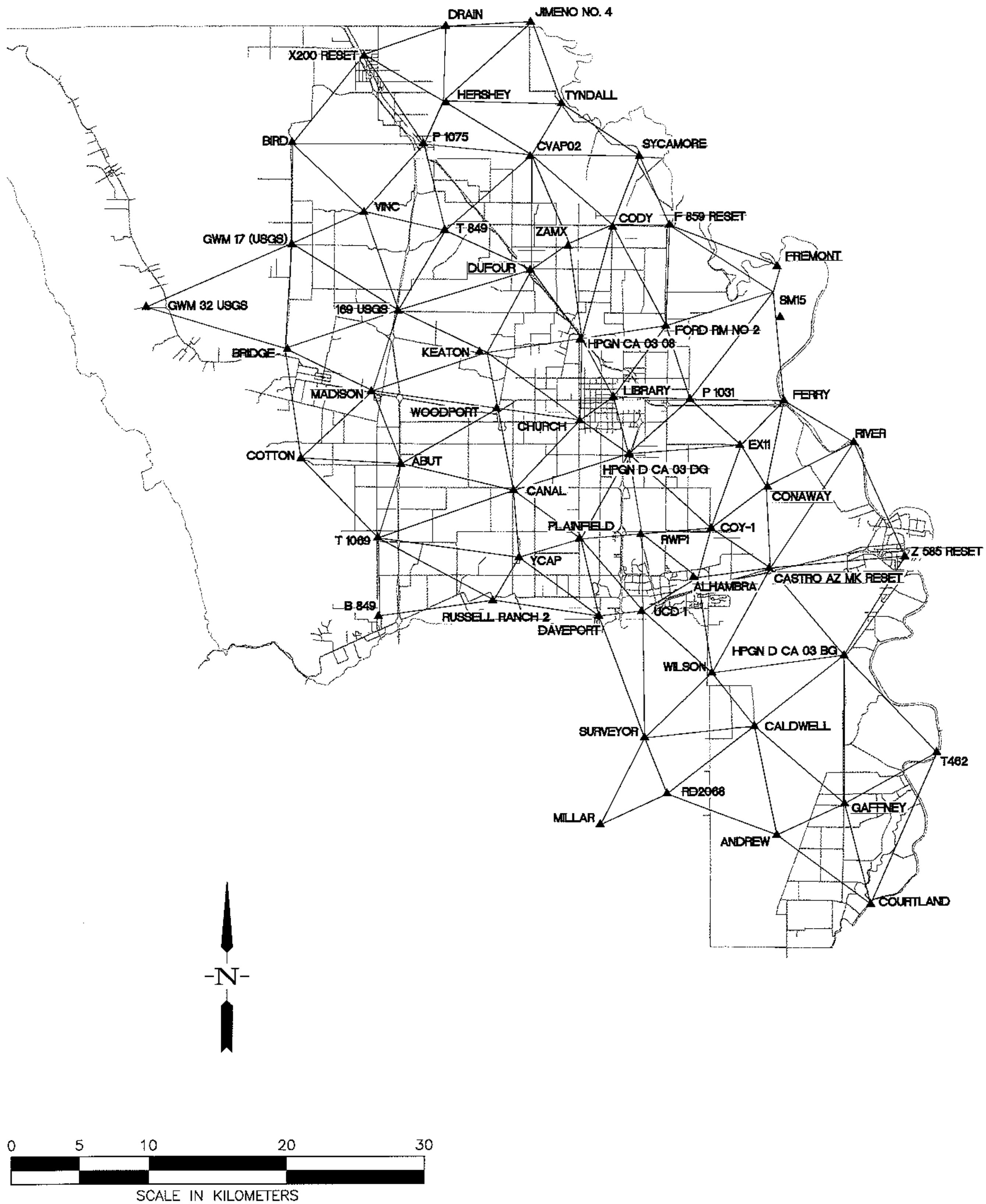
3. The orthometric values shown for 2005 may change following reconciliation between NGS and CSRC methodology.




**FRAME** SURVEYING & MAPPING
609 A Street
(530) 756-8584 (TEL)
Davis, CA 95616
(530) 756-8201 (FAX)
1280-039D

# APPENDIX C

CUMULATIVE SUBSIDENCE, 1999 - 2005
SOURCE: CSRC ELLIPSOID HEIGHT DATA
FEBRUARY, 2006 SCALE: 1"= 10KM




**FRAME SURVEYING & MAPPING**

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1280-039D

# APPENDIX D

YOLO SUBSIDENCE NETWORK
LOCAL NETWORK DIAGRAM
FEBRUARY, 2006 SCALE: 1"= 10KM

# APPENDIX E.

## NAD83/NAVD88 Station Coordinates

From the provisional NAD83/NAVD88 orthometric height adjustment performed by Frame Surveying & Mapping, epoch 2005.53.

| Name | Latitude | Longitude | Elevation |
|---|---|---|---|
| 0308 | 38°43'01.99912"N | 121°48'07.54199"W | 23.67m |
| 1031 | 38°40'38.14545"N | 121°42'34.07851"W | 10.23m |
| 1069 | 38°35'09.99988"N | 121°58'17.45682"W | 54.68m |
| 1075 | 38°50'51.29614"N | 121°56'00.25863"W | 14.85m |
| 1200 | 38°47'09.87441"N | 121°14'32.09663"W | 77.38m |
| 1699 | 38°44'12.69655"N | 121°57'15.85761"W | 52.46m |
| 2068 | 38°24'54.17942"N | 121°43'48.53696"W | 12.43m |
| 03BG | 38°30'20.00966"N | 121°34'55.09259"W | 9.91m |
| 03DG | 38°38'27.43783"N | 121°45'39.59676"W | 24.05m |
| 03EH | 38°51'59.61326"N | 121°32'32.95872"W | 10.74m |
| ABUT | 38°38'05.70691"N | 121°57'06.70369"W | 52.97m |
| ALHA | 38°33'31.09844"N | 121°42'26.68932"W | 12.95m |
| ANDR | 38°23'12.17822"N | 121°38'18.72121"W | 3.70m |
| B849 | 38°32'01.29164"N | 121°58'15.18465"W | 39.69m |
| BIRD | 38°50'54.73577"N | 122°02'37.47813"W | 94.08m |
| BRID | 38°42'41.39602"N | 122°02'50.18451"W | 64.15m |
| CALD | 38°27'33.51381"N | 121°39'24.21525"W | 5.44m |
| CANA | 38°37'02.05496"N | 121°51'30.11681"W | 29.77m |
| CAST | 38°33'50.77672"N | 121°38'37.80451"W | 5.28m |
| CHUR | 38°39'48.00606"N | 121°48'09.05896"W | 24.09m |
| CNDR | 37°53'47.04470"N | 121°16'42.53232"W | 11.68m |
| CODY | 38°47'30.59822"N | 121°46'29.02105"W | 12.68m |
| CONA | 38°37'05.49521"N | 121°38'40.42972"W | 7.68m |
| COTT | 38°38'20.24510"N | 122°02'08.12319"W | 91.49m |
| COUR | 38°20'24.76030"N | 121°33'40.05187"W | 8.06m |
| COY1 | 38°35'28.05177"N | 121°41'31.83561"W | 8.52m |
| CVAP | 38°50'19.76454"N | 121°50'39.17729"W | 7.96m |
| DAVE | 38°31'59.46481"N | 121°47'14.17767"W | 19.39m |
| DRAI | 38°55'31.04609"N | 121°54'52.46304"W | 12.93m |
| DUFO | 38°45'48.09680"N | 121°50'39.06873"W | 20.18m |
| EX11 | 38°38'46.40956"N | 121°40'03.02645"W | 7.85m |
| F859 | 38°47'34.20154"N | 121°43'36.01819"W | 14.16m |
| FERR | 38°40'32.00765"N | 121°37'49.18140"W | 12.10m |
| FORD | 38°43'33.23620"N | 121°43'47.39279"W | 17.49m |
| FREM | 38°45'52.89431"N | 121°38'08.00645"W | 12.54m |
| GAFF | 38°24'25.68547"N | 121°34'56.13691"W | 1.02m |
| GW17 | 38°46'52.25893"N | 122°02'38.10825"W | 84.78m |
| GW32 | 38°44'21.97173"N | 122°09'59.02874"W | 112.50m |
| HERS | 38°52'28.84831"N | 121°54'51.96597"W | 13.94m |
| JIME | 38°55'39.86256"N | 121°50'35.87572"W | 12.25m |
| KEAT | 38°42'33.52335"N | 121°53'11.08379"W | 35.78m |
| LIBR | 38°40'44.18520"N | 121°46'28.10144"W | 19.86m |
| MADI | 38°41'00.22860"N | 121°58'36.36143"W | 46.98m |
| MILL | 38°23'41.28013"N | 121°47'10.32967"W | 10.88m |
| P268 | 38°28'24.67974"N | 121°38'47.02602"W | 7.94m |

