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Arnold Schwarzenegger, Governor

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Lester A. Snow, Director

BUTTE COUNTY GROUNDWATER INVENTORY ANALYSIS

Division of Planning and Local Assistance
Northern District

February 2005

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BUTTE COUNTY GROUNDWATER INVENTORY ANALYSIS

Division of Planning and Local Assistance
Northern District

February 2005

FOREWORD

The following report is a detailed inventory and discussion of the groundwater resources in Butte County, and is the Department of Water Resources contribution to the Butte County Inventory Analysis.

The Butte County Inventory Analysis was a cooperative study between the Butte County Water Resources and Conservation Department, the consultant to Butte County - Camp Dresser & McKee, Inc., and the Department of Water and Resources, Northern District. The focus of the inventory analysis was to identify and quantify the surface water and groundwater resources of Butte County.

The Butte County groundwater inventory is presented in three sections. Section 1 provides an introduction to the study area, a presentation of the project scope, and a detailed discussion of the analytical methods used throughout the report. Section 2 presents a regional overview of Butte County geology and a discussion of the age, composition, depositional environment, and water-bearing properties of the major fresh groundwater-bearing units. Section 3 provides a more detailed discussion of the groundwater resources and the distribution, depth, and yield of the existing county wells at the subregional and local levels. Section 3 was developed and presented so that the information for each local and regional area could be referenced in a stand-alone fashion. This approach results in some redundancy in the explanation and presentation of the data but, overall, serves as a good approach for those wanting to reference local areas within the body of Section 3 alone. Appendix A consists of plates that were too large to incorporate into the body of the report. Appendix B consists of a series of tables that summarize groups of similar data, providing a source for quick reference and a comparison of regional, subregional, and local information. Appendix C provides a list of references used throughout the text.

Dwight Russell
District Chief
Department of Water Resources, Northern District

Acronyms

af/acre	acre-foot (feet) per acre
af/yr	acre-foot (feet) per year
BCDWRC	Butte County Department of Water and Resource Conservation
CSUC	California State University, Chico
CVP	Central Valley Project
CWSC	California Water Service Company
DWR	California Department of Water Resources, Northern District
gpm	gallons per minute
gpm/ft	gallons per minute per foot
gpd/ft	gallons per day per foot
mi^2	square miles
msl	mean sea level
mybp	million years before present
%	percent
SWP	State Water Project
taf	thousand acre feet
USGS	United States Geologic Survey

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SECTION I.

Butte County Groundwater Inventory

The Butte County Inventory Analysis is a cooperative study prepared by the Butte County Department of Water Resources and Conservation (BCDWRC), the consultant to Butte County - Camp Dresser & McKee, Inc., and the California Department of Water Resources (DWR), Northern District. The focus of the inventory analysis was to identify and quantify the surface water and groundwater resources of Butte County. The following report is a detailed discussion of the county's groundwater resources and is DWR's contribution to the Butte County Inventory Analysis.

This groundwater inventory is presented in three sections. This section (Section 1) provides an introduction to the study areas, a presentation of the project scope, and a detailed discussion of the analytical methods used throughout the report. Section 2 presents a regional discussion of the geology and groundwater resources of Butte County, while Section 3 provides a more detailed discussion of the groundwater resources and infrastructure of wells at the subregional and local levels.

Introduction and Scope

The groundwater inventory presents the results of a county-wide assessment of groundwater resources at the regional, subregional, and local levels. At the regional level the groundwater inventory is divided into three areas: the Sacramento Valley Region, the Foothill Region, and the Mountain Region. At the subregional and local levels, the Sacramento Valley and Foothill regions are further divided into inventory and sub-inventory units. The breakdown of units at the regional level serves to group areas of similar hydrology and hydrogeology, while the local breakdown at the sub-inventory unit level serves to group areas of similar land use, water use, and local water purveyor areas. The study areas are listed in Table 1 and illustrated on Plate 1, Appendix A.

Much of the information presented in this report was obtained from published reports, unpublished information, and data on file with DWR. Only a limited amount of new data were collected or developed as part of this investigation; the majority of the information provided was derived from the analysis of existing data. Due to the limited amount of groundwater data for the Foothill and Mountain regions of the county, emphasis was placed on the Sacramento Valley Region of Butte County.

Regional characterization of Butte County geology and groundwater resources presented in Section 2 includes discussions of the following subject areas:

- surface and subsurface geology
- fresh groundwater-bearing units
- movement of groundwater

A more detailed characterization of groundwater resources and existing infrastructure are presented for inventory and sub-inventory unit areas within the Sacramento Region than for the Foothill and Mountain regions of Butte County. Local groundwater characterization at the inventory and sub-inventory unit levels presented in Section 3 will include discussions of the following subject areas:

- local hydrogeology
- well distribution

Table 1.
Inventory and Sub-inventory Units for the Butte County Groundwater Inventory Analysis.

Regions	Inventory Units	Sub-Inventory Units
Sacramento Valley	Vina	California Water Service Area (partial)
	West Butte	California Water Service Area (partial) Durham-Dayton M&T Angel Slough Llano Seco Western Canal (partial)
	East Butte	Pentz Esquon Cherokee Western Canal (partial) Richvale Thermalito Biggs-West Gridley Butte Butte Sink
	North Yuba	
Foothill	Foothill	Cohasset Ridge Wyandotte
Mountain	Mountain	

- groundwater levels
- groundwater hydrographs
- groundwater contours
- groundwater movement
- groundwater extraction
- well depths
- well yield (inventory unit level only)
- specific capacity (inventory unit level only)
- groundwater storage capacity (inventory unit level only)
- groundwater in storage (inventory unit level only)
- changes in groundwater in storage (inventory unit level only)

Methods

A brief overview of the methods and procedures used to determine aquifer parameters and characterize the groundwater resources in Butte County are presented below.

Regional and Local Hydrogeology

The regional geology of the Sacramento Valley is based on a geologic map developed by DWR that illustrates the surface geology of the valley, surrounding foothills, and mountainous areas. The regional geologic map is a compilation of previously developed geologic maps obtained from the following sources:

- *Geologic Map of the Late Cenozoic Deposits of the Sacramento Valley and Northern Sierran Foothills*, *California*, Helley and Harwood, U.S. Geological Survey (Maps: California 1985);
- *Seismotectonic Evaluation, Northern Coast Ranges, California*, William Lettis and Associates, Inc. (Lettis 1999);
- *Geologic Map of California: 1969-1973*, Jennings, California Department of Conservation, Division of Mines and Geology (Maps: California 1977); and
- *Geologic Maps of California,* Strand, California Department of Conservation, Division of Mines and Geology (Chico 1992, Redding 1962, Ukiah 1960, and Westwood 1960).

Regional geologic contacts were largely obtained from the sources cited above. Where questions arose concerning the location of geologic contacts on a local scale, the geologic contacts were field verified. The Butte County geologic map is included as Plate 2, in Appendix A. The associated geologic legend is included as Plate 3, Appendix A.

Subsurface geology of Butte County was interpreted by DWR from electric resistivity well data and is presented in a series of geologic cross-sections. Electric resistivity well data were obtained from Division of Oil and Gas test and production wells and from electric resistivity logs of DWR observation and production wells. Additional electric resistivity log and lithology data were obtained from well completion reports submitted to DWR by individual drilling companies.

The subsurface geology, geologic stratigraphy, and hydrogeologic units were delineated in a total of six geologic cross-sections throughout the Sacramento Valley, four of which are located in Butte County. Of the six cross-sections, four are oriented east-to-west, and two are oriented north-to-south. The cross-section locations are shown on Plate 2, Appendix A. The individual cross-sections are presented on Plates 4 and 5, Appendix A. A vertical exaggeration of 1:1,000 feet and a horizontal exaggeration of 1:10,000 feet were used to portray the topographic surface and subsurface geologic units with greater detail.

The base of fresh water shown on the cross-sections is derived from criteria established by C. F. Berkstresser, Jr. in *Base of Fresh Ground Water, Approximately 3,000 Micromos, in the Sacramento Valley and Sacramento-San Joaquin Delta, California* (Berkstresser 1973). This report characterized fresh groundwater as having a specific conductance of less than 3,000 micromhos per centimeter. Groundwater with a specific conductance that exceeds 3,000 micromhos per centimeter is considered saline.

Regionally, the approximate base of fresh groundwater tends to correspond with the base of post-Eocene deposits. Locally, the base of fresh groundwater fluctuates depending on local changes in subsurface geology and geologic formational structure.

Well Distribution

Since 1949, the California Water Code (Section 13751) has required water well contractors to file a well completion report with DWR. The distribution, by use, of groundwater wells in Butte County was compiled from the well location data provided in well completion reports filed at DWR and from the field-verified locations of wells included in the groundwater monitoring database. Well locations associated with groundwater monitoring wells have been field-verified and accurately

located to within about 300 feet. Well locations derived from well completion reports are recorded and plotted to the nearest township, range, and section. Well locations derived from the well completion reports were randomly plotted within the given section.

Although most well completion reports accurately locate wells to the nearest section (1-mile radius), some well completion reports may mislocate well locations by several miles. Well distribution data listed in this report should be used as a general indicator of well location and distribution. The number and distribution of wells are grouped according to location and five well types: domestic, irrigation, municipal, monitoring, and other. Municipal wells include wells identified on the well completion report as municipal or public. Wells identified as "other" includes wells listed as stock wells, test wells, abandoned wells, or unidentified wells. Well distribution data are provided at the inventory and sub-inventory unit levels in Section 3. Summaries of well distribution by area and installation date are presented in Tables 1 and 2, Appendix B.

Groundwater Level

In a groundwater basin, water levels fluctuate as a result of changes in the amount of groundwater in aquifer storage. Factors that affect the amount of groundwater in storage include the annual amount of extraction and aquifer recharge. The aquifer system is recharged from subsurface inflow to the basin and percolation of precipitation, streams, and irrigation water. Aquifer discharge occurs when groundwater is extracted by wells, discharges to streams, or flows out of the groundwater basin into the subsurface. In general, dry years cause groundwater levels to decline because more water is discharged than recharged. During wet years, groundwater levels typically recover because more water is recharged than discharged.

Analysis of groundwater levels in Butte County is based on data collected by DWR, Butte County, the California Water Service Company (CWSC), and other data collection cooperators within the county. Groundwater level data collected by DWR consist predominantly of semi-annual measurements. However, some monthly and continuous recordings of groundwater levels are also conducted. Semi-annual groundwater level measurements are recorded in the spring when levels are at their highest and in the fall when the levels are recovering from active summer pumping. In 1997, Butte County, in cooperation with DWR, developed a groundwater level monitoring program designed to increase the measurement frequency and extent of the existing DWR monitoring grid. Butte County currently monitors groundwater levels during the summer months when groundwater extraction is at its peak and on a continuous basis in 5 other wells added since 1997. Groundwater levels are typically measured to the nearest one-tenth of a foot using an electric sounder or a steel tape. Groundwater level measurements are recorded as depth below ground surface and later converted to elevation above mean sea level.

The groundwater level data were used to develop groundwater hydrographs for selected wells within Butte County. Groundwater hydrographs are graphical plots of depth to groundwater versus time. They are used to help illustrate historic trends or changes in levels over time. To help visualize changes in groundwater levels, a series of individual measurements are often presented in the hydrograph as a solid line. It is important to remember, however, that the line connecting the actual measurement

points does not represent a continuous recording of groundwater levels; it serves, rather, as an approximation of levels between a series of known levels taken at individual points in time. Hydrographs presented in this report are used to help estimate the seasonal and long-term fluctuations in Butte County groundwater levels at both a local and regional level.

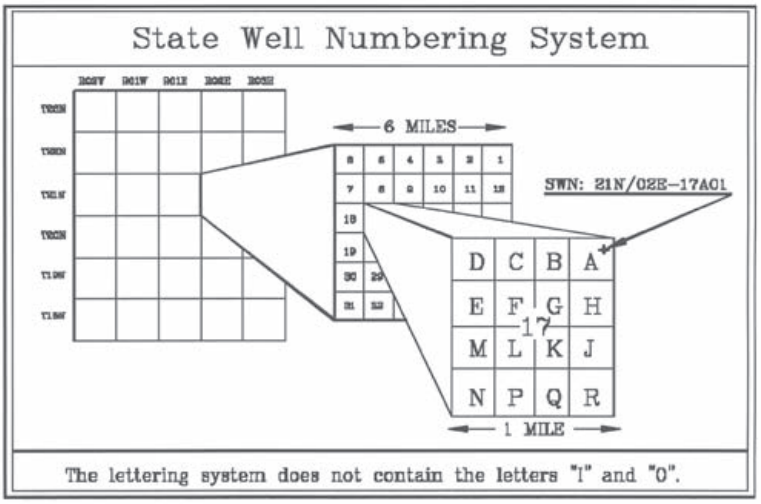
The monitoring wells are numbered using the State Well Numbering System. The system identifies each well by its location according to the township, range, section, and tract system. Figure 1 illustrates the State Well Numbering System.

Select hydrographs for current monitoring wells are presented under the discussion of groundwater levels at the inventory and sub-inventory levels of the report. Additional hydrographs and groundwater level data for monitoring wells can be obtained from the DWR Web site at *http://www.wdl.water.ca.gov.* The on-line groundwater level data can be retrieved via a graphical map interface or by a designated basin area and State well number.

When reviewing hydrographs on-line, note that the solid circles (dots) indicate a static groundwater level measurement, while the red symbols indicate a measurement that has been qualified as questionable. DWR assigns a numerical code to all questionable groundwater level measurements in an effort to help increase the accuracy of data analysis. Questionable measurement codes are used to differentiate between static versus pumping groundwater level measurements and/or identify whether nearby wells are pumping during the measurement. A key to explaining the various types of questionable measurement codes used with the on-line hydrographs is available at the DWR Web site. In the hydrographs presented in this report, symbols are used to indicate several of the more common types of questionable measurements. A legend correlating the measurement symbol to the type of questionable measurement is presented at the base of each hydrograph.

When interpreting changes in groundwater levels over time, care should be used when comparing measurements taken only during similar times of the year. Prior to 1990, much of the groundwater level data for Butte County consisted only of spring and fall data. Since 1990, summer measurements have been collected from many of the monitoring wells. Comparison of the spring measurements is recommended when using a hydrograph to compare multiple years of groundwater level data. Breaks or

Figure 1.
California State Well Numbering System.



discontinuities in a hydrograph represent missing measurements. The Butte County groundwater monitoring grid is shown on Plate 6, Appendix A. Individual groundwater hydrographs and discussions of groundwater level data at the inventory and sub-inventory unit levels are provided in Section 3.

Groundwater Movement

Groundwater level data were also used to develop groundwater elevation contour maps for the Sacramento Valley portion of Butte County. Groundwater contour maps were developed using groundwater level data from Butte, Glenn, Colusa, Tehama, Sutter, and Yuba counties. Similar to topographic contours, the patterns and spacing of groundwater elevation contours can be used to help estimate the direction and gradients of groundwater movement. Groundwater contours can also be used to help determine and illustrate the spring-to-spring and spring-to-summer changes in groundwater elevations and storage.

Groundwater contour maps were constructed using a computer-aided groundwater surface modeling program. The software generates approximate contour locations based on a network of triangulated grids. Accuracy of the groundwater elevation contours varies with respect to the data density, groundwater gradients, and proximity of the contours to the eastern basin boundary. Where appropriate, additional editing of contour locations was completed using general knowledge of the region's hydrogeologic characteristics.

Groundwater level measurements used to create elevation contour maps are from wells that represent mixed aquifer conditions (confined, unconfined, and composite). Within the same inventory unit, the groundwater level in a shallow well constructed in the unconfined portion of the aquifer system may be significantly different from the groundwater level of a deep well constructed in the confined portion. Because of the potential differences in groundwater levels between separate aquifer systems, care should be taken when using the contour maps to interpret groundwater occurrence, movement, and changes in storage on a local scale.