| | | | |
|---|---|---|---|
| P271 | 38°39'26.44695"N | 121°42'52.32465"W | 13.10m |
| PLAI | 38°35'05.49797"N | 121°48'11.62253"W | 19.96m |
| RIVE | 38°38'50.46155"N | 121°34'20.06352"W | 12.01m |
| RUSS | 38°32'38.06565"N | 121°52'33.83899"W | 29.37m |
| RWF1 | 38°35'09.99921"N | 121°45'05.10194"W | 14.60m |
| SM15 | 38°43'51.60440"N | 121°37'59.39294"W | 7.27m |
| SURV | 38°27'08.54500"N | 121°44'56.17353"W | 13.45m |
| SUTB | 39°12'20.99549"N | 121°49'14.10261"W | 646.08m |
| SYCA | 38°50'19.12405"N | 121°45'06.39012"W | 7.65m |
| T462 | 38°26'25.99278"N | 121°30'17.76296"W | 9.15m |
| T849 | 38°47'24.93361"N | 121°54'56.34535"W | 36.12m |
| TYND | 38°52'26.17801"N | 121°49'03.81267"W | 9.04m |
| UCD1 | 38°32'10.44819"N | 121°45'04.37875"W | 31.42m |
| VINC | 38°48'08.11990"N | 121°59'00.32287"W | 48.24m |
| WILS | 38°29'41.85159"N | 121°41'31.51549"W | 9.59m |
| WOOD | 38°40'17.76208"N | 121°52'20.38185"W | 39.70m |
| X200 | 38°54'20.73206"N | 121°58'59.79260"W | 29.85m |
| YCAP | 38°34'20.34492"N | 121°51'18.37410"W | 29.61m |
| Z585 | 38°34'15.79736"N | 121°31'49.55629"W | 6.29m |
| ZAMX | 38°46'45.78557"N | 121°48'44.63079"W | 12.95m |

# APPENDIX F.

**Subsidence Projections**

Quantitative monitoring of subsidence in Yolo County has been conducted over a relatively short time span, and presently comprises only 3 monitoring events (1999, 2002 and 2005). The monitoring measurement technology and its associated analytical tools continue to evolve, which may necessitate a comprehensive review of prior analyses. Nevertheless, it may be useful to consider the potential long-term effects of land subsidence by projecting the rates of subsidence observed to date.

In the examples below, a range of cumulative subsidence has been projected to the year 2030 at selected stations in Davis (ALHAMBRA), Woodland (LIBRARY) and the area of most rapid subsidence (ZAMX). The ranges are bounded by the more conservative ellipsoid height results returned by CSRC following a readjustment of the 1999 through 2005 data sets, and on the higher end by values derived from the published 1999 and 2002 NGS orthometric heights and the provisional 2005 orthometric heights produced by Frame Surveying & Mapping.

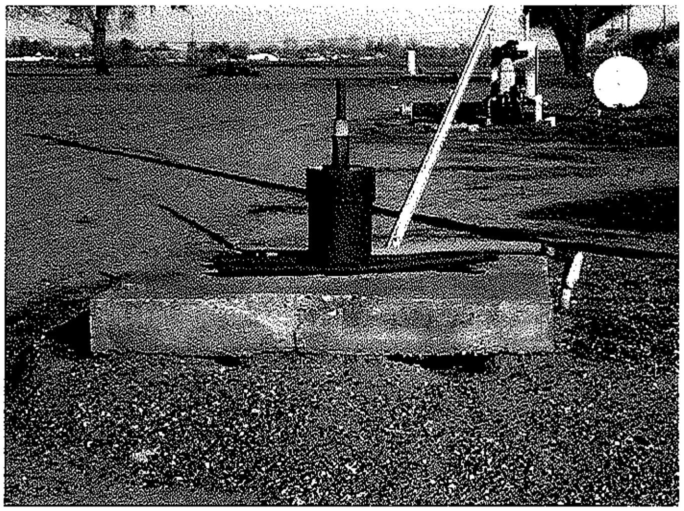
As more data are gathered in future years and the analytical tools refined, these rates will likely change. Caution is advised in applying these projected results to subsidence mitigation planning efforts.

| Site | Cumulative Subsidence 1999 to 2030 Low Projection | Cumulative Subsidence 1999 to 2030 High Projection |
|---|---|---|
| | | |
| ALHAMBRA | -0.20 | -0.21 |
| LIBRARY | -0.12 | -0.36 |
| ZAMX | -0.63 | -0.78 |

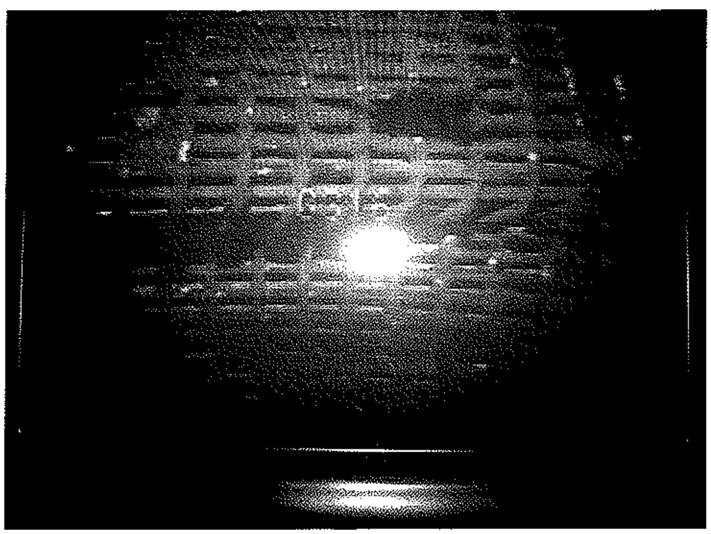
Subsidence values are in meters.