The groundwater elevation contours provide a good regional estimate of groundwater occurrence, movement, and changes in storage within the mid-to-upper aquifer systems. Discussions of groundwater movement at the inventory and sub-inventory unit levels are provided in Section 3. A groundwater elevation contour map showing the direction and movement of groundwater during the spring of a normal water year is provided on Plate 7, Appendix A. A groundwater level map showing the changes in spring-to-summer groundwater levels in a normal-year is provided on Plate 8, Appendix A.

Groundwater Extraction

Awareness of the amount of groundwater being extracted from a basin contributes to a better understanding of the current level of groundwater development and a better understanding of which management methods are the most appropriate for maintaining a sustainable groundwater resource. One method of determining groundwater extraction is by direct measurement via the metering of individual production wells within the basin. However, in most areas of the Sacramento Valley, agricultural wells are not metered, and a direct measurement of groundwater extraction is not monitored. An alternative method used in this study estimates the amount of groundwater extraction through the use of a land use survey and the water balance approach.

The annual groundwater demand was determined for normal and drought years using the water balance approach, municipal records, and land use data developed by DWR and Butte County. In areas of the county having a mixed supply of surface water and groundwater, the difference between the agricultural demand and the surface water delivery is assumed to be equal to the amount of groundwater extraction. The annual groundwater extraction estimates are divided into summer and winter agricultural use, annual municipal and industrial uses, and annual wildlife refuge use. Municipal and industrial groundwater extraction estimates for regions outside of a municipal water service area include the estimated domestic use from private wells. Within a municipal water service area, the municipal and industrial groundwater extraction estimates do not include domestic use from private wells. The estimated amount of groundwater extracted from private wells is based on population, population density, landscaping, and local climatic conditions. Domestic use of groundwater from rural private wells is typically minor in comparison to agricultural use.

Groundwater extraction estimates for a normal-year incorporate 1997 land use and municipal extraction data and closely approximate the annual amount of groundwater extracted under the current level of county development. Groundwater extraction estimates for a drought year represent the potential maximum amount of groundwater extraction that can be expected to take place under the current level of development and under a worst case scenario of precipitation, evapotranspiration, runoff, and reduction in surface water deliveries to the county. A detailed description of normal and drought years is presented below. Groundwater extraction data at the inventory and sub-inventory unit levels are presented in Section 3. A summary of groundwater extraction estimates for normal and drought years is presented in Tables 3 and 4, Appendix B. A water source map for Butte County is provided on Plate 9, Appendix A.

Determination of Normal- and Drought-Type Years

An important aspect of the Butte County groundwater inventory analysis was identifying how the groundwater basin responds to a range of climatic conditions, such as those that occur during normal versus drought years. Ideally, several water years can be selected to accurately represent and compare the annual groundwater extraction and basin response during normal and drought year conditions. However, an accurate determination of what constitutes normal versus drought conditions, and the selection of years that appropriately represent each of these climatic conditions was often difficult. Many factors can affect the annual amount of groundwater that is extracted from a given area. Some of the factors that were considered when selecting a representative normal or drought year for Butte County are listed below:

- precipitation,
- runoff to the major streams and rivers,
- evapotranspiration,
- level of agricultural and urban development, and
- surface water availability.

The 95-year precipitation record for the station at the California State University, Chico (CSUC) farm is shown in Figure 2. The precipitation record for this station is considered representative of historical rainfall conditions in the Sacramento Valley portion of Butte County. Figure 2 also shows the average annual precipitation over the 95-year period of record. Classification of the precipitation years in Figure 2 as wet, above normal, dry, and critically dry were developed to correlate to a similar

classification system used to estimate annual runoff for the Sacramento River 40-30-30 Water Supply Index. The CSUC precipitation station has operated at its existing location, just south of Chico off of Hegan Lane (T21N/R01E-12), since 1973. Between 1875 and 1973 the station was located about 4 miles west of the current location.

The annual runoff from local and regional streams was evaluated through local stream gage records and review of the Sacramento River 40-30-30 Water Supply Index. The Sacramento River Index is a regional indicator of the annual water supply for the northern Sacramento Valley. The index incorporates the sum of the unimpaired monthly runoff measured in the Sacramento River at Bend Bridge, the Feather River inflow to Lake Oroville, the Yuba River at Smartville, and the American River inflow to Folsom Lake. Unimpaired runoff represents the natural water production of a river basin unaltered by upstream diversions, storage, and export of water to, or import of water from, other basins. The Sacramento River Index is calculated as the sum of 40 percent of the current April through June flow, 30 percent of the current October through March flow, and 30 percent of the index for the previous water year. Based on the calculated runoff in million acre-feet, each year of the index is then classified as wet, above normal, below normal, dry, or critical. Figure 3 shows the Sacramento River Index since 1906 and the classification range for each year.

Evapotranspiration rates, level of development and surface water supply were also examined in order to establish agricultural water use for representative years. Monthly evapotranspiration rates were derived from lysimeter and pan evaporation data collected by DWR. Crop evaporation coefficients were developed jointly by DWR and the University of California Davis Cooperative Extension. The level of development was reviewed based on DWR land use and the Butte County Agricultural Commissioner's data. The potential curtailment of surface water deliveries were examined based on the existing agreements for Central Valley Project and Feather River settlement rights.

The normal-year is intended to represent a typical water year scenario, or the amount of groundwater extraction that can be expected under normal climatic and land use conditions. Based on multiple data sources, 1997 was determined to best represent normal precipitation, evapotranspiration, runoff conditions, and full surface water availability. However, the most recently completed Butte County land and water use survey was conducted by DWR in 1994. Using the 1997 Butte County Agricultural Commissioner's data, the 1994 land and water use survey was updated to match 1997 cropping trends.

In summary, estimates of the amount of groundwater extraction that occurs in Butte County during a normal-year scenario were calculated based on:

- 1997 precipitation, evapotranspiration, and runoff data,
- 1994 land and water use projected to 1997 agricultural cropping trends, and
- full surface water supply availability.

The drought year is an artificial set of annual conditions. It is intended to represent a worst-case water year scenario, or the maximum amount of groundwater extraction that can be expected to occur under predicted natural conditions. The worst case scenario for an annual evaporation rate is best represented by 1997 data. With respect to precipitation and runoff, 1977 is considered to best represent drought-year conditions in agricultural land use areas. However, because the land and water use

Figure 2.
Butte County Precipitation Record from CSUC Farm Station.

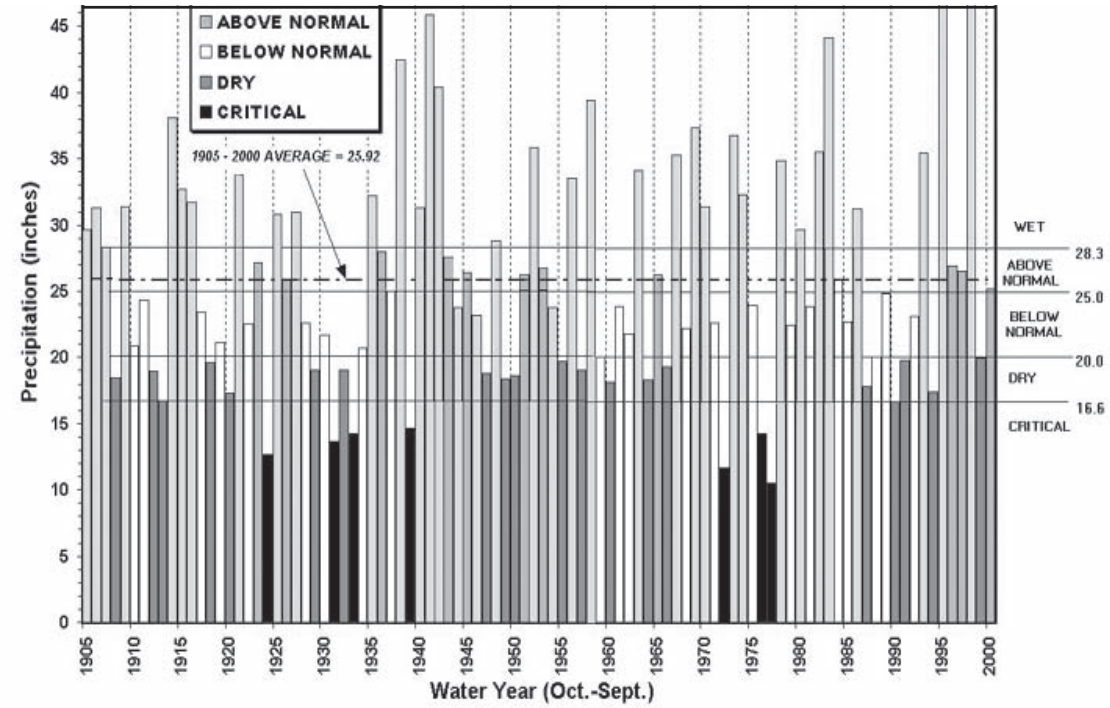
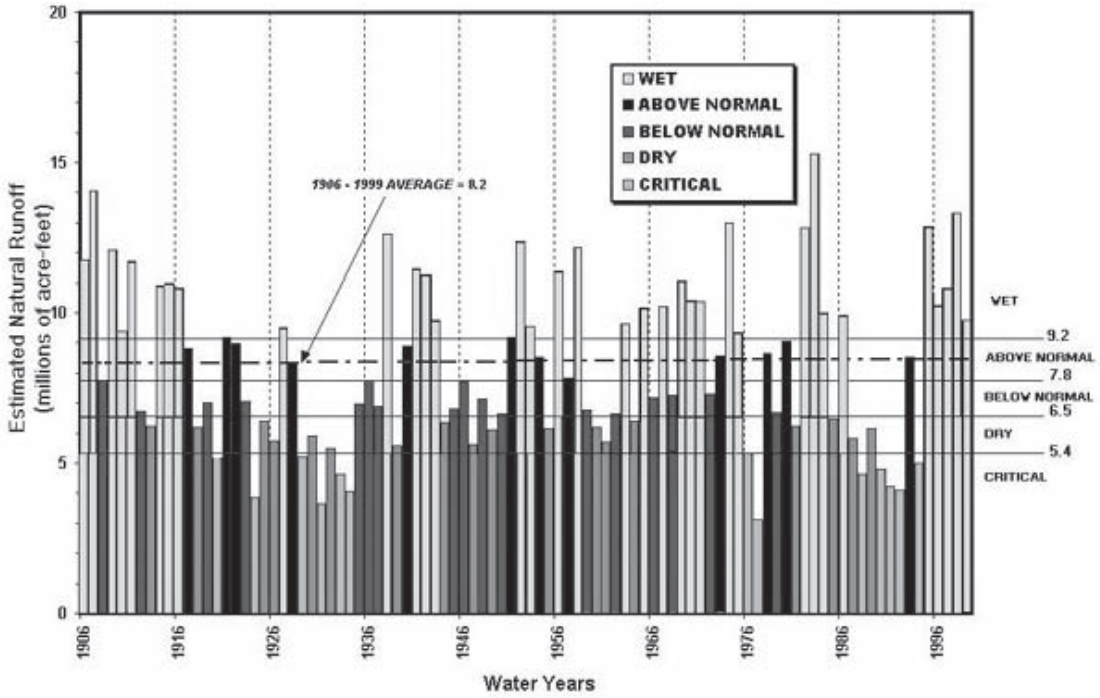


Figure 3.
Sacramento River 40-30-30 Water Supply Index.



data from 1977 does not accurately represent the current level of agricultural and urban development, 1994 land use data normalized to 1997 agricultural cropping trends were selected to best represent a worst case land use condition. A worst case scenario for a drought-year surface water supply was represented by reducing surface water deliveries by an amount equal to the maximum allowable single-year cutback for State and Federal water projects. Worst case scenarios for municipal and industrial water requirements were best represented by applying the 1987 per-capita water use (high evaporation and low precipitation) to 1997 population estimates.

In summary, the worst case scenario for groundwater extraction in Butte County during a drought year is based on:

- 1977 precipitation and runoff data,
- 1997 evapotranspiration rates,
- 1994 land and water use projected to 1997 agricultural cropping trends,
- a 50 percent reduction in SWP water deliveries and a 25 percent reduction in CVP water deliveries, and
- 1987 per-capita municipal and industrial water uses adjusted to 1997 population estimates.

Well Depth

The depths of existing wells in each inventory and sub-inventory unit were analyzed to provide a basis for estimating the amount of available groundwater in storage and to assess potential impacts of increased groundwater development on a region. In many parts of the Sacramento Valley, the potential impacts of groundwater extraction on shallow wells are the limiting factors in the amount of groundwater that can be extracted from a particular area. Extraction of too much groundwater can adversely affect shallow wells by causing levels to be lowered below the pump bowls or the bottom of the wells.

In areas where sufficient information was available, a well depth analysis was completed for domestic, irrigation, and municipal water wells. The well depth data were plotted in the form of histograms and cumulative frequency distribution curves for analysis and evaluation. The well depth data were collected from well completion reports filed with DWR. Well depth data at the inventory and sub-inventory unit levels are provided in Section 3 and summarized in Table 5, Appendix B.

Well Yield

Well yield is the maximum amount of groundwater that can be continuously extracted from a well. Well yield values are largely a function of well size, well performance, and aquifer productivity. Sources of well yield data reviewed for this investigation include well completion reports filed with DWR, published and unpublished investigations, and utility pump test records.

The well yield data listed in well completion reports are often derived by using a variety of pumping methods that often produce variable results. Well yield data listed in those reports are often collected during well drilling or development and are commonly more a function of the particular pump test method, rather than an accurate indication of maximum well yield for a given area. As such, well yield data from well completion reports should serve only as a general approximation of actual well yield.

A more accurate estimate of well yield is provided through utility pump test records for municipal and agricultural wells. Utility pump tests are typically performed using the existing pump motor and bowls that were specifically designed for each well. Utility pump test records are generally used to provide an accurate estimate of well yield. As part of this investigation, the data from records of approximately 2,600 utility pump tests taken in Butte County between 1989 and 1998 were collected and analyzed. The pump test records represent about 900 individual wells. The data from wells having more than one pump test were averaged to avoid skewing the overall averages for the Sacramento Valley inventory unit areas.

In addition to the analysis of recent utility data, the work done by Olmsted and Davis of the United States Geological Survey was analyzed. This work included their collection of utility pump test records from the 1940s, as stated in the 1961 USGS report entitled, *Geologic Features and Groundwater Storage Capacity of the Sacramento Valley, California*. In their report, Olmsted and Davis gathered well yield data from large-capacity irrigation, industrial, and municipal wells in 21 study areas within the Sacramento Valley through 1948. Of the 21 study areas, three are located in the valley portion of Butte County. Well yield data developed for the Olmsted and Davis report is presented to help characterize production in this area. Well yield data are provided at the inventory unit level in Section 3 and summarized in Table 6, Appendix B.

Specific Capacity

The specific capacity of a well is the pumping rate divided by the total drawdown after a specified period of pumping. Similar to well yield, specific capacity is a method of measuring well productivity. Specific capacity is usually reported in gallons per minute per foot (gpm/ft) of drawdown. Sources of specific capacity data reviewed for this investigation include published and unpublished investigations and utility pump test records. Use of well completion report data was determined to be inadequate for an accurate evaluation of specific capacity on an inventory or sub-inventory level.

Utility pump test records provide an accurate and consistent measurement of specific capacity. Approximately 2,600 utility pump test records taken in Butte County between 1989 and 1998 were analyzed to determine estimates of specific capacity at the inventory unit level. Of the utility pump test records, 974 had enough data to calculate specific capacity. The 974 tests represent specific capacity measurements from 433 individual wells. Wells having specific capacity data from more than one pump test were averaged. The utility records primarily represent pumping test data from municipal and agricultural wells within the Sacramento Valley portion of Butte County.