# APPENDIX G.

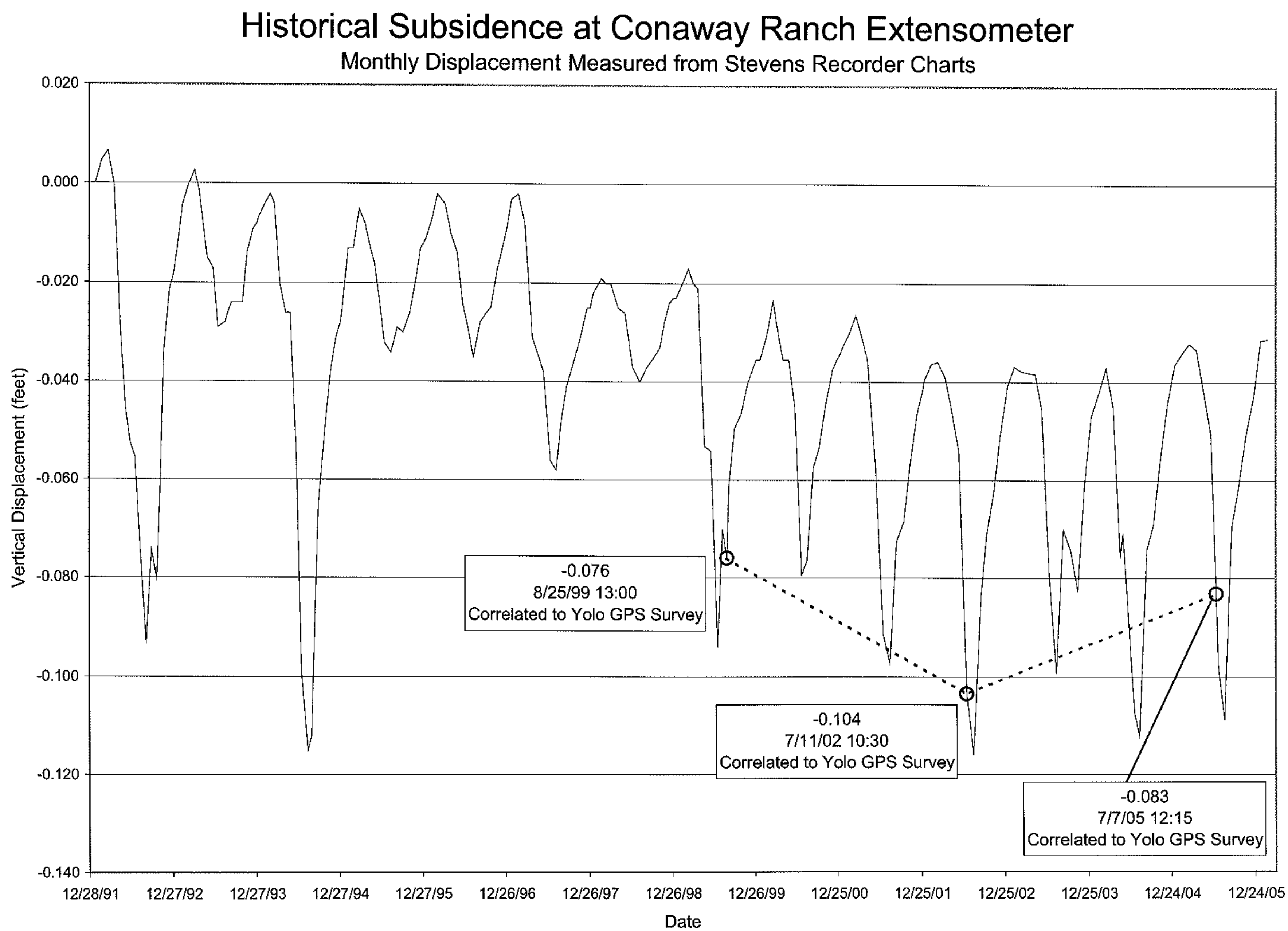
### Subsidence Impact Evidence



Well pad near Zamora. The pad appears to be fixed to the well casing, while the adjacent ground surface appears to have subsided.