Specific capacity data were also collected from work conducted by Olmsted and Davis and published in their 1961 USGS report. Specific capacity data from the Olmsted and Davis report is provided at the inventory unit level in Section 3 and summarized in Table 7, Appendix B.

Groundwater Storage Capacity

For the purposes of this investigation, groundwater storage capacity is defined as the maximum volume of fresh groundwater capable of being stored within an aquifer, beneath a given area. Estimates of groundwater storage capacity and groundwater in storage were calculated for each of the Butte County inventory unit areas by

multiplying the inventory unit area by the specified saturated thickness of the aquifer and by the estimated average specific yield of the aquifer system (see equation below). Groundwater storage estimates were developed to help further a general understanding of Butte County groundwater resources within each of the inventory units.

$$S=T_a*S_y*A$$

Where:

S = Groundwater storage capacity
T_a = Specified saturated thickness of the aquifer system
S_y = Average specific yield of the aquifer system
A = Inventory unit area

Calculation of groundwater storage capacity requires estimating how high groundwater levels could rise in the aquifer system before damaging the existing agriculture, urban infrastructure, or natural draining of the basin. During the spring of most normal water years, the aquifer system in the southern East Butte Inventory Unit is at maximum groundwater storage capacity when the average depth to groundwater is 6 feet. Based on this data, the maximum groundwater storage capacity estimates were calculated using a saturated thickness equal to the base of fresh water minus a uniform depth to groundwater of 10 feet. The base of fresh water, which are shown in the geologic cross-sections on Plates 4 and 5, Appendix A, was estimated using electric resistivity logs.

Specific yield is the ratio of the volume of water a rock will yield under gravity drainage to the volume of the entire rock. Estimates of specific yield were derived from input values for the Butte Basin *Flow 3D* groundwater model as reported in *Development of a Groundwater Model, Butte Basin Area, California* (Hydrologic Consultants, Inc. 1995) and from estimates developed by the USGS (Olmsted and Davis 1961). Estimates of groundwater storage capacity are provided at the inventory unit level in Section 3 and summarized in Table 8, Appendix B.

Groundwater in Storage

Groundwater in storage is defined as the volume of water contained within the aquifer system at the time of measurement. Groundwater in storage was examined at the inventory unit level using three scenarios:

- the estimated volume of groundwater currently in storage over the entire freshwater portion of the aquifer system,
- the estimated seasonal decline in groundwater levels associated with the removal of groundwater from storage during a normal water year, and
- the estimated seasonal decline in groundwater levels associated with the removal of groundwater from storage during a drought water year.

Groundwater in storage scenarios were calculated using the above storage formula and previously described methods for estimating normal- and drought-year groundwater extraction. Further descriptions of the scenarios are presented below.

- **Estimated Total Volume of Groundwater in Storage.** This scenario estimates the total amount of fresh groundwater in storage beneath the valley portion of Butte County during a normal water year. The spring 1997 groundwater levels were used to represent the normal water-year conditions, with the saturated thickness equal to the base of fresh water, minus the spring 1997 average depth to groundwater. Storage estimates based on the total saturated thickness of the

fresh water aquifer beneath a given inventory unit area are intended to serve as a general reference of aquifer size, not as a guideline of potential production capabilities. Attempts to use all of the fresh groundwater in storage would result in disastrous consequences to the groundwater resource, local groundwater users, and surrounding communities. Estimates of the total volume of groundwater in storage are presented at the inventory unit level in Section 3 and summarized in Table 9, Appendix B.

- **Estimated Seasonal Decline in Groundwater Levels Associated with Normal-Year Groundwater Extraction.** This scenario estimates the seasonal decline in groundwater levels during a normal water year for each inventory and sub-inventory unit. Seasonal groundwater extraction estimates were developed by adjusting the annual extraction estimates for the 1997 normal year. The annual extraction estimates were adjusted to reflect seasonal use by using 100 percent of the estimated summer agricultural extraction, plus 70 percent of the annual municipal extraction, minus 30 percent of the annual deep percolation. The decline in groundwater levels was calculated using the storage formula to solve for the saturated thickness (amount of groundwater level lowering) associated with the estimated volume of seasonal groundwater extraction. Methods of calculating normal-year groundwater extraction were described previously in the groundwater extraction portion of Section 1. Estimates of the decline in groundwater levels based on normal-year groundwater extraction can be used as a general reference and for comparison of measured changes in groundwater levels that occur during similar normal-year periods. These estimates of the decline in groundwater levels associated with normal-year extraction are presented in Section 3 and summarized in Table 10, Appendix B.

- **Estimated Seasonal Decline in Groundwater Levels Associated with Drought-Year Groundwater Extraction.** This scenario estimates the seasonal decline in groundwater levels during a drought year for each inventory and sub-inventory unit. Seasonal drought-year groundwater extraction estimates were developed by adjusting the annual extraction estimates for the 1997 drought year. The annual extraction estimates were adjusted to reflect seasonal use by using methods similar to those described above. These estimates can provide awareness of potential drought-related impacts and be used to guide development of drought-year groundwater management plans. Estimates of decline in groundwater levels associated with drought-year extraction are presented in Section 3 and summarized in Table 10, Appendix B.

The storage estimates presented in these sections were developed to help facilitate a general understanding of the amount of groundwater storage that exists within the natural basin area and to estimate the seasonal declines in groundwater levels during normal and drought years. The actual change in groundwater levels associated with normal and drought years, along with the actual amount of usable groundwater in storage, can only be determined empirically through active management and adequate monitoring of the groundwater resource. Concern over potential impacts to shallow domestic wells will ultimately limit the amount of acceptable drawdown that can occur at a local level.

Changes in the Volume of Groundwater in Storage

Changes in the volume of groundwater in storage are dependent on many factors, including climatic conditions, the annual rate of groundwater extraction, and the

annual rate of groundwater recharge. The volume of groundwater in storage commonly fluctuates within a given year and from year to year. The volume of groundwater in storage will typically decline during periods of drought and rebound during periods of above-normal precipitation. Within the same year, the volume of groundwater in storage will decline through the summer months as it is extracted for municipal and agricultural uses, then recover as extraction slows and seasonal precipitation increases recharge. In basins where the amount of annual groundwater extraction is at or below the amount of normal-year recharge, the long-term change in the volume of groundwater in storage will generally remain the same. In basins where the annual amount of groundwater extraction exceeds the amount of normal-year recharge, the long-term trend will be a decline in the volume of groundwater in storage. Depletion of the volume of groundwater in storage is typically exhibited by a decline in groundwater levels during periods of normal precipitation.

The annual spring-to-spring changes in the volume of groundwater in storage for the Sacramento Valley portion of Butte County were calculated over a 20-year period from 1980 to 2000. The spring-to-spring changes in the volume of groundwater in storage were calculated using groundwater contour maps developed from spring groundwater level measurements from wells completed in the upper portion of the aquifer. Digital three-dimensional groundwater elevation surfaces were constructed using the spring groundwater level data. The volume differences between consecutive spring-to-spring groundwater elevation surfaces were calculated. Changes in the volume of groundwater in storage calculated from groundwater elevation contour maps are a good approximation of the actual changes in the volumes of groundwater in storage over time. However, the accuracy of groundwater elevation contours varies with respect to the groundwater gradient, the data density, and proximity to the basin boundary. Overall, the calculated volumes of groundwater in storage are considered accurate within plus or minus 10 percent.

The spring-to-spring changes in the volume of groundwater in storage are graphically illustrated in the cumulative spring-to-spring changes in the volume of groundwater in storage graphs found under each inventory unit in Section 3. The spring-to-spring graphs start with a baseline of zero for the spring of 1980. Similar to the 1997 water year, basin-wide groundwater levels during the spring of 1980 closely characterize groundwater conditions associated with a normal water year. Changes in spring-to-spring storage in subsequent years are shown as cumulative changes and are calculated based on the difference between groundwater levels during the 1980 base year and the spring of any given year. Changes in groundwater in storage data are summarized in Table 11, Appendix B.

SECTION 2.
Regional Groundwater Geology

Butte County covers several geologic regions and a wide range of diverse groundwater- bearing units. Discussions of the regional groundwater geology are grouped into areas encompassing the inventory units within the Sacramento Valley, Foothill, and Mountain regions. These regions are shown on the location map, Plate 1, Appendix A.

The major groundwater aquifers in Butte County lie within the larger Sacramento Valley groundwater basin. The basin extends north to south from Red Bluff to the Sacramento-San Joaquin Delta and is bordered by the Coast Ranges to the west and the Cascade Range and Sierra Nevada to the east. It covers an area of 4,900 square miles, which includes all of Sutter County and parts of Butte, Glenn, Tehama, Colusa, Yuba, Yolo, Solano, Placer, and Sacramento counties.

The Sacramento Valley is a structural basin filled with up to 5 miles of sediment. These marine and continentally derived sediments have been deposited almost continuously from the Late Jurassic period to the present. Of these deposits, older sediments in the basin were emplaced in a marine environment and usually contain saline or brackish groundwater. Younger sediments were deposited under continental conditions and generally contain fresh groundwater. Sediments thin near the margins of the basin, exposing older metamorphic and granitic rocks underlying and bounding the Sacramento Valley sediments.

Principal hydrogeologic units of the Sacramento Valley groundwater basin consist of Pliocene sedimentary deposits, such as the Tuscan, Laguna, and Tehama formations, and Quaternary terrace deposits, such as the Riverbank and Modesto formations. The Tuscan, Laguna, and Tehama formations are the source of water for deep irrigation and municipal wells, while the Riverbank and Modesto formations yield water to the shallower domestic wells.

Butte County is composed of a diverse mix of geologic units ranging from very productive water-bearing sedimentary units to nonwater-bearing plutonic and metamorphic rocks. The main hydrogeologic unit and source of groundwater in Butte County is the Tuscan Formation. Other units that supply lesser amounts of groundwater to the county are the Laguna, Riverbank, and Modesto formations.

Groundwater occurs under both unconfined and confined conditions in Butte County. Unconfined conditions are present in the surficial Quaternary deposits and in the Pliocene deposits that are exposed at the surface. Confined conditions usually exist at a depth of 200 feet or more, where a confining layer rests above the underlying aquifer deposits. Although the Tuscan Formation is unconfined where it is exposed near the valley margin, at depth the Tuscan Formation is confined and forms the major aquifer system in Butte County.

The following is a discussion of the geologic units found within the Sacramento Valley, Foothill, and Mountain regions of Butte County and their hydrogeologic properties.

Sacramento Valley Region

The Sacramento Valley Region of Butte County lies within the Sacramento Valley groundwater basin, as shown on Plates 1 and 2, Appendix A. Upland portions of the region range in elevation from 300 to 400 feet above mean sea level (msl). This upland topography consists of low hills, dissected uplands, and alluvial fans of moderate relief. The land surface slopes downward toward the axis of the valley, where the elevation is generally about 70 to 90 feet above msl, with the ground surface elevation decreasing southward toward the Sutter Buttes. The majority of Butte County's groundwater resources come from the Sacramento Valley Region.

A notable feature within this region is the Butte Basin. This area lies south of Chico and west of the Feather River. Characterized by an expansive, flat topography, the Butte Basin was, prior to flood control on the Feather and Sacramento rivers, an area of extensive seasonal flooding. Early reports depict a slow-moving sea of water covering from 30 to nearly 150 square miles (Bryan 1923). This slow-moving floodwater deposited the fine clay that now provides the rich agricultural soil used primarily for rice production.

South of the Butte County line, the Sutter Buttes provide the only significant topographic relief on the Sacramento Valley floor. This small-scale volcanic mountain range intruded the valley sediments during the early Pleistocene (1.2 million years before present (mybp)) epoch. The intrusion buckled the valley sediments upward, forming a barrier to groundwater flow. The Sutter Buttes block the general north-to-south trend of groundwater migration, forcing groundwater to the surface. The upward movement results in a shallow groundwater table and the formation of wetlands along the west side of the Sutter Buttes.

In an effort to better understand the groundwater resources of the Sacramento Valley groundwater basin, DWR developed a series of maps illustrating the surface and subsurface geology of Butte County. The surface geology of the Butte County portion of these maps is shown on Plate 2, Appendix A, and in four geologic cross-sections shown on Plates 4 and 5, Appendix A. The geologic legend for the maps is shown on Plate 3, Appendix A. The cross-sectional maps also illustrate the subsurface geology, base of fresh water, geologic structure, and stratigraphic sequence beneath the Sacramento Valley portion of Butte County.

Following is a discussion of the surface and subsurface geology of Butte County. The major water-bearing units will be discussed in greater detail in the succeeding section entitled "Fresh Groundwater-Bearing Units."

Surface and Subsurface Geology

The regional structure of the Sacramento Valley groundwater basin consists of an asymmetrical trough tilting to the southwest with a steeply dipping western limb and a gently dipping eastern limb (Page 1986). Older granitic and metamorphic rocks underlie the valley forming the basement bedrock on which younger marine and continentally derived sediments and volcanic rock have been deposited. Along the valley axis and west of the present-day Sacramento River, basement rock is at considerable depth, ranging from 12,000 to 19,000 feet below ground surface. Immediately overlying the basement bedrock is a thick sequence of sandstone, shale, and conglomerate rocks of marine origin, ranging from Jurassic to Eocene in age. Within the Butte County portion of the Sacramento Valley, these sediments are saline or brackish and serve as the base of fresh groundwater.

The oldest of the Jurassic to Eocene marine sediments is known as the Great Valley Sequence which is Jurassic to Cretaceous in age. Sediments of the Great Valley Sequence were originally deposited as horizontal layers, but due to compressive stress within the region, the margins of the formation have been folded and faulted upward. Post-depositional erosion cut large-scale valleys into the Great Valley Sequence. Subsequent in-filling of these canyons created wide-scale deposition of the Lower Princeton Submarine Valley fill. This relationship can be seen on all four cross-sections of the Sacramento Valley. Water contained within the Great Valley Sequence is primarily saline.

The Lower Princeton Submarine Valley fill of the Eocene epoch consists of a mixture of marine sediments and continental materials derived from the walls of an eroded submarine canyon that was carved into the Great Valley sediments (Redwine 1972). Groundwater contained within these sediments is almost exclusively saline. The Lower Princeton Submarine Valley fill is one of several formations in the Sacramento Valley Region that exist in the subsurface but are not exposed at the surface. Information on the extent and position of this unit is limited because the majority of data concerning its existence and character come from oil and gas exploration well logs.

In most locations, the Lower Princeton Submarine Valley fill is unconformably overlain by the Eocene Ione Formation or the Miocene Upper Princeton Valley fill, as shown on Plates 4 and 5, Appendix A. The Ione Formation is present in both the surface and subsurface of the Sacramento Valley Region. It is comprised of poorly cemented, easily eroded, deltaic-type deposits of sandstone, siltstone, and conglomerate and is believed to mark a change in the depositional environment (Maps: California 1985). Groundwater within the Ione Formation is primarily saline.

In Butte County, surface exposure of the Ione Formation is limited to areas protected by the overlying Lovejoy Basalt. Exposures of the Ione Formation and the Lovejoy Basalt can be seen at the surface in the Campbell Hills area located northwest of Oroville, as shown on the geologic map and on Cross-section C-C'. The Ione Formation is mapped in the subsurface of all four cross-sections. The Ione Formation underlies the Lovejoy Basalt, the Upper Princeton Valley fill, or the Neroly Formation at various locations within the valley portion of Butte County.

Following deposition of the Ione Formation, several volcanic eruptions in the Cascade Range produced a series of basalt flows that spread across the valley sediments during the Miocene epoch. These flows comprise the hard, black, microcrystalline Lovejoy Basalt. Surface exposures of the basalt can be seen in the Table Mountain and Campbell Hills areas northwest of Oroville. Occurrences of the Lovejoy Basalt are intermittent within the valley and can be seen in the subsurface of all four cross-sections. Groundwater, primarily saline or brackish, is transmitted and stored within the secondary porosity created by the fracturing and jointing of the basalt. Either the Upper Princeton Valley fill or the Neroly Formation overlies the Lovejoy Basalt in most locations. The Lovejoy Basalt can be seen as the cap rock of Table Mountain in Cross-section C-C'.

The Miocene Upper Princeton Valley fill is widespread throughout the Sacramento Valley but present only in the subsurface. Depending on location, the fill may overlie portions of the Lower Princeton Submarine Valley fill, the Ione Formation, or the

Lovejoy Basalt. This formation consists primarily of sandstone with interbedded layers of conglomerate. In contrast to the submarine depositional environment of the Lower Princeton Submarine Valley fill, the Upper Princeton Valley fill was deposited by terrestrial rivers draining the valley after the regression of marine waters (Redwine 1972). Water contained within the Upper Princeton Valley fill is primarily saline to brackish. The Upper Princeton Valley fill is overlain by the Neroly Formation in nearly all locations. The position and thickness of the Upper Princeton Valley fill can be seen within Butte County in all four cross-sections of the Sacramento Valley.

Also Miocene in age, the Neroly Formation is the youngest formation in the northern Sacramento Valley that is not exposed at the surface. It is composed of bluish-grey, tuffaceous sandstone with interbeds of light grey tuff and tuffaceous shales with minor beds of conglomerate (Redwine 1972). Sediments of the Neroly Formation most likely represent deposition of eroded materials in a bay or estuary environment. The Neroly Formation is overlain by the Tuscan Formation on the east side of the valley, the Tehama Formation on the west side of the valley, and the Laguna Formation in the southeast portion of the valley. The position of the Neroly Formation can be seen in Butte County in all four cross-sections of the Sacramento Valley.

Overlying the Neroly Formation are the Pliocene Tuscan, Tehama, and Laguna formations, which are the major fresh groundwater-bearing units in the northern Sacramento Valley. Only the Tuscan and Laguna formations are exposed at the surface in Butte County. Surface exposures of the Tehama Formation can be seen along the western side of the Sacramento Valley. Dipping eastward, the Tehama Formation interfingers with the Tuscan Formation in the subsurface along the central north-south axis of the valley.

The Pliocene Tuscan Formation is composed of a series of volcanic mudflows (lahars), tuff breccias, tuffaceous sandstone, and volcanic ash layers. Mudflows originated in the vicinity of present-day Lassen Peak and most likely filled ancient stream channels as they flowed toward the valley. On reaching the valley, the mudflows fanned out across the valley floor. Some larger lahars may have continued to flow southward in the valley, along stream channels. The Tuscan Formation is described as four separate but lithologically similar units, Units A through D, which in some areas are separated by layers of thin tuff or ash units (Maps: California 1985). These units will be discussed in greater detail in the following section.

The Laguna Formation, also of the Pliocene epoch, is composed of continental deposits containing predominantly fine-grained, poorly-bedded, and compacted sediments. These deposits are composed of a heterogeneous mixture of interbedded alluvial silt, clay, and fine sand of granitic and metamorphic origin, with minor conglomerate lenses (Olmsted and Davis 1961). Clay predominates in the fine-grain sediments south of Oroville. The sand is arkosic and contains abundant weathered feldspar, biotite, and angular quartz clasts. Near Oroville, the coarse gravel deposits are of granitic or metamorphic composition and are contained within a silty-to-sandy matrix. The Arroyo Seco gravels are considered by some sources to be part of the Laguna Formation.

West-flowing rivers and streams draining from the Sierra Nevada deposited the Laguna Formation. These rivers and streams spilled over their banks and spread out across the broad floodplains of the valley, depositing eroded materials from the Sierra Nevada. Exposure of the Laguna Formation is discontinuous and extends southward

from Oroville to Lodi. The only exposures within Butte County occur to the southwest of Oroville. The position and thickness of the Laguna Formation can be seen in Cross-section D-D'. More recent alluvial fan and terrace deposits overlie the Laguna Formation in the valley portion of Butte County.

The surface geology of the Sacramento Valley portion of Butte County is comprised primarily of alluvial deposits, the source of which is the eroded material derived from surrounding mountain ranges. These sediments were deposited as alluvial fan, terrace, and basin deposits by a network of streams and rivers flowing into the Sacramento Valley. Along the front of the foothills, alluvial fan and terrace deposits of the Riverbank and Modesto formations mark the edge of the valley sedimentary units.

The Pleistocene Riverbank Formation represents the oldest of the alluvial fan and terrace deposits. The Riverbank Formation was formed by streams carrying eroded material from the Cascade Range, Sierra Nevada, and foothill areas to the base of the foothills where it was deposited in wide alluvial fans. It is present in discontinuous surface exposures, primarily from west of Oroville southward. In many places, the Riverbank Formation has been covered by more recent alluvial fan development. The thickness of the formation varies from less than 1 foot to over 200 feet, depending on location (Maps: California 1985). The Riverbank Formation primarily overlies the Laguna Formation in the southern portion of Butte County and the Tuscan Formation in the northern portion of the county. The position and thickness of the Riverbank Formation can be seen in Cross-section B-B' (Plate 4, Appendix A). Overlying the Riverbank Formation in many locations is the Modesto Formation.

The alluvial fans and terrace deposits of the Pleistocene Modesto Formation were deposited in a similar manner to those of the Riverbank Formation but mark a more recent period of erosion and deposition from 42,000 to 14,000 years ago (Marchandt and Allwardt 1981). The terrace deposits of the Modesto Formation are exposed in many of the presently active stream-cut canyons along the foothills. Extending into the valley, Modesto Formation deposits widen into broad fans. As with the Riverbank Formation, the thickness of the Modesto Formation varies from less than 10 feet in many of the terraces to nearly 200 feet across the valley (Maps: California 1985). The extent and thickness of the Modesto Formation can be seen in Butte County on all four cross-sections of the Sacramento Valley. The Modesto Formation overlies the Riverbank Formation or Laguna Formation in the southern portion of Butte County and overlies the Riverbank Formation or Tuscan Formation in the northern portion of the county.

Overlying the alluvial fans of the Riverbank and Modesto formations are the fine silts and clays of the Holocene basin deposits. Basin deposits are the result of sediment-laden floodwater that rose above the natural levees of streams and rivers and spread out across vast low-lying areas. Basin deposits in Butte County are seen primarily in the western and southern portions of the county, forming the highly productive agricultural soils characteristic of these areas. Discontinuous basin deposits are also scattered throughout the northern portion of the Sacramento Valley Region in areas corresponding to the topographic depression of the Modesto Formation (Maps: California 1985).

Thickness of the basin deposits varies generally from less than 10 feet along the margins of the exposure to more than 100 feet in the center of the valley. Basin deposits provide limited quantities of groundwater to shallow wells due to the fine-grained nature of the sediments. The location and thickness of basin deposits in Butte

County can be seen on the geologic map as well as on the four cross-sections. Alluvium overlies the basin deposits along presently active stream and river channels.

Holocene alluvium is the youngest of the geologic units present within the Sacramento Valley Region. Alluvium consists of unweathered gravel, sand, and silt that has been transported and deposited by streams and rivers, forming natural levees along the Sacramento and Feather rivers (Maps: California 1985). Also included in the geologic description of alluvium are mine tailings. Mine tailings were deposited as a result of mining operations in the Sierra Nevada. The most obvious occurrence of mine tailings is the sliver in the alluvium northwest of Oroville shown on the geologic map on Plate 2, Appendix A. Mine tailings can also be seen on Cross-section C-C' (Plate 4, Appendix A) between Highway 99 and Highway 70.

Alluvial deposits primarily overlie the Modesto Formation and basin deposits except where the alluvium is comprised of mine tailings. In this case, it is difficult to generalize a stratigraphic relationship between units. Due to its limited extent and thickness, alluvium is not considered a significant water-bearing unit. The position and thickness of alluvium can be seen on all four cross-sections of the Sacramento Valley.

Deformational structures within the Sacramento Valley Region of Butte County include several faults and folds. Offset on the Chico Monocline fault resulted in a monoclinal flexure, the Chico Monocline, that forms the eastern boundary of the region north of Durham. The Chico Monocline is a northwest-trending southwest-facing flexure that roughly follows the northeastern boundary of the Sacramento Valley Region extending from Chico to Red Bluff. North of Chico, the Chico Monocline deforms the Tuscan Formation and has a dip of up to 25 degrees where it becomes the eastward aquifer boundary (CDWR 1978). South of Chico, beds have a gentler slope of approximately 2 to 5 degrees, and evidence of the monocline disappears north of Oroville.

North of the Sutter Buttes, a minor splay fault associated with the Willows fault system is present at depth and displaces only Jurassic to Cretaceous sediments (see Plate 2, Appendix A). In the western portion of Butte County, the Glenn Syncline has produced some minor downward flexure of the deeper sedimentary units, as seen in Cross-section C-C' (Plate 4, Appendix A).

Fresh Groundwater-Bearing Units

On a regional scale, the base of post-Eocene continental deposits is commonly considered the approximate base of fresh groundwater in the Sacramento Valley (Page 1974). Locally, the base of fresh groundwater fluctuates depending on local changes in the subsurface geology and geologic formational structure.

The approximate base of fresh groundwater is shown on the geologic cross-sections on Plates 4 and 5, Appendix A. The base of fresh groundwater was determined through examination of electric resistivity logs, which were derived from criteria established by C.F. Berkstresser, Jr., in *Base of Fresh Ground Water, Approximately 3,000 Micromos, in the Sacramento Valley and Sacramento-San Joaquin Delta, California*. This 1973 report determined that the base of fresh groundwater is water with a specific conductance of less than 3,000 micromhos per centimeter; water with a specific conductance that exceeds 3,000 micromhos per centimeter is considered to be saline.

In the Sacramento Valley Region of Butte County, fresh groundwater-bearing units include the Tuscan, Laguna, Riverbank, and Modesto formations. Groundwater in these formations exists largely within the primary porosity associated with the spaces between the individual sand and gravel deposits and within the secondary porosity associated with fractures and jointing of the more competent volcanic rocks.

A detailed discussion of the major groundwater-bearing formations within the Butte County portion of the Sacramento Valley is presented below. Geologic surface exposures of the water-bearing formations described below are shown on the geologic plan-view map on Plate 2, Appendix A, and on the subsurface maps on Plates 4 and 5, Appendix A.

Tuscan Formation

Age and Composition. The Pliocene Tuscan Formation is composed of a series of volcanic mudflows, tuff breccia, tuffaceous sandstone, and volcanic ash layers. The formation is described as four separate but lithologically similar units, Units A through D, which in some areas are separated by layers of thin tuff or ash units (Maps: California 1985). Stratigraphic position and general lithologic character distinguish each unit. Unit A consists of the oldest deposits of the Tuscan Formation. Units B and C overlie Unit A in most locations in Butte County. Unit D is the youngest unit and is exposed only in localized areas northeast of Red Bluff. Groundwater in the Sacramento Valley portion of Butte County is contained primarily within the two lower units of the Tuscan Formation, Units A and B.

Unit A is the oldest water-bearing unit of the Tuscan Formation. This unit is distinguished from the other units by the presence of metamorphic clasts within the interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone. Unit A contains the Nomlaki Tuff, a dacitic pumice tuff, at its base or within the basal portion of the unit. The presence of the Nomlaki Tuff within the basal sections of the Tuscan, Tehama, and Laguna formations indicates simultaneous deposition of these units. Exposures of Unit A are shown on the geologic map of Butte County and in all four cross-sections of the Sacramento Valley.

Unit B is composed of a fairly equal distribution of lahars, tuffaceous sandstone, and conglomerate. These evenly layered, moderately thin beds form the characteristic look of the Tuscan Formation seen in the foothills of Butte County. Extending westward into the subsurface, the sediments of Unit B form a very productive water-bearing system. In most locations, Unit C overlies Unit B. Unit B can be seen on the geologic map of Butte County and in all four cross-sections of the Sacramento Valley.

Unit C consists of massive mudflow, or lahar, deposits with some interbedded volcanic conglomerate sandstone. In the foothills, these lahars are well cemented and form the cap rock for the ridges in Butte County. Evidence of wood fragments found in Unit C suggests fast-moving, massive mudflows at the time of deposition. In the subsurface, these low-permeability lahars form thick, confining layers for groundwater contained in the more permeable sediments of Unit B. Unit C is the youngest unit of the Tuscan Formation in Butte County and can be seen on the geologic map and in all four cross-sections of the Sacramento Valley. Unit C is overlain in some locations by Unit D.

Unit D is the youngest depositional unit and is characterized by large masses of grey hornblende andesite. Exposures of Unit D are found in limited extent northeast of Red Bluff. No exposures of Unit D are mapped at the surface or in the subsurface within Butte County.

The Tuscan Formation is overlain by Holocene and Pleistocene alluvial sediments, which include the Modesto and Riverbank formations and younger stream channel and basin deposits. In most places, the Tuscan Formation unconformably overlies either Upper Cretaceous marine sedimentary rocks or the basement complex with angular unconformity (Olmsted and Davis 1961). In other areas, the Tuscan Formation rests unconformably on the Neroly Formation, the Ione Formation, and/or the Lovejoy Basalt.

The volcanic sediments of the Tuscan Formation interfinger with the nonmarine and nonvolcanic sediments of the Tehama Formation in the subsurface (Lydon 1969). This contact is considered to occur at depth in the vicinity west of the Sacramento River. As mentioned previously, the presence of the Nomlaki Tuff at the base of the Tuscan, Tehama, and Laguna formations suggests simultaneous deposition and an age correlation of these units.

Depositional Environment and Source Area. The Tuscan was deposited as a series of volcanic lahars over a period of about one million years (Lydon 1969). The source areas of the lahars were eroded volcanoes historically located northwest and south of Lassen Peak. Mudflows most likely followed ancient stream channels and valleys while travelling in a southwestward direction. The flows then fanned out upon reaching the valley floor, causing deposition to vary in thickness and in topographic elevation. As areas of the well-cemented volcanic lahars were eroded and redeposited, aquifer material on the valley floor resulted in a heterogeneous and, in some areas, unconsolidated mass of sediments.

Extent and Thickness. The Tuscan Formation extends from east of Redding to west of Oroville and from the base of the Cascade Range and Sierra Nevada into the subsurface about 5 miles west of the Sacramento River (Page 1986). The maximum thickness of the formation ranges from about 1,700 feet in the east, thinning to approximately 300 feet at the westward extent (Lydon 1969). Unit A has an average mapped thickness of 250 feet, and Units B and C each have a mapped thickness of about 600 feet, for a total approximate thickness of about 1,450 feet.

Water-bearing Properties. Groundwater in the Sacramento Valley Region is contained primarily within the pore spaces of the reworked sand and gravel layers. Much of the groundwater in the Tuscan Formation is confined under pressure by layers of impermeable clays, lahars, or tuff breccia.

Groundwater encountered within Unit A is associated with primary porosity of the conglomerate and sandstone layers and with secondary porosity associated with the fractured tuff breccia. Within Unit B, the interbedded, permeable layers of reworked sand and gravel become a conduit for groundwater movement, transmitting water into the aquifer from recharge areas in the Cascade foothills. The permeable layers of the Unit B sediments comprise the main aquifer material for groundwater storage in the valley. The fine-grained, consolidated lahars of Unit C form thick, low-permeability, confining layers for groundwater contained in the more permeable sediments of Unit B.