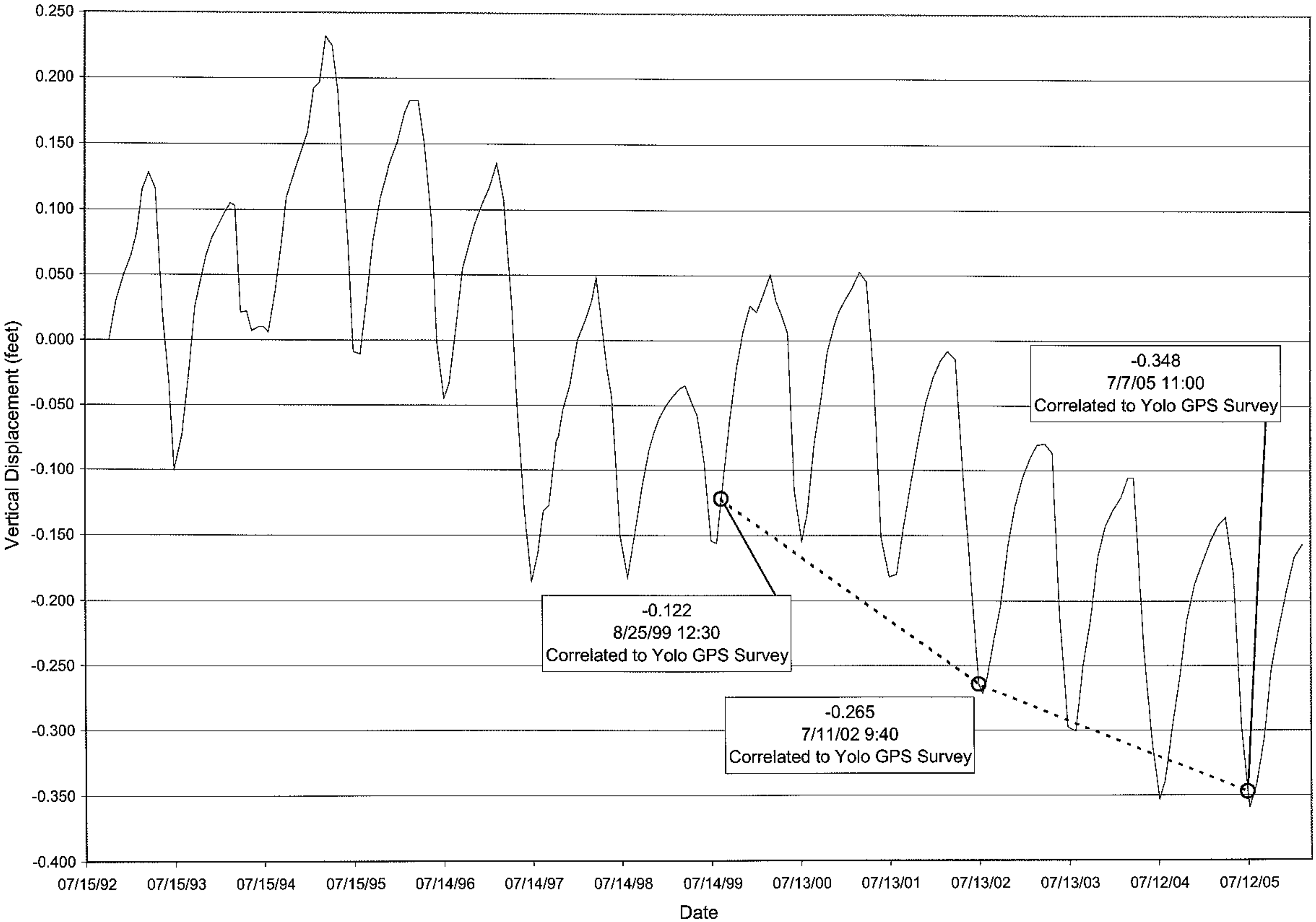
Crushed well screen, Well 22, City of Davis. This is a photo of a monitor displaying a well inspection video. The well screen at 316 feet below the surface appears to have deflected inward in response to downward pressure on the casing above. This might occur when the friction of a subsiding land mass upon a well casing exceeds the compressive strength of the well screen.



Historical Subsidence at Conaway Ranch Extensometer
Monthly Displacement Measured from Stevens Recorder Charts
Vertical Displacement (feet)
0.020
0.000
-0.020
-0.040
-0.060
-0.080
-0.100
-0.120
-0.140
12/28/91
12/27/92
12/27/93
12/27/94
12/27/95
12/26/96
12/26/97
12/26/98
12/26/99
12/25/00
12/25/01
12/25/02
12/25/03
12/24/04
12/24/05
Date
-0.076
8/25/99 13:00
Correlated to Yolo GPS Survey
-0.104
7/11/02 10:30
Correlated to Yolo GPS Survey
-0.083
7/7/05 12:15
Correlated to Yolo GPS Survey

## Historical Subsidence at Zamora Extensometer

Monthly Displacement Measured from Stevens Recorder Charts



**Yolo Subsidence Network** **GPS/Extensometer Comparisons** **March, 2005**

| SITE | SOURCE | YEAR 1999 | YEAR 2002 | YEAR 2005 | NET CHANGE (2005 - 1999) | GPS - EXTENSOMETER (DISCREPANCY) |
|---|---|---|---|---|---|---|
| CONAWAY | GPS | -22.835 | -22.865 | -22.863 | -0.028 | |
| | EXTENSOMETER | -0.023 | -0.032 | -0.025 | -0.002 | -0.026 |
| ZAMORA | GPS | -17.289 | -17.357 | -17.411 | -0.122 | |
| | EXTENSOMETER | -0.037 | -0.081 | -0.106 | -0.069 | -0.053 |

GPS SOURCE: 2005 CSRC ELLIPSOID HEIGHTS
EXTENSOMETER SOURCE: DWR
VALUES SHOWN ARE IN METERS

# APPENDIX C

## Quality Assurance for Groundwater Measurements and Sampling

# Appendix C
# Quality Assurance for Groundwater Measurements and Sampling

## Standard Operating Procedures

The City of Davis (City) and UC Davis are each developing their own detailed Standard Operating Procedures (SOPs) for monitoring. The SOPs are being developed according to these common guidelines so that each agency has a consistent approach.

## Staff Qualifications

Staff selected for groundwater level monitoring and sampling should be trained in the procedures given in this appendix and in any detailed SOPs that are to be followed.

## Groundwater Level Measurements

Groundwater level measurements should be taken as close to the beginning of each month as possible to allow comparison between City and UC Davis measurements. Pumping water levels should be measured for wells that have been pumping for at least 24 hours. Static water level measurements should be measured after wells have been shut off for at least 2 hours. For static water level measurements, the date and time of both well shutoff and water level measurement should be recorded for each well.

Water level measurement results that are questionable because of field conditions, equipment behavior, inadequate non-pumping duration, or other issues observed by the measurement personnel should be marked as such for entry into the joint groundwater management database. Water level measurement results should also be compared with previous trends to note results that appear out of reasonable bounds. Apparent out of bounds results should trigger recalibration of the measurement equipment and additional measurements.

## Groundwater Quality Sampling

Applying a common, consistent purging procedure is especially important for obtaining representative data that can be compared. Short purging durations will result in samples that are more affected by seepage down the well gravel pack, which often are not representative of water quality conditions in the general aquifer.

For the monitoring purposes envisioned, the pumps in the wells are adequate for purging the well and pumping the water for sampling. Purging should include pumping 5 well volumes and then checking for stabilization of indicator parameters (EC, pH, temperature, ORP) measured with a field meter as discussed in Appendix C.

Sampling equipment and field meters should be standardized to get comparable data. Field meters should also be routinely calibrated according to manufacturer's specifications.

Depth to water should be measured prior to initiation of all purging and sampling activities.

## Field QA/QC Samples

Additional samples should be collected for the specific purpose of documenting the Quality Assurance/Quality Control (QA/QC) of the field sampling procedures. Field QA/QC samples provide technically and legally defensible data regarding the reproducibility and overall quality of the groundwater sample. These additional QA/QC samples will normally be specified by the analytical lab. Further discussion of QA/QC samples is contained in Appendix C.

## Sample Containers and Shipping

The appropriate sample containers and associated preservatives must be obtained from the lab or be lab-approved. Containers and tubing that won't react with the constituents of interest must be used. Delivery of samples should utilize chain of custody forms and should follow all QA/QC recommendations from the analytical laboratory.

## Field Records

Accurate field records must be maintained to document groundwater sampling activities. These records include technical field data, sample identification labels, and chain-of-custody information for each sample. These records are described in detail in Appendix C. Field data sheets should be initiated prior to the start of sampling. An example purging and sampling form is also contained in Appendix C.

## Sample Analysis Procedures

Sample Analysis procedures should be in accordance with Title 22 requirements and methods. Identical methods should be used for analyzing groundwater samples from both Davis and UC Davis. Joint procurement of analytical services from a common lab for both agencies would be ideal from a data consistency viewpoint.