Volcanic sands of the Tuscan Formation yield high amounts of water to wells in many areas of the eastern Sacramento Valley. California Water Service Company (CWSC) wells in the Chico area have well yields that range between 900 and 3,000 gallons per minute (gpm) (CDWR 1978). Three wells at the Chico Airport produce between 900 and 950 gpm with specific capacities between 26 and 45 gpm per foot (gpm/ft) of drawdown (Olmsted and Davis 1961).

Well yields and specific capacities for the Sacramento Valley Region were also calculated with data obtained from utility pump tests. Results from 2,662 pump tests on 944 wells showed that average well yields range from a low of 976 gpm in the North Yuba Inventory Unit, to a high of 1,395 gpm in the Vina Inventory Unit. The average specific capacity calculated from 974 pump tests on 433 wells was 78 gpm/ft for the entire Sacramento Valley Region. Specific capacities for the valley inventory units ranged from a low of 48 gpm/ft in the North Yuba Inventory Unit to a high of 87 gpm/ft in the Vina Inventory Unit.

Aquifer performance tests have been conducted in several areas of Butte County. These tests were used to evaluate the water-bearing characteristics of the Tuscan Formation. Transmissivity values within the Butte Basin portion of the East and West Butte inventory units ranged from 97,000 to 182,000 gallons per day per foot (gpd/ft). Storativity values ranged from 0.0003 to 0.0015. Specific capacity measurements made for wells in this study provided a range of 45.7 to 104.7 gpm/ft of drawdown (CDWR 1991).

A similar test was performed on a well located in the West Butte Inventory Unit. The extraction well utilized for this test was designed and constructed to draw water only from the lower confined portion of the Tuscan Formation. Aquifer transmissivity was calculated to be approximately 75,000 gpd/ft. Storativity was estimated between 0.0001 and 0.00001. The specific capacity of the extraction well was measured at 23 gpm/ft of drawdown (CDWR 1995).

Laguna Formation

Age and Composition. The Pliocene Laguna Formation is composed of continental deposits containing predominantly fine-grained, poorly bedded, and compacted sediments. These deposits are composed of a heterogeneous mixture of interbedded alluvial fine sand, silt, and clay of granitic and metamorphic origin with minor conglomerate lenses (Olmsted and Davis 1961). Clay is more predominate in the fine-grain sediments south of Oroville. The sand is arkosic and contains abundant weathered feldspar, biotite, and angular quartz clasts. The Arroyo Seco gravels are considered to be part of the Laguna Formation by some sources. Near Oroville, the gravel deposits are of granitic or metamorphic composition and are contained within a silty-to-sandy matrix.

Depositional Environment and Source Area. West-flowing rivers and streams draining the Sierra Nevada deposited the Laguna Formation. Uplift of the Sierra Nevada during their formation increased erosion of the metamorphic and plutonic rocks. Rivers and streams carried these eroded materials to the valley floor, where they overtopped their banks and spread out across the broad floodplains of the valley, depositing eroded materials into broad alluvial fans.

Extent and Thickness. Exposure of the Laguna Formation is discontinuous and extends southward from Oroville to Lodi. The only exposures within Butte County occur southwest of Oroville. The thickness of the Laguna Formation is difficult to determine because the base of the unit is rarely exposed. Estimates of the maximum thickness range from 180 feet (Maps: California 1985) to 1,000 feet (Olmsted and Davis 1961).

Water-bearing Properties. Quantitative water-bearing data for the Laguna Formation is limited, especially in the Butte County area. Wells completed in the finer-grained sediments of the Laguna Formation yield only moderate quantities of

water. Well yield data from the Sacramento-American rivers area indicate yields as high as 1,000 gpm, with specific capacity values ranging between 24 and 42 gpm/ft of drawdown (Olmsted and Davis 1961). In areas where soft, well-sorted granitic sand dominates, well yields are much higher. Some of the sand aquifers are highly permeable, but the average permeability is low to moderate. In the Gridley area, a sand unit that is stratigraphically equivalent to the Laguna Formation was reported to have a specific capacity of 60 gpm/ft of drawdown (Olmsted and Davis 1961).

Riverbank Formation

Age and Composition. The Riverbank Formation was deposited between 450,000 and 130,000 years ago, forming wide alluvial fans and terrace deposits. Stream terrace deposits of the formation appear topographically above the younger Modesto Formation terrace deposits. Due to post-depositional weathering of the Riverbank Formation, deposits exhibit a reddish color. The topographic location and weathered red color distinguish the Riverbank from more recent alluvial fan and terrace deposits (Maps: California 1985).

Depositional Environment and Source Area. The Riverbank Formation consists of gravel, sand, and silt eroded from the surrounding Coast, Klamath, and Cascade ranges and the Sierra Nevada and deposited in the Sacramento Valley. The source area determines the mineral constituents of the deposits. Near Sacramento, the deposits are primarily arkosic; however, mafic content of igneous rock fragments increases northward.

Extent and Thickness. Exposures of the Riverbank Formation within Butte County are observed primarily west of Oroville and southward. The thickness of the formation ranges from less than 1 foot to over 200 feet, depending on location. More recent depositions of the Modesto Formation and basin deposits have produced the limited surface exposure of this formation.

Water-bearing Properties. The thickness of the Riverbank Formation can be a limiting factor to the water-bearing capabilities of the formation. The Riverbank Formation is moderately to highly permeable and yields moderate quantities of water to domestic and shallow irrigation wells. It also provides water to deeper irrigation wells that have multiple zones of perforation. Well yields are higher in areas where concentrations of gravel and sand are present. Groundwater occurs generally under unconfined conditions.

Modesto Formation

Age and Composition. Radiocarbon dating indicates that the Modesto Formation is Pleistocene in age with the upper and lower members dated at 14,000 and 42,000 years old, respectively (Marchandt and Allwardt 1981). The formation consists of tan and light grey, gravelly sand, silt, and clay. Where it overlies the Tuscan Formation, the clasts within the Modesto are distinctly red, brown or black. The upper member shows no indication of weathering, while the lower member shows slight weathering (Maps: California 1985).

Depositional Environment and Source Area. The Modesto Formation consists of gravel, sand, and silt eroded from the surrounding Coast, Klamath, and Cascade ranges and the Sierra Nevada and deposited in the Sacramento Valley. The Modesto forms coalescing alluvial fans and streambank terraces. Exposures of the Modesto Formation are present along most of the major streams and rivers within Butte County.

Extent and Thickness. The Modesto Formation is widespread throughout the Sacramento Valley, occurring from Redding southward into the San Joaquin Valley. The most notable occurrences are found along the Sacramento and Feather rivers. Similar to the Riverbank, the Modesto Formation ranges in thickness from less than 10 feet in many of the terraces and along the margins of the valley to nearly 200 feet across the valley floor (Maps: California 1985).

Water-bearing Properties. Like the Riverbank Formation, the thickness of the Modesto Formation limits the water-bearing capabilities of the formation. These deposits provide water to domestic and shallow irrigation wells, as well as to deeper wells with multiple zones of perforations. In locations where gravel and sand predominate, groundwater yields are moderate. Lesser yields are found in areas with high silt and clay content. Groundwater occurs generally under unconfined conditions.

Movement of Groundwater

Groundwater movement in the Sacramento Valley Region was evaluated utilizing groundwater elevation contours developed for Butte County. The contours shown on Plates 7 and 8, Appendix A, were developed using March 1997 groundwater level data collected by DWR and local cooperators. The flow arrows on Plate 7, Appendix A, indicate the general direction of groundwater movement.

The directional flow arrows illustrate that regional groundwater movement in Butte County is southwestward from the foothills toward the Sacramento River. This indicates that groundwater from the northern and central portions of the county drain to the river. Some localized contour anomalies along the boundary between the West and East Butte inventory units can be attributed to the draining of groundwater toward Butte Creek. The general southwestward flow pattern within Butte County is disrupted in the Chico Urban Area by municipal groundwater extraction. This disruption is indicated on Plate 7, Appendix A, by small-scale, localized groundwater depressions and mounds. A larger-scale groundwater depression is depicted in the southwest portion of the North Yuba inventory unit.

The final notable anomaly is located in the southwest portion of Butte County. In this area, groundwater converges under the Butte Sink and Biggs-West Gridley inventory units. Groundwater from the East Butte Inventory Unit flows southwestward, while groundwater from the Sacramento River flows southeastward and eastward. The Sutter Buttes and the buried Colusa Dome located west of the Sutter Buttes deform the valley sediments, causing this anomalous flow pattern.

Outside of Butte County, a change occurs in the groundwater flow along the Sacramento River near Princeton. North of this location, the groundwater flows toward the Sacramento River, where it drains groundwater from the northern Sacramento Valley. South of Princeton, groundwater flows away from the river, thereby recharging the groundwater system.

Foothill Region

The Foothill Region of Butte County lies between the Sacramento Valley and Mountain regions. The Foothill Region ranges in elevation from about 100 feet msl at the southwestern margin of the Sacramento Valley, to about 3,500 feet msl north of Sterling City, where it merges into the Mountain Region. Groundwater occurs primarily within the reworked gravels and sands deposited between successive lahar

and mudflows of the Tuscan Formation (Slade 2000). Limited amounts of groundwater are also available through secondary porosity associated with fracturing of the geologic formations in the region.

The Foothill Region is a recharge area for the Butte County portion of the Sacramento Valley groundwater basin aquifer. Groundwater recharge occurs in the form of precipitation and deep percolation of runoff from nearby creeks, streams, and reservoirs.

Following is a summary of the surface and subsurface geology in the Foothill Region of Butte County that focuses on the fresh groundwater-bearing units of the region. The description of the surface geology is based on the geologic map of Butte County developed by DWR that is shown on Plate 2, Appendix A. The description of the subsurface geology is based on geologic cross-sections also developed by DWR, which are shown on Plates 4 and 5, Appendix A. Geologic map symbols for Plates 2 through 5, Appendix A, are referenced in parenthesis in Section 3.

Surface and Subsurface Geology

The Foothill Region occupies the transitional geologic zone between Tertiary sediments in the western part of Butte County and Mesozoic-Paleozoic rocks in the eastern part of the county (see Plates 1 and 2, Appendix A). Mesozoic rocks encompass the Jurassic and Cretaceous rocks ranging in age from 245 to 65 mybp. Older Paleozoic rocks range in age from 544 to 245 mybp.

The eastern Mesozoic-Paleozoic deposits exhibit very little, if any, primary porosity. However, due to secondary porosity, small amounts of water can be found within the fractures and joints of these dense, hard rocks. Jurassic and Cretaceous sedimentary rocks seen in outcrops in the northern Foothill Region tend to contain brackish water and do not contribute to the region's fresh groundwater system. Tertiary sediments (65 to 1.8 mybp) exposed in the northern and western zones of the region tend to contain fresh groundwater mainly through primary porosity. Surficial Quaternary sediments found along a few of the drainages in the Foothill Region supply modest amounts of groundwater to shallow domestic wells.

Paleozoic rocks consist of metavolcanic and metasedimentary geologic units. These units, exposed mainly in the eastern and southern margins of the Foothill Region, were deposited during periods of volcanic activity and subsequently metamorphosed due to tectonic compression and contact metamorphism. Metavolcanic rocks consist primarily of breccia and tuff with lesser amounts of greenstone, diabase, and pillow lavas. Metasedimentary rocks are composed of slate, shale, sandstone, chert, conglomerate, limestone, dolomite, marble, phyllite, schist, hornfels, and quartzite. Groundwater found in these areas is associated mainly with secondary porosity.

Resting unconformably on top of the Paleozoic deposits are rocks of the Late Mesozoic Era. Late Mesozoic rocks were deposited in a marine forearc-basin setting. After deposition, tectonic stress caused the eastern limb of the Sacramento Valley trough to be uplifted, raising Great Valley sediments to their present elevation above the valley floor. These older sediments are seen in outcrops in Little Chico, Big Chico, and Butte Creek drainages shown on Plate 2, Appendix A. Groundwater in these sediments is usually brackish and does not contribute to the region's fresh groundwater supply.

A series of Tertiary continental deposits unconformably overlie Late Mesozoic marine deposits. The Tuscan Formation, composed of Units A, B, and C, is the major

geologic formation exposed in the northern and western parts of the Foothill Region. The formation was deposited as a series of mudflows originating from ancient, eroded volcanoes of the Cascade Range. Other Tertiary units in the Foothill Region consist of older, undifferentiated andesites and basalts of the Tertiary Volcanics, basalt deposits of the Lovejoy Formation, and marine to nonmarine sandstone and siltstone deposits of the Ione Formation. Although the continentally derived Laguna Formation is marginally exposed in the southern portion of the Foothill Region, the majority of this unit falls within the Sacramento Valley portion of Butte County, as seen on Plate 2, Appendix A. The Tuscan Formation is the primary source of fresh groundwater to wells in the northern and western areas of the Foothill Region.

Quaternary deposits situated on the western margin of the Foothill Region consist of the Modesto Formation and alluvium (see Plate 2, Appendix A). These sediments were deposited along the streams and creeks draining from the Foothill Region, creating stream terraces and alluvial fans. The Modesto Formation consists of unconsolidated, unweathered to slightly weathered gravel, sand, silt, and clay with thicknesses ranging from 1 to 200 feet. Shallow domestic wells can draw moderate amounts of groundwater from these terrace deposits. Alluvial deposits range in size from boulders to sand and silt and have high infiltration rates (CDWR 1978). These deposits are thin at higher elevations, thickening downstream to a maximum thickness of 80 feet, and provide low to moderate amounts of groundwater.

The major geologic structure in the Foothill Region is the Foothill fault system. This fault system includes the Cohasset Ridge fault, the Magalia fault, and a mapped, but as yet unnamed fault located south of the Magalia, which is shown on Plate 2, Appendix A. These faults are included in a system of northwest-trending, steeply east-dipping to vertical faults that have experienced up to 100 feet of movement in the past 2.4 million years (Maps: California 1985). The Magalia fault may be a barrier to groundwater movement (Slade, Oct., 2000).

Another major structural feature in the Foothill Region is the Chico Monocline. The Chico Monocline is a northwest-trending, southwest-facing flexure that roughly follows the northwestern boundary of the Foothill Region, extending from Chico to Red Bluff. North of Chico, the Chico Monocline deforms the Tuscan Formation and has a dip of up to 25 degrees where it becomes an eastward aquifer boundary (CDWR 1978). South of Chico, beds have a gentler slope of approximately 2 to 5 degrees, and evidence of the monocline disappears.

Fresh Groundwater-Bearing Units

The Tuscan Formation is the major source of groundwater in the Foothill Region. Groundwater occurs in the fractures and joints of the volcanic mudflows, as well as in the weathered horizons between buried mudflows (Slade 2000 – 3 reports). Lesser amounts of groundwater are found in the Modesto Formation, which is a localized source of groundwater and supplies moderate amounts of water to shallow wells.

Following is a detailed description of the two major groundwater-bearing units found in the Foothill Region.

Tuscan Formation

Age and Composition. The Pliocene Tuscan Formation is composed of tuff breccia, lapilli, tuff, and volcanic conglomerate, sand, and silt (Lydon 1969). The formation is described as four separate, but lithologically similar units, Units A through D, which

are separated in some areas by layers of thin tuff or ash units (Maps: California 1985). In the Foothill Region, only Units A through C are exposed at the surface, and Unit D is not present.

Unit A is the oldest water-bearing unit of the Tuscan Formation and consists of fragmented metamorphic rocks found within the interbedded lahars, volcanic conglomerate, sandstone, and siltstone.

Unit B is differentiated from Unit A by its lack of metamorphic content. Unit B is defined along the Chico Monocline by a series of interbedded lahars, volcanic conglomerate, sandstone, and siltstone. It is characterized on resistivity curves by its distinctive and consistently high deflections, as shown in the cross-section maps on Plates 4 and 5, Appendix A. It is differentiated from Unit C by its coarser-grained sediments, thereby providing it with a higher groundwater storage capacity.

Unit C is characterized by its fine-grained, more consolidated nature. Unit C consists of lahars with some interbedded volcanic conglomerate and sandstone. Evidence of wood fragments found in Unit C suggests fast-moving, massive mudflows at the time of deposition. Unit C is the exposed cap rocks on the hills east of Chico and becomes a confining layer to Unit B in the subsurface.

Depositional Environment and Source Area. The Tuscan was deposited as a series of mudflows, or lahars, over a period of about one million years (Lydon 1969). Eroded volcanoes historically located northwest and south of Lassen Peak were the source areas for the lahars. Mudflows most likely followed ancient stream channels and valleys while travelling in a southwestward direction. The flows then fanned out on reaching the valley floor, causing deposition to vary in thickness and in topographic elevation. As areas of the well-cemented volcanic lahars were eroded and redeposited, aquifer materials deposited on the valley floor resulted in a heterogeneous and, in some areas, an unconsolidated mass of sediments.

Extent and Thickness. The Tuscan Formation extends from east of Redding to west of Oroville and from the Cascade Range and Sierra Nevada into the subsurface about 5 miles west of the Sacramento River (Page 1986). Maximum thickness of the formation ranges from about 1,700 feet in the east to approximately 300 feet at the westward extent (Lydon 1969). Unit A has an average mapped thickness of around 250 feet, and Units B and C each have a mapped thickness of about 600 feet, for a total approximate thickness of about 1,450 feet.

Water-bearing Properties. The Tuscan Formation exposed in the Foothill Region is a recharge area for the aquifer system in the Sacramento Valley. Groundwater intercepted in wells in this region is generally of an unconfined nature, with groundwater levels reflecting rainfall patterns. Most groundwater in the formation is confined under pressure by layers of impermeable clays and tuff breccia (CDWR 1978). On average, specific yields for the Tuscan Formation range from 900 to 3,000 gpm (CDWR 1978). However, specific yields are much lower in the Foothill Region.

Based on work done by Slade and Associates, LLC (Slade, June, 2000), transmissivity values in the Tuscan Formation are approximately 10,000 gpd/ft in areas adjacent to Clark Road in Paradise. However, in the Lime Saddle area, Slade determined (Slade, July, 2000) that transmissivity values in the confined portion of the Tuscan Formation are an extremely low 1,100 gpd/ft. Another study, also

conducted by Slade and Associates, LLC (Slade, Oct., 2000), estimated transmissivity based on PG&E pump test data for the Magalia area. Estimates from the PG&E pump test data indicate a transmissivity range of 10,000 to 20,000 gpd/ft for the Tuscan Formation.

Modesto Formation

Age and Composition. Radiocarbon dating indicates that the Modesto Formation is Pleistocene in age with the upper and lower members dated at 14,000 and 42,000 years old, respectively (Marchandt and Allwardt 1981). It consists of tan and light grey, gravelly sand, silt, and clay. Where it overlies the Tuscan Formation, clasts are distinctly red, brown, or black (Maps: California 1985). Both members contain unconsolidated sediments, however the upper member is unweathered, whereas the lower member is slightly weathered.

Depositional Environment and Source Area. The Modesto Formation was deposited under fluvial conditions as a series of coalescing alluvial fans by streams that still exist today (Maps: California 1985). The lower member forms terraces that are topographically higher than the upper member. The Cascade Range and Sierra Nevada are the source areas for the Modesto Formation in Butte County.

Extent and Thickness. The Modesto Formation is widespread throughout the Sacramento Valley, occurring from Redding south into the San Joaquin Valley. The most notable occurrences are found along the Sacramento and Feather rivers. The formation is exposed along the upper reaches of Butte Creek in the northern part of the Foothill Region. Thickness of the unit ranges up to 200 feet in the basin and thins toward the foothills (Marchandt and Allwardt 1981, CDWR 1999).

Water-bearing Properties. In areas where silt and clay predominate, permeability of the Modesto Formation is variable, and well yields are limited. In locations where gravel and sand predominate, groundwater yields to domestic wells are higher. In the Foothill Region, the formation is thin to moderate in thickness and yields only moderate amounts of water to wells. Groundwater in the Modesto Formation occurs under unconfined conditions.

Movement of Groundwater

There are limited data to accurately determine the direction and rate of groundwater movement in the Foothill Region. In general, groundwater generally moves down-gradient, following the contour of the topographic surface. In the Foothill Region, this can be interpreted as groundwater flowing from high to low elevations, following drainages toward the center of the valley, where it tends to track the course and direction of the Sacramento River.

Mountain Region

The Mountain Region is the easternmost region in Butte County. There are no appreciable geologic units supplying groundwater to the mountain area. Where groundwater is encountered, it is mainly derived from secondary porosity associated with fracturing and jointing of pre-Tertiary and Tertiary rock. Elevations range from around 230 feet at the southernmost boundary of Butte County near the confluence of Honcut and Wilson Creeks to 2,180 feet at Humboldt Peak in the northeastern part of the county.

Following are an overview of the surface and subsurface geology and a discussion of the groundwater-bearing units of the Mountain Region. The surface geology is based on a compilation of geologic maps developed by DWR, which are shown on Plate 2, Appendix A.

Surface and Subsurface Geology

Mesozoic and Paleozoic plutonic, volcanic, and metamorphic rocks make up the majority of the surface and subsurface geology of the Mountain Region. Mesozoic rocks encompass Jurassic and Cretaceous rocks ranging in age from 245 to 65 mybp. Older Paleozoic rocks range in age from 544 to 245 mybp.

Primary porosity is virtually nonexistent in these rocks due to the amount of cementation, consolidation, crystallization, or metamorphism that has occurred (Slade 2000 – 3 reports). Other geologic formations consist of Tertiary volcanic sediments exposed in the northern part of the Mountain Region. Of these units, only the Tuscan Formation, located in a small northwestern segment of the Mountain Region, is considered to be a groundwater-bearing unit. There are no significant surficial alluvial deposits in this region.

Plutonic, volcanic, and metamorphic rocks of the Mesozoic and Paleozoic eras are found throughout the region. Paleozoic rocks consisting of metasedimentary and metavolcanic rocks were deposited during periods of volcanic activity and then metamorphosed due to tectonic compression and contact metamorphism. Metasedimentary rocks consist of slate, shale, sandstone, chert, conglomerate, limestone, dolomite, marble, phyllite, schist, hornfels, and quartzite. Metavolcanic sediments are composed primarily of breccia and tuff but also include greenstone, diabase, and pillow lava. Groundwater found in these areas is very limited and associated mainly with secondary porosity.

Granitic plutonic rocks were emplaced during the Mesozoic Era, as were gabbro and dioritic rocks. Ultramafic rocks, composed of serpentine, peridotite, gabbro, and diabase, are exposed primarily in the central and southern portions of the Mountain Region. Mixed rocks are composed of undifferentiated metasedimentary and metavolcanic rocks. The plutonic rock demarcates the boundary between the Sierra Nevada and the Cascade Range to the north and generally coincides with the dividing of Feather River drainage. The limited amount of groundwater encountered in this type of geologic environment is derived mainly through secondary porosity associated with fractured and jointed rock.

Tertiary sediments (65 to 1.8 mybp) are exposed in the northern, southeastern, and southwestern portions of the Mountain Region. The major geologic unit of any importance for the occurrence of groundwater is the Unit B Tuscan Formation. This unit was deposited as a series of mudflows originating from ancient, eroded volcanoes of the Cascade Range. It is exposed only in the northwestern portion of the region. Additional Tertiary units include the Tertiary volcanics and the Ione Formation. The Tertiary volcanics are exposed in the north and southeastern areas and are composed of older, undifferentiated andesites and basalts. The Ione Formation is composed of sandstone and siltstone and was deposited in a marine to nonmarine environment. A small exposure of the Ione Formation is located in the southwestern portion of the Mountain Region. Although groundwater is encountered in the Ione Formation, the quality is poor due to its brackish nature. In general, the limited amount of fresh groundwater encountered in the Tertiary sediments is associated with secondary porosity.

Fresh Groundwater-Bearing Units

Although the Tuscan Formation is the main groundwater-bearing unit for the Foothill and Sacramento Valley regions, it is tightly cemented and consolidated in the Mountain Region and supplies only limited amounts of water. Where groundwater does occur, it is limited to the fractures and joints within the volcanic mudflows and breccias.

Following is a general description of the groundwater-bearing unit found in the Mountain Region.

Tuscan Formation

Age and Composition. The Pliocene Tuscan Formation is composed of tuff breccia, lapilli, tuff, and volcanic conglomerate, sand, and silt (Lydon 1969). The formation is described as four separate, but lithologically similar units. Units A through D are separated in some areas by layers of thin tuff or ash units (Maps: California 1985). Unit B is the only unit exposed in the Mountain Region and is described as a series of interbedded lahars, volcanic conglomerate, sandstone, and siltstone. It is characterized on resistivity curves by its distinctive and consistently high deflections seen in the cross-sections on Plates 4 and 5, Appendix A.

Depositional Environment and Source Area. The Tuscan was deposited as a series of mudflows, or lahars, over a period of about one million years (Lydon 1969). Eroded volcanoes historically located northwest and south of Lassen Peak are the source areas of the lahars. Mudflows most likely followed ancient stream channels and valleys while travelling in a southwestward direction.

Extent and Thickness. The Tuscan Formation extends from east of Redding to west of Oroville and from the Cascade Range and Sierra Nevada into the subsurface about 5 miles west of the Sacramento River (Page 1986). Maximum thickness of the formation ranges generally from about 1,700 feet in the east to approximately 300 feet at the westward extent (Lydon 1969). Unit B has a maximum thickness of about 600 feet.

Water-bearing Properties. In the Mountain Region, groundwater is related largely to secondary porosity and does not supply appreciable amounts of groundwater. Where groundwater does occur, it is found in the fractures and joints of the volcanic mudflows and breccias.

Movement of Groundwater

There are limited data to accurately determine the direction and rate of groundwater movement in the Mountain Region. Groundwater generally moves down gradient following the contour of the topographic surface. In the Mountain Region, this can be interpreted as groundwater flowing from high to low elevations following drainages toward the center of the valley, where it tends to track the course and direction of the Sacramento River.

SECTION 3.
Local Groundwater Geology

The Local Groundwater Geology section is an overview of the infrastructure and groundwater resources of the three main inventory unit regions: the Sacramento Valley Region, the Foothill Region and the Mountain Region. This will be followed by a more detailed analysis at the inventory and sub-inventory unit levels. The inventory units serve to group regional areas of similar hydrology and hydrogeology and help define the natural boundaries of the Butte County portion of the Sacramento Valley groundwater basin. The inventory units were also selected to coincide with the Butte County portion of the Vina, West Butte, East Butte, and North Yuba groundwater subbasins, as defined by the California Department of Water Resources, Northern District (DWR). The sub-inventory units serve to group areas of similar land use, water use and local public and private water purveyors. The location of the inventory and sub-inventory units are illustrated on Plate 1, Appendix A, and listed in Table 2.

Table 2.
Inventory and Sub-inventory Units for the Butte County

Regions	Inventory Units	Sub-Inventory Units
Sacramento Valley	Vina	California Water Service Area (partial)
	West Butte	California Water Service Area (partial)
		Durham-Dayton
		M&T
		Angel Slough
		Llano Seco
		Western Canal (partial)
	East Butte	Pentz
		Esquon
		Cherokee
		Western Canal (partial)
		Richvale
		Thermalito
		Biggs-West Gridley
		Butte
		Butte Sink
	North Yuba	
Foothill	Foothill	Cohasset
		Ridge
		Wyandotte
Mountain	Mountain	

Sacramento Valley Region

The majority of Butte County's groundwater resources lie beneath the Sacramento Valley Region, which is part of the larger Sacramento Valley groundwater basin. The Butte County portion of the groundwater basin covers an area of about 400,000 acres, equal to 625 square miles (mi^2), and is bordered by the Butte County line to the north and south, the Sacramento River and Butte Creek to the west, and by the foothills to the east. About 106,000 acres (165 mi^2) of the valley portion of Butte County is in summer agricultural production supported by groundwater.

Principal hydrogeologic units in the Sacramento Valley Region of the county consist of Pliocene sedimentary deposits such as the Tuscan, Laguna, and Tehama formations and Quaternary terrace deposits, such as the Riverbank and Modesto formations. The Tuscan, Laguna, and Tehama formations are the sources of water for deep irrigation and municipal wells, while the Riverbank and Modesto formations yield water to the shallower domestic wells.

The Sacramento Valley Region is comprised of four inventory units: the Vina Inventory Unit, the West Butte Inventory Unit, the East Butte Inventory Unit, and the North Yuba Inventory Unit. The inventory units are further subdivided into 14 sub-inventory units. Two sub-inventory units, the California Water Service Sub-inventory Unit and the Western Canal Sub-inventory Unit, cross inventory unit boundaries. The California Water Service Sub-inventory Unit is located in both the Vina and West Butte inventory units. The Western Canal Sub-inventory Unit is located in both the West Butte and East Butte inventory units.

Portion of the Sacramento Valley Groundwater Basin

The West Butte Inventory Unit encompasses four sub-inventory units that lie fully within its boundaries: the Durham-Dayton, M&T, Angel Slough and Llano Seco sub-inventory units. The East Butte Inventory Unit is composed of eight sub-inventory units located fully within its borders: the Pentz, Esquon, Cherokee, Thermalito Richvale, Biggs-West Gridley, Butte Sink, and Butte sub-inventory units. The North Yuba Inventory Unit does not contain any sub-inventory units.

At the regional and inventory unit level, the groundwater inventory will include discussions of well distribution, groundwater level, groundwater extraction, well depth, well yield, specific capacity, groundwater storage capacity, groundwater in storage, and changes in groundwater in storage. At the sub-inventory unit level, the groundwater inventory will include discussions of well distribution, groundwater level, groundwater extraction, well depth, well yield, and specific capacity.

Well Distribution

A thorough understanding of the infrastructure that extracts groundwater from the aquifer system, or systems, is an important first step to proper groundwater basin management. As part of this investigation, the well completion report database files at DWR were analyzed to determine the number, types, dates of installation and distribution of wells in Butte County. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data by area and by installation date is provided in Tables 1 and 2, Appendix B.

There are over 14,000 wells located in Butte County. The general distribution of these wells is shown in Figure 4. In the Sacramento Valley Region alone, there are about

9,400 wells. Table 1, Appendix B, summarizes the number of wells by use and location. The wells in Table 1 are grouped according to five well types: domestic, irrigation, municipal, monitoring, and other. Municipal wells include wells classified in the well completion reports as municipal. Table 1 shows that, of 9,363 wells in the Sacramento Valley Region of Butte County, about 5,484 are listed as domestic, 2,199 are listed as irrigation, 112 are listed as municipal, 561 are listed as monitoring, and 1,007 are listed as other. Figure 5 illustrates the breakdown of wells by use for the Sacramento Valley Region of Butte County.