## Quality Assurance/Quality Control

Quality assurance and quality control protocols should be coordinated with the analytical lab. The steps in developing QA/QC protocols are as follows:

- Define quality control parameters;
- Target analyte list;
- List maximum reporting limits and proper limits;
- Determine spike recovery limits (based on laboratories' abilities and project data quality objectives);
- Determine duplicate frequency and maximum relative percent difference; and
- Specify adequate numbers of blanks.

After receipt of analytical results from the lab, the following items should be checked to insure that the data quality is reasonable:

- Check for completeness and accuracy of data transfer;

- Review laboratory case narrative and data qualifiers;
- Check holding times;
- Check reporting limits;
- Check blanks for contamination;
- Check spike recoveries; and
- Check precision of duplicate samples.

After checking the quality of the data, the data usability should be summarized, including the following measures:

- Percent complete;
- Rejected data;
- Qualified data; and
- Statement of data usability.

Data that have been qualified as estimated or rejected during the data review process should be marked as such prior to storage and use as part of the database.

### Data Compilation and Storage

Data should be compiled and stored in the joint groundwater management database. New data should be exported annually to YCFCWCD for incorporation into the countywide database.

# APPENDIX D

## Recommended Purging and Sampling Procedures

# Appendix D

## Recommended Purging and Sampling Procedures

The primary objective of a standard operating procedure (SOP) is to establish a uniform method for the collection of representative groundwater samples from monitoring wells, and to reduce the potential variability associated with purging and sampling.

Equipment that will be in contact with the sample must be decontaminated prior to each use. This is necessary to minimize inadvertent contamination of the sample. Specific methods for equipment cleaning are dependent upon a number of factors including the sample media, analytical parameters, the purpose of the investigation, the equipment to be cleaned, and the specific regulatory guidelines that may apply.

Some of the factors that should be considered in the selection of purging and sampling devices include:

- Well yield;
- Depth to water;
- Well diameter and depth;
- Required material of construction;
- Analytical parameters;
- Regulatory requirements; and
- Cost.

### Purging Strategies

The strategy that will be employed for well purging should be determined prior to sampling and presented in project-specific planning documents. Several different strategies are commonly used in order to assess the completeness of well purging. The most common purging strategies are listed below.

- Purging is continued until stabilization of certain indicator parameters is observed in successive measurements over a specified time or volume. The most commonly used indicator parameters include pH, specific conductivity, turbidity, temperature, oxidation/reduction potential (ORP), and dissolved oxygen (DO).
- Purging 3 to 5 well volumes of water from the well.

### Sample Containers and Preservatives

The appropriate sample containers and associated preservatives must be obtained to prevent absorption or reactions with the constituents sampled. The containers and preservatives are normally, but not always, supplied by the laboratory that will be responsible for the analyses. Sample containers should be organized and inventoried several days prior to initiation of the sampling program in order to provide sufficient time to rectify any problems, should they occur. Whenever possible, pre-printed sample labels should be created prior to mobilization, if possible.

## Initiation of Field Data Records

Field data sheets should be initiated prior to the start of sampling. Examples of initial data to be recorded include site and sampling location identification, well depth and construction, and purging and sampling collection methods. Field data sheets can be combined in a bound field notebook as well. Field data sheet forms are usually part of detailed agency or lab SOP's.

## Water Level Measurements

The depth to water should be measured prior to initiation of all purging and sampling activities.

## Calculation of Well Purge Volume

The volume of water standing in the well should be calculated through the application of the depth to water data, the known well depth, and the well diameter using the constants presented below. Well depth information obtained from the well completion records are generally sufficiently precise for the purpose of well volume calculations that would be used for subsequent purging determinations.

Alternatively, the well casing volume may be calculated using the formula:

$V = CF*d^2h$, where

V = volume of water (gallons)
d = diameter of well (inches)
h = height of water column (feet)
CF = conversion factor (0.0408) that includes conversion of cubic feet to gallons, inches to feet, and diameter to radius.

Add extra for the borehole volume calculated by the formula:

$V = 0.0408\ d^2h + 0.0408\ (D^2-d^2)\ h*Theta$ including borehole, where

D = diameter of borehole (inches)
Theta = porosity of gravel pack, usually approximately 0.4

An adequate purge is normally achieved when three to five times the volume of standing water in the well has been removed. After three well volumes have been removed, if the chemical parameters have not stabilized according to the criteria given below, additional well volumes may be removed. If the parameters have not stabilized within five volumes, it is at the discretion of the project manager whether or not to collect a sample or to continue purging.

Considering groundwater chemistry, an adequate purge is achieved when the pH, specific conductance, and temperature of the groundwater have stabilized and the turbidity has either stabilized or is below 10 Nephelometric Turbidity Units (NTUs). Stabilization occurs when parameter measurements are within 10 percent between two readings spaced approximately one well volume apart.

## Field QA/QC Samples

Additional samples should be collected for the specific purpose of documenting the Quality Assurance/Quality Control (QA/QC) of the field sampling procedures. Descriptions of the type and frequency of QA/QC sampling should be specified in the project-specific planning documents. Field QA/QC samples include field blanks, equipment blanks, trip blanks, and blind duplicates. These samples are collected in addition to the laboratory QA/QC samples which may include method blanks, matrix spikes and matrix spike duplicate samples.

## Field Records

Accurate field records must be maintained to document groundwater sampling activities. These records include technical field data, sample identification labels, and chain-of-custody information for each sample.

Specifically for groundwater sampling, the field sampling records should include, at a minimum, the following information:

- Sampling location;
- Date and time;
- Condition of the well;
- Static water level (depth to water);
- Depth to the bottom of the well;
- Calculated well volume;
- Purging method;
- Actual purged volume;
- Sample collection method;
- Sample description;
- Field meter calibration data;
- Water quality measurements; and
- General comments (weather conditions, etc.).

All data entries should be made using black indelible ink and should be written legibly. Entry errors should be crossed out with a single line, dated, and initialed by the person making the correction.