Figure 4.
Distribution of Wells in Butte County (all types)

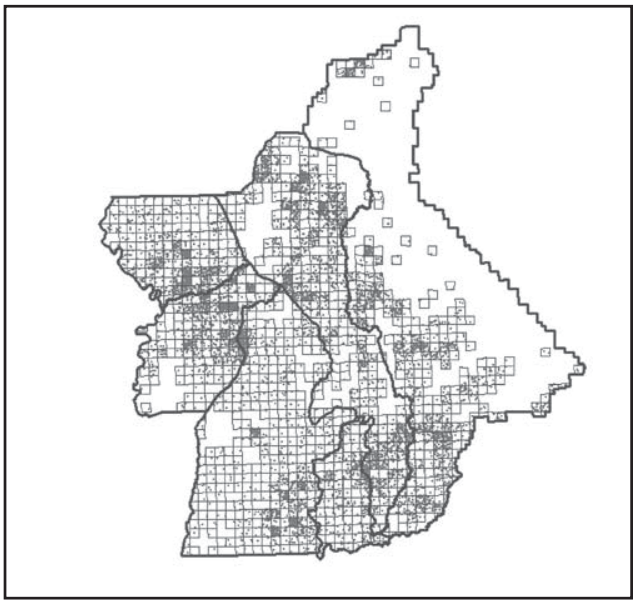
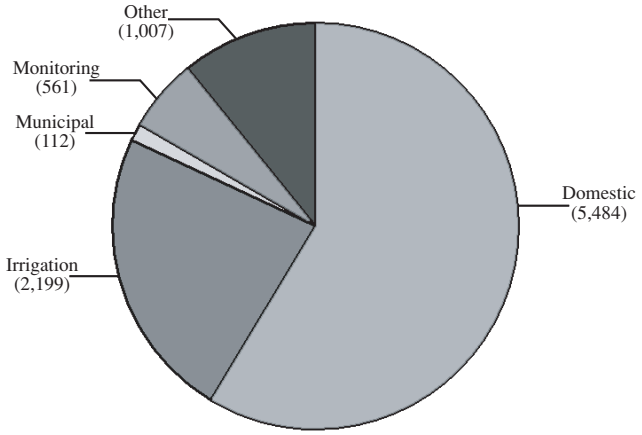
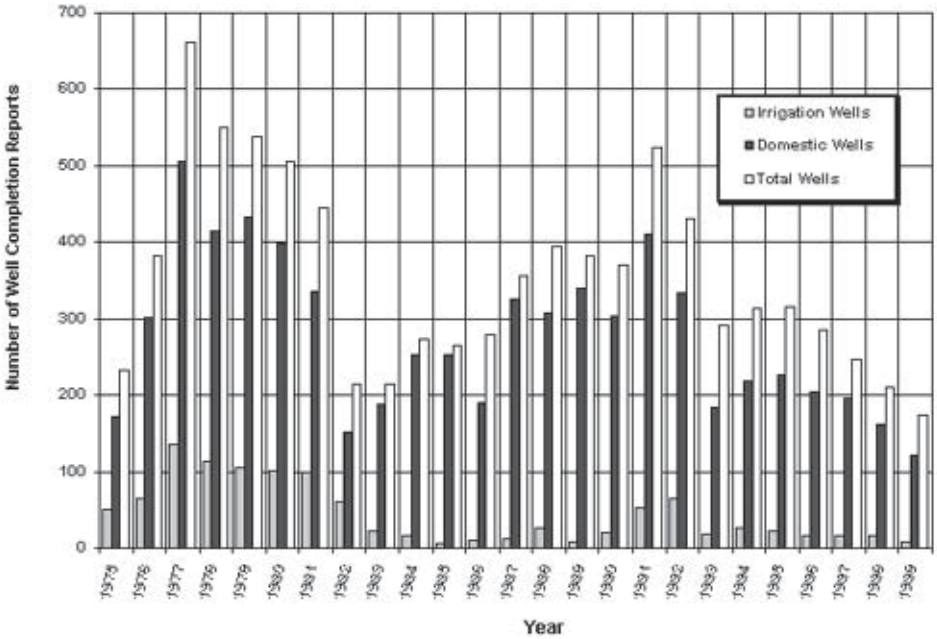


Figure 5.
Number of Wells by Use, Sacramento Valley Portion of Butte County



Total Number of Well = 9,363

Figure 6.
Number of Well Completion Reports Filed Per Year,
Sacramento Valley Portion of Butte County



In addition to analyzing the number of wells by use and location, the wells were analyzed by installation date. Examination of the number and types of wells drilled over time can help offer a perspective on the average age of the existing infrastructure and the approximate number of wells installed during normal and drought years. Table 2, Appendix B, summarizes the annual number and types of wells drilled between 1975 and 1999 in each of the six inventory unit areas. The wells in Table 2 are divided into domestic, irrigation, miscellaneous, and total.

Table 2, Appendix B, shows that 3,467 wells were drilled in the Sacramento Valley Region of Butte County between 1975 and 1999. The number of wells drilled per year range from a low of 91 in 1998 to a high of 401 in 1977, with an average of about 139 wells per year. About 55 percent (%) of the wells drilled in the valley during 1998 are listed as domestic and 18% are listed as irrigation. About 64% of the wells drilled in the valley during 1977 are listed as domestic and 33% are listed as irrigation. In the entire Butte County area, the number of wells drilled per year range from a low of 175 in 1999 to a high of 661 in 1977. About 69% of the wells drilled in the entire county area during 1999 are listed as domestic and less than 1% are listed as irrigation. About 77% of the wells drilled in the entire county area during 1977 are listed as domestic and 21% are listed as irrigation. A graphical illustration of the number of well completion reports filed per year for the Sacramento Valley Region of Butte County is shown in Figure 6.

Groundwater Level

Groundwater level monitoring in the Sacramento Valley Region of Butte County is currently being conducted by a number of different private and public agencies. Historically, DWR has maintained the most comprehensive, long-term groundwater level monitoring grid, with about 210 different wells monitored over the last 50 years in the Sacramento Valley Region of Butte County. Within this period, the annual size of the monitoring grid has fluctuated from as few as 50 wells to about 180 wells, depending on the activity of special studies in the area. Until 1989, the majority of

these wells were measured twice per year, during the spring and fall. Beginning in 1990, groundwater level monitoring was increased to monthly, before returning to a semi-annual measurement in 1995.

In 1997, the Butte County Department of Water and Resource Conservation (BCDWRC), in cooperation with DWR, began to expand the number and frequency of groundwater level monitoring in the valley portion of Butte County. The current monitoring grid has 88 wells and consists of a mixture of domestic and irrigation wells, along with several dedicated observation wells. About 14 of the 88 wells are equipped to continuously monitor and record changes in groundwater levels. The remaining wells are measured four times per year, during March, July, August, and October. The current Butte County groundwater level monitoring grid is shown on Plate 6, Appendix A, and listed below in Table 3. Table 3 lists the state well number, well use, aquifer system within which the well is constructed (qualification), confidence of the qualification, and estimated seasonal fluctuations in groundwater levels during normal and drought years.

In addition to the groundwater level monitoring conducted by BCDWRC and DWR, the California Water Service Company (CWSC) currently measures monthly groundwater levels in about 60 municipal groundwater supply wells in the Chico urban area. CWSC wells are typically deep wells that draw from the middle to lower portion of the aquifer system.

The seasonal and long-term fluctuations in groundwater levels within the Sacramento Valley Region of Butte County were estimated for normal and drought years based on groundwater hydrographs and groundwater contour maps. Groundwater hydrographs illustrate changes in groundwater levels over time. Discussions of seasonal and long-term changes in groundwater levels at the inventory and sub-inventory unit levels associated with individual well hydrographs will be presented later in this section. Further information regarding groundwater level data, hydrograph interpretation, and on-line access to hydrographs was presented in Section 1.

Table 3 shows that the seasonal fluctuations in groundwater levels in the unconfined portion of the aquifer system average from 3 to 5 feet during years of normal precipitation and 7 to 9 feet during years of drought. The annual fluctuations in groundwater levels in the confined or semi-confined portions of the aquifer system average about 10 feet during periods of normal precipitation and about 20 feet during times of drought.

Additional review of the hydrographs for long-term comparison of spring-to-spring groundwater levels indicates a decline in groundwater levels associated with the 1976-77 and 1987-94 droughts, followed by a recovery in groundwater levels to predrought conditions of the early 1970s and 1980s. Valley-wide comparison of spring-to-spring groundwater level data also indicates that there has been little overall change in groundwater levels in most areas of the valley since the 1970s and 1980s. However, further long-term comparisons of spring-to-spring groundwater levels from the 1950s and 1960s, versus today's levels, indicate about a 10-foot decline in groundwater levels in portions of the West Butte and Vina inventory units.

Groundwater hydrographs were also developed for the CWSC monitoring wells using static groundwater level data collected by CWSC. Although the groundwater level measurements presented in the CWSC hydrographs were collected when the wells were off (static groundwater levels), it should be noted that the effects from the recent pumping of these production wells could result in groundwater level readings that are

Table 3.
Butte County Groundwater Monitoring Grid and Estimated Seasonal Fluctuations in Groundwater Levels.

State Well Number	Well Use	Aquifer System	Confidence	Seasonal GW Fluctuation: Normal Years (feet)	Seasonal GW Fluctuation: Drought Years (feet)
17N/01E-10A01M	Domestic	Composite	Probable	3-5	6-7
17N/01E-17F01M	Observation	Semi-Confined	Probable	3-5	5-8
17N/01E-17F02M	Observation	Confined	Probable	4-5	7-8
17N/01E-17F03M	Observation	Confined	Probable	4-5	6-9
17N/02E-14A01M	Irrigation	Composite	Possible	2-3	5-10
17N/02E-16C01M	Domestic	Unconfined	Possible	1-2	3-5
17N/03E-03D01M	Irrigation	Composite	Possible	5-10	14-18
17N/03E-05C01M	Irrigation	Composite	Possible	3-5	8-10
17N/03E-08G01M	Domestic	Composite	Possible	3-5	5-10
17N/03E-16N01M	Domestic	Confined	Probable	3-6	5-10
17N/04E-08A01M	Irrigation	Composite	Possible	5-9	20
17N/04E-22B01M	Domestic	Confined	Probable	4-7	20
18N/01E-13M01M	Domestic	Composite	Probable	2-3	10
18N/01E-15D02M	Domestic	Composite	Probable	2-3	5
18N/02E-16F01M	Irrigation	Unconfined	Probable	1-2	2-4
18N/02E-25M01M	Irrigation	Composite	Probable	1-2	3-5
18N/02E-32Q02M	Domestic	Composite	Possible	2-3	3-4
18N/03E-05K01M	Irrigation	Confined	Possible	3-7	5-10
18N/03E-18F01M	Irrigation	Confined	Possible	3-5	5-8
18N/03E-21G01M	Irrigation	Composite	Possible	5-8	3-5
18N/03E-25N01M	Irrigation	Confined	Probable	10	10-15
18N/04E-08M01M	Irrigation	Confined	Probable	8-10	10-12
18N/04E-16C01M	Irrigation	Confined	Possible	4-15	15-25
18N/04E-28L01M	Irrigation	Confined	Possible	8-12	30
19N/01E-09Q01M	Irrigation	Confined	Probable	5	10
19N/01E-27Q01M	Observation	Confined	Definite	3	10
19N/01E-28R01M	Domestic	Unconfined	Probable	3-4	4-5
19N/02E-15N02M	Unused/Irr.	Confined	Possible	N/A	N/A
19N/02E-17A01M	Domestic	Unconfined	Possible	3-4	4-5
19N/03E-05N02M	Domestic	Composite	Probable	3-6	15-25
19N/04E-32P01M	Park	Confined	Possible	3-6	10-13
20N/01E-10C02M	Irrigation	Composite	Probable	3-5	8-12
20N/01E-18L01M	Observation	Confined	Probable	8	N/A
20N/01E-35C01M	Domestic	Confined	Probable	2-3	4-8
20N/02E-06Q01M	Irrigation	Composite	Definite	8-10	10-12
20N/02E-09L01M	Irrigation	Composite	Probable	4-6	10-13
20N/02E-15H01M	Observation	Confined	Probable	10-20	N/A
20N/02E-15H02M	Observation	Unconfined	Definite	2-4	N/A
20N/02E-16P01M	Irrigation	Composite	Possible	5	30-40
20N/02E-24C01M	Observation	Semi-Confined	Possible	15	N/A
20N/02E-24C02M	Observation	Semi-Confined	Possible	15	N/A
20N/02E-24C03M	Observation	Confined	Possible	12	N/A
20N/02E-28N01M	Unused/Irr.	Unconfined	Possible	2-4	6-8
20N/03E-33L01M	Unused/Irr.	Semi-Confined	Possible	25	N/A

Table 3 (continued).
Butte County Groundwater Monitoring Grid and
Estimated Seasonal Fluctuations in Groundwater Levels.

State Well Number	Well Use	Aquifer System	Confidence	Seasonal GW Fluctuation: Normal Years (feet)	Seasonal GW Fluctuation: Drought Years (feet)
21N/01E-08K02M	Irrigation	Confined	Possible	5-9	25
21N/01E-10B03M	Irrigation	Confined	Probable	10-13	18-23
21N/01E-12D01M	Irrigation	Composite	Definite	N/A	N/A
21N/01E-12K01M	Irrigation	Confined	Probable	20	30
21N/01E-13F01M	Irrigation	Composite	Probable	35	40
21N/01E-14Q02M	Irrigation	Semi-Confined	Probable	20	40
21N/01E-21C01M	Irrigation	Confined	Probable	10	30
21N/01E-22B01M	Domestic	Semi-Confined	Probable	20	25
21N/01E-25K01M	Domestic	Semi-Confined	Possible	15-25	25-35
21N/01E-26K01M	Irrigation	Confined	Probable	15	40
21N/01E-27B01M	Irrigation	Confined	Possible	15	40
21N/01E-27D01M	Domestic	Confined	Possible	5-8	25
21N/01E-28F01M	Unused/Irr.	Confined	Possible	20	N/A
21N/01E-33F01M	Unused/Irr.	Confined	Probable	4-12	N/A
21N/02E-07C01M	Irrigation	Confined	Probable	10-15	20-25
21N/02E-20P01M	Irrigation	Composite	Probable	N/A	N/A
21N/02E-26E02M	Unuse/Dom.	Unconfined	Probable	2-4	5
21N/02E-26F01M	Irrigation	Unconfined	Probable	5	15
21N/02E-30L01M	Domestic	Confined	Probable	20	30
21N/03E-22C01M	Domestic	Semi-Confined	Probable	N/A	N/A
21N/03E-32B01M	Unused/Irr.	Unconfined	Possible	5	N/A
21N/03E-36A01M	Unused/Irr.	Semi-Confined	Possible	N/A	N/A
21N/01W-23J01M	Unused/Irr.	Unconfined	Probable	3-5	6-8
21N/01W-24B01M	Observation	Confined	Definite	10	N/A
21N/01W-35K02M	Irrigation	Composite	Probable	4-5	N/A
22N/01W-05M01M	Irrigation	Composite	Possible	4-8	10-15
22N/01E-09J02M	Domestic	Unconfined	Possible	5-7	10-16
22N/01E-20K01M	Domestic	Composite	Possible	5-10	12-16
22N/01E-28J01M	Observation	Confined	Definite	15-20	30
22N/01E-28J03M	Observation	Confined	Probable	10-15	15-25
22N/01E-28J05M	Observation	Confined	Definite	15-20	20-30
22N/01E-28J06M	Domestic	Semi-Confined	Possible	20-25	N/A
22N/01E-29R01M	Irrigation	Confined	Probable	10	20
22N/01E-32E04M	Domestic	Composite	Probable	15	25
22N/02E-17E01M	Domestic	Confined	Probable	3-7	60
22N/02E-28E01M	Domestic	Confined	Probable	3-5	N/A
23N/01E-18A01M	Domestic	Confined	Probable	3-4	15
23N/01E-29P02M	Domestic	Composite	Possible	10-15	N/A
23N/01W-09E01M	Irrigation	Confined	Possible	7-10	13-18
23N/01W-09J01M	Irrigation	Confined	Possible	10-15	N/A
23N/01W-14R02M	Stock	Composite	Probable	5	15
23N/01W-27L01M	Domestic	Confined	Probable	7-19	20-27
23N/01W-36P01M	Domestic	Composite	Possible	5-15	25
23N/02W-25C01M	Irrigation	Composite	Possible	5-9	10-15

deeper than stable static conditions. Select hydrographs for CWSC wells, using 1978 through 2000 groundwater level data, are presented in the California Water Service Sub-inventory Unit section of this report.