**Example Purging and Sampling Form**

# GROUNDWATER PURGE AND SAMPLING FIELD DATA SHEET

## 1. PROJECT INFORMATION

**WELL ID:** ______

Project Number:____________ Task Number:________ Date:________________ Time:__________

Client:________________________________ Personnel:________________________________

Project Location:______________________________ Weather:________________________________

## 2. WELL DATA

Casing Diameter:________ inches | Type of Casing: ________________________

Screen Diameter:________ inches (d) | Type of Screen:______________________ Screen Length : ____________

Total Depth of Well from TOC:____________ feet

Depth to Static Water from TOC:____________ feet

Depth to Product from TOC:____________ feet

Length of Water Column (h):____________ feet Calculated Casing Volume:________ gal (3 to 5 times one well volume)

Purge Volume Calculation (one casing volume = $0.041d^2h$):

*Note: 2-inch well = 0.167 gal/ft 4-inch well = 0.667 gal/ft*

## 3. PURGE DATA

Equipment Model(s)

Purge Method: ________________________________

Materials: Pump/Bailer ________________________________ 1. ________________

Materials: Rope/Tubing ________________________________ 2. ________________

Was well purged dry? ☐ Yes ☐ No Pumping Rate: gal/min

| Time | Cum. Gallons Removed | pH | Temp (Units) | Spec. Cond. (Units) | Eh (Units) | DO (Units) | Turbidity (NTU) | Other: ______ | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

## 4. SAMPLING DATA

Analyses Requested:

Method(s): ________________________________

Materials: Pump/Bailer ________________________________

Materials: Tubing/Rope ________________________________

Depth to Water at Time of Sampling:__________ Field Filtered? ☐ Yes ☐ No

Sample ID:__________ Sample Time:__________ # of Containers:______

Duplicate Sample Collected? ☐ Yes ☐ No ID:__________

## 5. COMMENTS

________________________________

# APPENDIX E

## City of Davis and UC Davis Well Information

## City of Davis Well Construction Information

| Well No. | Location | Year Constructed | Ground Elevation (ft AMSL) | Depth (ft) | Seal Depth (ft) | Casing Diameter | Motor HP | | Avg. Pumping Rates (Jul-Aug 2004) (gpm) | (mgd) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 617 E Street | 1982 | 46 | 510 | | 16" | 75 | * | 860 | 1.2 |
| 7 | 800 11th Street | 1952 | 44 | 390 | | 14" | 100 | | 989 | 1.4 |
| 11 | 1405 F Street | 1961 | 44 | 344 | | 14" | 100 | | 1319 | 1.9 |
| 12 | 921 Sycamore Lane | 1961 | 48 | 330 | 170 | 14" | 125 | | 816 | 1.2 |
| 14 | 530 L Street | 1970 | 45 | 352 | 190 | 16" | gas | | 1004 | 1.4 |
| 15 | 1812 Manzanita | 1965 | 38 | 520 | | 14",10"Lin | 100 | * | 1119 | 1.6 |
| 19 | 2910 Catalina Drive | 1973 | 44 | 615 | | 16",12",8" | 100 | * | 1343 | 1.9 |
| 20 | 2300 Evenstar Lane | 1976 | 55 | 456 | | 18",12" | 125 | | 1127 | 1.6 |
| 21 | 5050 Chiles Road | 1977 | 33 | 448 | | 16",12" | 100 | | 1165 | 1.7 |
| 22 | 1414 Tulip Lane | 1977 | 42 | 510 | | 16",12" | 125 | * | 1017 | 1.5 |
| 23 | 527 B Street | 1980 | 45 | 419 | | 16" | 150 | | 1763 | 2.5 |
| 24 | 1600 Olive Drive | 1982 | 44 | 480 | 186 | 18" | 150 | | 1808 | 2.6 |
| 25 | 1188 Arlington Blvd. | 1987 | 53 | 466 | 150 | 18" | 75 | | 1145 | 1.6 |
| 26 | 2850 Cowell Blvd. | 1987 | 38 | 492 | 210 | 18" | 125 | * | 1432 | 2.1 |
| 27 | 3000 Sycamore Lane | 1989 | 49 | 364 | 100 | 18" | 125 | * | 990 | 1.4 |
| 28 | 2101 Glacier Drive | 1991 | 51 | 1491 | 110 | 18" | 75 | * | 760 | 1.1 |
| 29 | 3535 Alhambra Drive | 1997 | 37 | 1502 | 210 | 18",14" | 150 | | 1231 | 1.8 |
| 30 | 1819 Lake Blvd. | 2002 | 55 | 1780 | 800 | | 300 | | 2537 | 3.7 |
| 31 | 2074 John Jones Road | 2003 | 50 | 1782 | 700 | | 300 | | 2540 | 3.7 |
| LIC | Lewis Investing Corp.#4 | | | 1364 | | | | | 775 | 1.1 |
| EM2 | 44285 S. El Macero Dr. | 1969 | 27 | 427 | | 14",12" | 100 | | 1007 | 1.5 |
| EM3 | 800 Mace Boulevard | 1991 | 33 | 471 | 220 | 18" | 125 | * | 973 | 1.4 |
| | | | | | | | **Totals** | | **27,720** | **39.9** |

* = submersible pump/motor

# UC Davis Well Data

| Well | Date Drilled | Method | Depth | Seal Depth | Perf Depth | Aquifer | UC Davis Classification |
|---|---|---|---|---|---|---|---|
| UDW-2 | Apr - 1952 | Cable Tool | 1,368 | none | 1,180-1,258<br>1,274-1,350 | Deep | Domestic |
| UDW-3 | 1952 | Cable Tool | 1,450 | none | 1,264-1,290<br>1,342-1,370<br>1,384-1,432 | Deep | Domestic |
| UDW-4 | 1971 | Rotary | 1,430 | 80 | 1,120-1,400 | Deep | Domestic |
| UDW-5 | 1969 | Rotary | 1,470 | 60 | 1,164-1,174<br>1,360-1,380<br>1,388-1,452 | Deep | Domestic |
| UDW-6A | 1987 | Rotary | 1,470 | 60 | 1,218-1,234<br>1,296-1,316<br>1,342-1,352<br>1,380-1,450 | Deep | Domestic |
| UDW-7 | Dec - 1978 | | 600 | 50 | 262-273<br>348-354<br>425-432 | Inter. | Domestic |
| UDW-7A | Sep - 1995 | Rev. Rotary | 857 | 595 | 740-780<br>822-842 | Deep | Domestic |
| UUW-2 | 1945 | | 352 | | 247-290<br>306-338 | Inter. | Utility |
| UUW-3 | 1929 | | 321 | | | Inter. | Utility |
| UUW-4 | 1938 | | 326 | none | 99-123<br>152-162<br>183-191<br>228-323 | Inter. | Utility |
| UUW-5 | 1968 | | 470 | 50 | 180-450 | Inter. | Utility |
| UUW-7 | 1951 | | 414 | none | 134-174<br>234-274<br>344-354<br>374-414 | Inter. | Utility |
| A1 | 1952 | | 300 | | 110-122<br>179-185<br>209-293 | Inter. | Ag. |
| B6N | 1964 | | 635 | | | Inter. | Ag. |
| B6S | 1972 | | 500 | | | Inter. | Ag. |
| C2A | 1932 | | 248 | | 202-248 | Inter. | Ag. |
| C2B | 1932 | | 285 | | 221-264 | Inter. | Ag. |
| C2F | 1932 | | 250 | | | Inter. | Ag. |
| C2H | 1932 | | 244 | | | Inter. | Ag. |
| C3C | 1932 | | 270 | | | Inter. | Ag. |
| D2 | 1946 | | 538 | | | Inter. | Ag. |
| D3 | 1936 | | 382 | | | Inter. | Ag. |
| D6A | 1936 | | 416 | | | Inter. | Ag. |
| D10 | 1939 | | 529 | | | Inter. | Ag. |

# UC Davis Well Data

| Well | Date Drilled | Method | Depth | Seal Depth | Perf Depth | Aquifer | UC Davis Classification |
|---|---|---|---|---|---|---|---|
| E2A | 1948 | | 250 | | | Inter. | Ag. |
| E3B | 1952 | | 240 | | 116-136<br>204-244 | Inter. | Ag. |
| E3D | 1972 | | 455 | | 185-225<br>250-270<br>366-371<br>418-443 | Inter. | Ag. |
| E4A | 1956 | | 340 | | unk | Inter. | Ag. |
| E5 | 1956 | | 344 | | unk | Inter. | Ag. |
| E8 | 1972 | | 517 | | | Inter. | Ag. |
| G6 | 1962 | | 400 | | | Inter. | Ag. |

# APPENDIX F

## Regional Database Schema

**Properties**

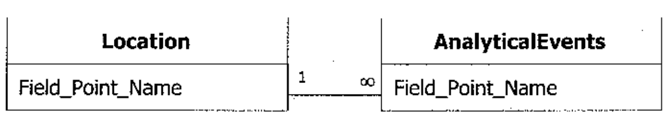
| | | | |
|---|---|---|---|
| DateCreated: | 9/29/2005 3:32:13 PM | DefaultView: | Datasheet |
| GUID: | {guid {BC454BD7-EF9E-4F02-AF35-83A306485D0E}} | LastUpdated: | 1/4/2006 5:00:55 PM |
| NameMap: | Long binary data | OrderByOn: | False |
| Orientation: | Left-to-Right | RecordCount: | 15605 |
| Updatable: | True | | |

**Columns**

| Name | Type | Size |
|---|---|---|
| AEID | Long Integer | 4 |
| Field_Point_Name | Text | 32 |
| Depth_Zone | Text | 4 |
| Sample_ID | Text | 24 |
| Sample_Date | Date/Time | 8 |
| Sample_Delivery_Group | Text | 10 |
| Lab | Text | 32 |
| Sub_Lab | Text | 32 |
| Chain_Custody_ID | Text | 16 |
| Lab_Sample_ID | Text | 24 |
| Analytical_Method | Text | 24 |
| Prep_Method | Text | 24 |
| Prep_Batch | Text | 12 |
| Analysis_Date | Date/Time | 8 |
| Parameter | Text | 16 |
| Result | Double | 8 |
| Par_Value_Qualifier | Text | 8 |
| MDL | Double | 8 |
| PQL | Double | 8 |
| Units | Text | 16 |
| Dilution | Double | 8 |
| Surrogate | Yes/No | 1 |
| Preservation | Text | 20 |
| Lab_Qualifier_Note | Text | 24 |
| Source | Text | 32 |
| Remarks | Text | 80 |
| QA_Status | Yes/No | 1 |

**Relationships**

**LocationAnalyticalEvents**

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|---|---|
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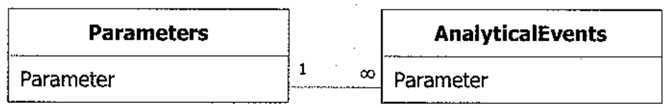
| RelationshipType: | One-To-Many |

**ParametersAnalyticalEvents**




| | |
|---|---|
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| RelationshipType: | One-To-Many |

**Properties**

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| GUID: | {guid {846F1736-5FA4-4DEB-AC0D-8E2C81891F2E}} | LastUpdated: | 11/4/2005 12:19:38 PM |
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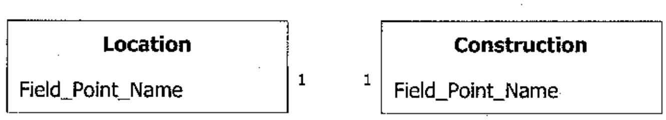
| Orientation: | Left-to-Right | RecordCount: | 38 |
| Updatable: | True | | |

**Columns**

| Name | Type | Size |
|---|---|---|
| CONSID | Long Integer | 4 |
| Field_Point_Name | Text | 32 |
| Constr_Date | Date/Time | 8 |
| Driller | Text | 32 |
| Drilling_Method | Text | 16 |
| Log_Exists | Yes/No | 1 |
| Lognum | Text | 32 |
| Logimg | Text | 50 |
| Use | Text | 32 |
| Casing_Dia | Single | 4 |
| HP | Long Integer | 4 |
| Well_Depth | Long Integer | 4 |
| Hole_Depth | Long Integer | 4 |
| Seal_Depth | Double | 8 |
| Source | Text | 50 |

**Relationships**

**LocationConstruction**

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|---|---|
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| RelationshipType: | One-To-One |

**Properties**

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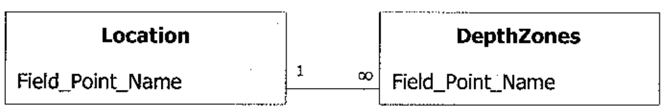
| LastUpdated: | 11/4/2005 12:24:19 PM | NameMap: | Long binary data |
| OrderByOn: | False | Orientation: | Left-to-Right |
| RecordCount: | 140 | Updatable: | True |

**Columns**

| Name | Type | Size |
|---|---|---|
| DZID | Long Integer | 4 |
| Field_Point_Name | Text | 32 |
| Depth_Zone | Text | 4 |
| Top_Of_Zone | Long Integer | 4 |
| Bottom_of_Zone | Long Integer | 4 |
| Screen_Type | Text | 24 |
| Screen_Dia | Double | 8 |
| Screen_Material | Text | 24 |
| Remarks | Text | 80 |
| Hydro_Zone | Text | 32 |

**Relationships**

**LocationDepthZones**

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|---|---|
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| RelationshipType: | One-To-Many |

**Properties**

| | | | |
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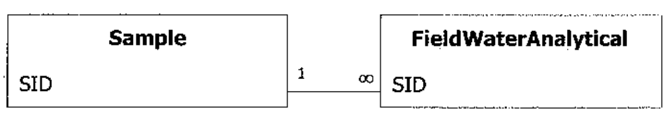
| LastUpdated: | 9/23/2005 2:27:01 PM | NameMap: | Long binary data |
| OrderByOn: | False | Orientation: | Left-to-Right |
| RecordCount: | 0 | Updatable: | True |

**Columns**

| Name | Type | Size |
|---|---|---|
| FWAID | Long Integer | 4 |
| SID | Long Integer | 4 |
| Sample_Date | Date/Time | 8 |
| Temperature | Single | 4 |
| pH | Single | 4 |
| DO | Text | 50 |
| ORP | Single | 4 |
| EC | Single | 4 |
| Personnel | Text | 50 |
| Source | Text | 50 |

**Relationships**

**SampleFieldWaterAnalytical**




| | |
|---|---|
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| RelationshipType: | One-To-Many |

**Properties**

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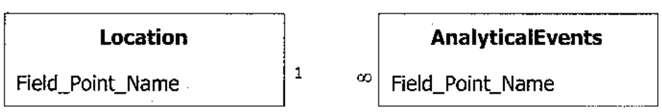
| NameMap: | Long binary data | OrderByOn: | False |
| Orientation: | Left-to-Right | RecordCount: | 38 |
| Updatable: | True | | |

**Columns**

| Name | Type | Size |
|---|---|---|
| LOCID | Long Integer | 4 |
| Field_Point_Name | Text | 32 |
| State_Well_Num | Text | 24 |
| YCFCWCD_Name | Text | 50 |
| Description | Text | 80 |
| Owner | Text | 50 |
| Lat | Double | 8 |
| Lon | Double | 8 |
| Coord_Datum | Text | 12 |
| X | Double | 8 |
| Y | Double | 8 |
| Tship_Range | Text | 16 |
| Location_Source | Text | 24 |
| GS_Elev | Double | 8 |
| Ref_Elev | Double | 8 |

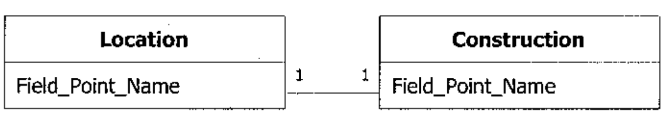
**Relationships**

**LocationAnalyticalEvents**



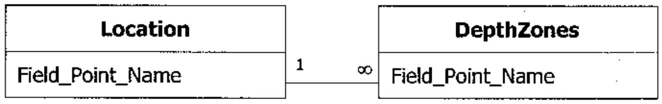

| | |
|---|---|
| Attributes: | Enforced, Cascade Updates, Cascade Deletes |
| RelationshipType: | One-To-Many |

**LocationConstruction**



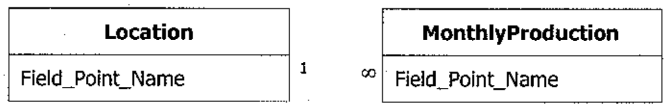

| | |
|---|---|
| Attributes: | Unique, Enforced, Cascade Updates, Cascade Deletes |
| RelationshipType: | One-To-One |

**LocationDepthZones**



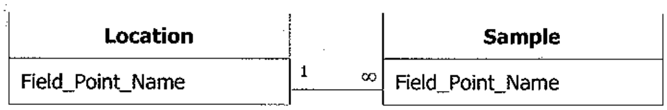

Attributes: Enforced, Cascade Updates, Cascade Deletes
RelationshipType: One-To-Many

**LocationMonthlyProduction**



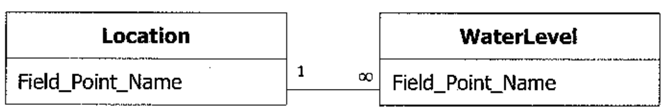

Attributes: Enforced, Cascade Updates, Cascade Deletes
RelationshipType: One-To-Many

**LocationSample**




Attributes: Enforced, Cascade Updates, Cascade Deletes
RelationshipType: One-To-Many

**LocationWaterLevel**

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RelationshipType: One-To-Many

**Properties**

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|---|---|---|---|
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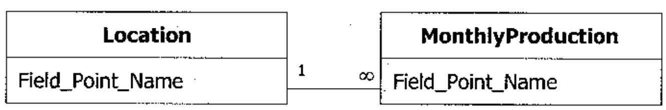
| Orientation: | Left-to-Right | RecordCount: | 3960 |
| Updatable: | True | | |

**Columns**

| Name | Type | Size |
|---|---|---|
| PRODID | Long Integer | 4 |
| Field_Point_Name | Text | 32 |
| Month | Date/Time | 8 |
| Production | Double | 8 |
| Source | Text | 50 |
| Remarks | Text | 80 |
| QA_Status | Yes/No | 1 |

**Relationships**

**LocationMonthlyProduction**




| | |
|---|---|
| Attributes: | Enforced, Cascade Updates, Cascade Deletes |
| RelationshipType: | One-To-Many |

**Properties**

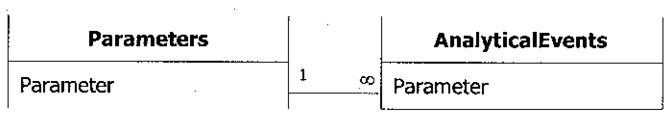
| | | | |
|---|---|---|---|
| DateCreated: | 11/4/2005 4:48:41 PM | DefaultView: | Datasheet |
| GUID: | {guid {D5850412-1FB2-4CAA-B811-2CA5B3EAC5F7}} | LastUpdated: | 1/4/2006 4:16:59 PM |
| NameMap: | Long binary data | OrderByOn: | False |
| Orientation: | Left-to-Right | RecordCount: | 64 |
| Updatable: | True | | |

**Columns**

| Name | Type | Size |
|---|---|---|
| ParID | Long Integer | 4 |
| Parameter | Text | 50 |
| Display_Name | Text | 50 |
| Next_Selected | Text | 50 |
| Units | Text | 32 |
| Analyte_Class | Text | 50 |
| Default_Method | Text | 50 |
| Default_DL | Double | 8 |
| MCL | Single | 4 |
| Description | Text | 160 |

**Relationships**

**ParametersAnalyticalEvents**




| | |
|---|---|
| Attributes: | Enforced, Cascade Updates, Cascade Deletes |
| RelationshipType: | One-To-Many |

**Properties**

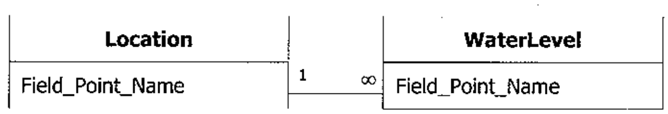
| | | | |
|---|---|---|---|
| DateCreated: | 2/28/2002 10:36:57 PM | DefaultView: | Datasheet |
| GUID: | {guid {1909671C-D960-422B-94AC-80E9EBA6CEB5}} | LastUpdated: | 12/2/2005 3:59:00 PM |
| NameMap: | Long binary data | OrderByOn: | False |
| Orientation: | Left-to-Right | RecordCount: | 4168 |
| Updatable: | True | | |

**Columns**

| Name | Type | Size |
|---|---|---|
| WLEVID | Long Integer | 4 |
| Field_Point_Name | Text | 32 |
| Sample_Date | Date/Time | 8 |
| Ref_Elev | Double | 8 |
| Depth_To_Water | Double | 8 |
| Q_CODE | Text | 16 |
| NO_CODE | Text | 16 |
| Source | Text | 50 |
| Remarks | Text | 80 |
| QA_Status | Yes/No | 1 |

**Relationships**

**LocationWaterLevel**




| | |
|---|---|
| Attributes: | Enforced, Cascade Updates, Cascade Deletes |
| RelationshipType: | One-To-Many |

# Major Data Table Relationships