Estimated Seasonal Fluctuations in Groundwater Levels

Overall analysis of the seasonal fluctuations in groundwater levels in CWSC wells indicates a rather uniform seasonal fluctuation of 15 to 20 feet during normal years. Analysis of seasonal groundwater levels during drought years shows a wide range of fluctuations depending on the individual well. Many wells show little or no seasonal changes among wet, normal and dry years, while other wells show large differences. The wide range of responses to seasonal changes in normal versus drought years is likely due to the wide range of operational scenarios that can be imposed on these active production wells.

Analyses of CWSC hydrographs for long-term changes in groundwater levels between 1978 and 2000 also show mixed results. While some wells indicate more than a 30-foot drop in groundwater levels over the last 20 years, other nearby wells, often drawing from similar aquifer zones, sometimes show little or no decline. Although the individual well results were variable, the overall analysis indicates that groundwater levels in the California Water Service Sub-inventory Unit have declined an average of 12 feet between 1978 and 2000. Further discussion of long-term groundwater level trends in the Chico urban area will be presented in the California Water Service Sub-inventory Unit section of this report.

Groundwater level data were also used to develop groundwater elevation contour maps for the Sacramento Valley Region of Butte County. Groundwater contour maps were developed using 1997 spring and summer groundwater level data from monitoring wells in Butte, Glenn, Colusa, Tehama, Sutter, and Yuba counties and from CWSC wells. Groundwater contours were used to help estimate the direction and gradient of groundwater movement and the seasonal changes in groundwater levels. Groundwater levels for 1997 are considered representative of a normal water year. Groundwater contour maps of the Sacramento Valley Region of Butte County are provided on Plates 7 and 8, Appendix A.

Plate 7, Appendix A, is a groundwater elevation contour map for spring 1997. The groundwater contour lines in Plate 7 represent levels of equal groundwater elevation and were developed with data collected during March and April 1997, prior to agricultural use of groundwater. Spring groundwater levels are commonly the highest of the year and, in areas unaffected by municipal use of groundwater, reflect the natural groundwater table distribution and direction of movement. Plate 7 shows that the spring groundwater levels vary from an elevation of about 60 feet in the Butte Sink Inventory Unit to an elevation of about 200 feet in the northeastern Vina Inventory Unit.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the 1997 spring and summer measurement periods. Plate 8 shows that the seasonal groundwater elevation fluctuations for a normal year in the Sacramento Valley Region of Butte County range from 0 to 30 feet. No change was recorded in the southeastern portion of the East Butte Inventory Unit, where the limited groundwater extraction and the application of agricultural water during the summer months compensate for the seasonal decline of groundwater levels.

The areas of greatest groundwater level decline are those where extraction of groundwater for agricultural and municipal uses occur during the summer months. Plate 9, Appendix A, illustrates the sources of agricultural water for areas within the Sacramento Valley Region of Butte County. The regions of summer groundwater extraction depicted on Plate 9 correlate to the areas of greatest normal seasonal groundwater level decline. These areas include portions of the Vina and North Yuba inventory units, the Durham area of the West Butte Inventory Unit, and the Cherokee Strip area of the East Butte Inventory Unit.

Overall comparison of seasonal changes in groundwater levels indicates that the amounts of fluctuation vary according to well location and well construction. In general, wells located in the southern portion of the East Butte Inventory Unit, show less seasonal fluctuation than similarly constructed wells in the northern portion of the county within the West Butte and Vina inventory units. The small seasonal fluctuations in groundwater levels in the southern county are largely due to recharging of the upper aquifer system from applied surface water and limited agricultural use of groundwater. Other valley-wide patterns show that wells constructed in the unconfined portion of the aquifer system tend to show less seasonal fluctuation in groundwater levels than similarly located wells constructed in the lower, confined portion of the aquifer system. A smaller seasonal fluctuation in groundwater levels in the upper aquifer system is due largely to the greater interconnection between the unconfined aquifer system and the overlying surface water systems.

Groundwater Movement

The direction of groundwater movement is illustrated on Plate 7, Appendix A, by a series of small arrows perpendicular to the groundwater elevation contours. Plate 7 shows that the regional pattern of spring groundwater movement is in a southwesterly direction toward the Sacramento River. North of Princeton, the Sacramento River is a gaining river with groundwater flowing from the valley aquifer system and discharging into the river. South of Princeton, the Sacramento River is primarily a losing river with surface water flows contributing to the recharge of the groundwater system along its course through the southern Sacramento Valley. Plate 7 shows that in other parts of the valley portion of Butte County, the general direction of groundwater flow is toward Butte Creek and away from the Feather River.

Plate 7, Appendix A, shows that one groundwater mound exists in the Sacramento Valley Region of Butte County. It occurs, south of the Thermalito Afterbay and is associated with recharge from that facility. Several isolated groundwater depressions are located within the City of Chico due to year-round pumping of groundwater for municipal use. A more widespread depression is located in the southwest portion of the North Yuba Inventory Unit.

An interesting flow pattern is also present in the southeastern corner of the East Butte Inventory Unit. In this area, groundwater flow converges toward the Butte Sink Sub-inventory Unit from the Sacramento River to the west and the lower basin to the east. The converging groundwater flow in this area is structurally controlled due to the intrusion of the Sutter Buttes to the east and the buried Colusa Dome to the west.

The groundwater gradient is generally greatest along the eastern edge of the valley, becoming relatively flat to the west and south. Groundwater gradients range from a high of about 60 feet per mile along the eastern foothills to a low of about 3 feet per

mile within the East Butte Inventory Unit. The average gradient across the central portion of the county is about 5 feet per mile.

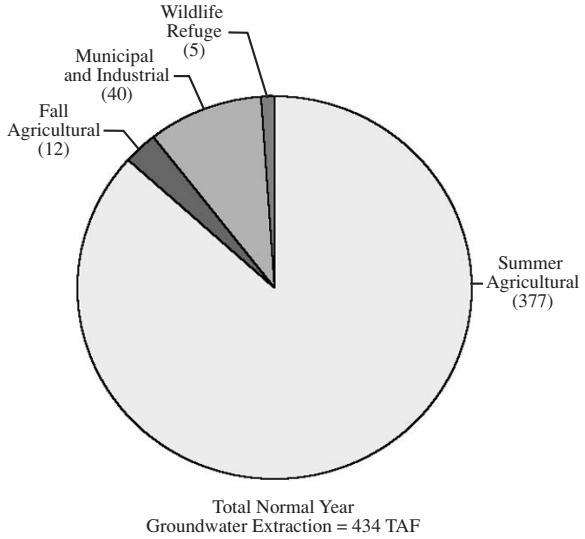
Groundwater Extraction

Approximately 30% of the Sacramento Valley Region of Butte County is in summer agricultural production supported by groundwater. Estimates of groundwater extraction in the valley portion of Butte County were developed for normal- and drought-year scenarios. Groundwater extraction estimates for normal years incorporate 1997 land use and municipal extraction data and closely represent the annual amount of groundwater extracted at the current level of county development. Groundwater extraction estimates for drought years represent the maximum amount of groundwater extraction that can be expected to potentially occur under the current level of development and a worst case scenario with respect to annual precipitation, evapotranspiration, runoff, and reduction in surface water deliveries to the county.

Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction estimates, along with deep percolation rates of applied groundwater, are illustrated below and summarized in Tables 3 and 4, Appendix B. The groundwater extraction estimates are divided into summer and winter agricultural use, annual municipal use, and annual wildlife refuge use. The annual deep percolation estimates are divided into agricultural, municipal and industrial uses.

The estimated amounts of normal-year groundwater extraction, by type of use, are illustrated in Figure 7 and listed in Table 3, Appendix B. Figure 7 shows that normal-year groundwater extraction for the valley portion of Butte County is estimated at 434 thousand acre-feet (taf). Of the 434 taf of groundwater extracted during a normal year, about 377 taf are for summer agricultural use, 40 taf are for annual municipal and industrial uses, 12 taf are for fall agricultural use, and 5 taf are for wildlife refuge use. Table 3, Appendix B, shows that summer agricultural groundwater in a normal year is applied to about 106,000 acres, for an applied water average of 3.6 acre-feet per acre (af/acre). Table 3 also shows that about 91 taf of the extracted groundwater return to the aquifer via deep percolation during a normal year.

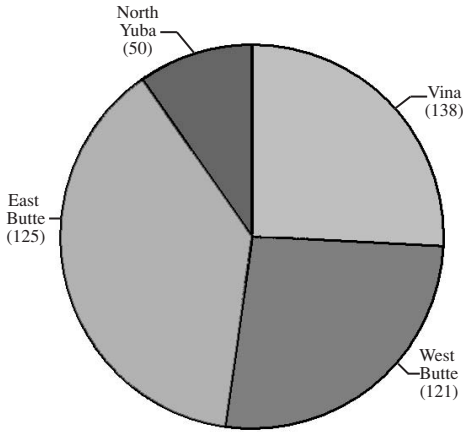
Figure 7.
Estimated Amounts of Normal-Year Groundwater Extraction by Use, Sacramento Valley Portion of Butte County



The estimated amounts of normal-year groundwater extraction by inventory unit are illustrated in Figure 8 and listed in Table 3, Appendix B. Of the 434 taf of groundwater extracted during a normal year, about 138 taf are extracted from the Vina Inventory Unit, 121 taf are extracted from the West Butte Inventory Unit, 125 taf are extracted from the East Butte Inventory Unit and 50 taf are extracted from the North Yuba Inventory Unit.

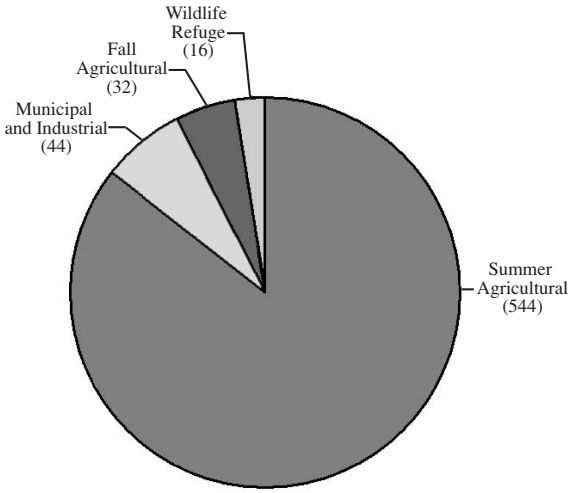
The estimated amounts of drought-year groundwater extraction by type of use are illustrated in Figure 9 and listed in Table 4, Appendix B. Figure 9 shows that drought-year groundwater extraction in the valley portion of Butte County is estimated at 635 taf, an increase of about 46% over the normal-year extraction estimate. Of the 635 taf of groundwater extracted during a drought year, about 544 taf are for summer agricultural use, 44 taf are for municipal use, 32 taf are for fall agricultural use and 16 taf are for wildlife refuge use.

Figure 8.
Estimated Amounts of Normal-Year Groundwater Extraction by Inventory Unit, Sacramento Valley Portion of Butte County.



Total Normal Year Groundwater Extraction = 434 TAF

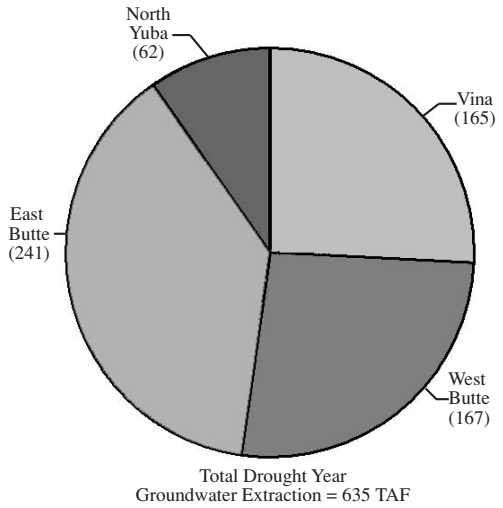
Figure 9.
Estimated Amounts of Drought-Year Groundwater Extraction By Type of Use, Sacramento Valley portion of Butte County.



Total Drought Year Groundwater Extraction = 635 TAF

The estimated amounts of drought-year groundwater extraction by inventory unit are illustrated in Figure 10 and listed in Table 4, Appendix B. Of the 635 taf of groundwater extracted during a drought year, about 165 taf are extracted from the Vina Inventory Unit, 167 taf are extracted from the West Butte Inventory Unit, 241 taf are extracted from the East Butte Inventory Unit and 62 taf are extracted from the North Yuba Inventory Unit.

Figure 10.
Estimated Amounts of Drought-Year Groundwater Extraction By Inventory Unit, Sacramento Valley Portion of Butte County.



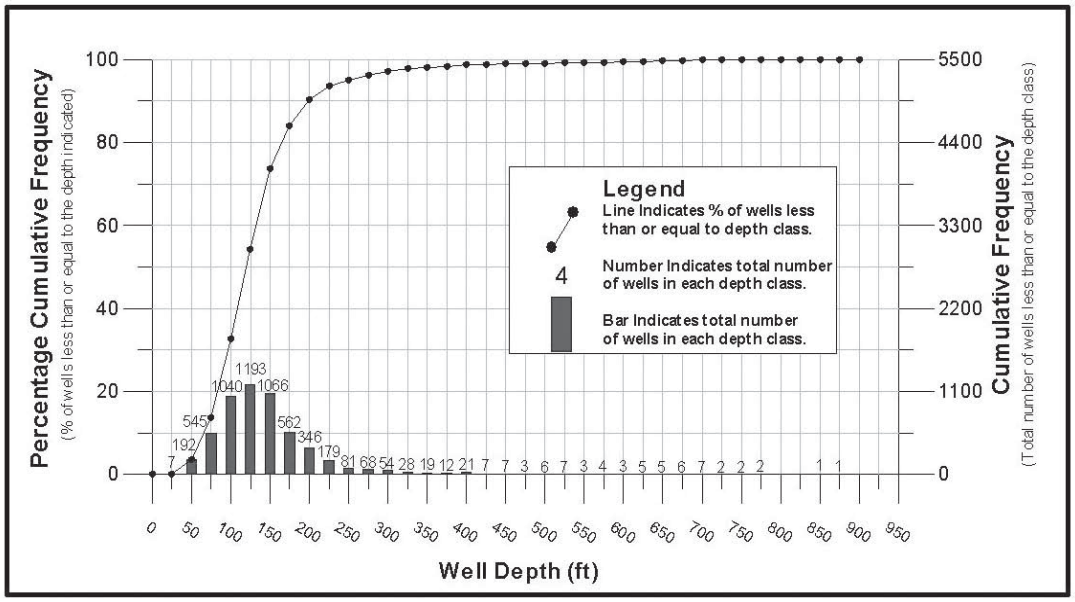
Well Depth

Well depth and well use data for the Sacramento Valley inventory units were collected from well completion reports filed with DWR. A total of 7,794 well records with depth data were evaluated and classified into three well types: domestic, irrigation, and municipal. A summary of the minimum, maximum, and average well depths, listed by well type, is presented in Table 5, Appendix B. The statistical distribution of the well depth data was also evaluated through a series of cumulative frequency distribution curves for domestic, irrigation, and municipal wells. Cumulative frequency curves associated with the Sacramento Valley area are presented in Figures 11, 12, and 13.

Table 5, Appendix B, shows that the average depth of domestic wells in the Sacramento Valley Region of Butte County is 135 feet. Table 5 also shows that wells drilled for irrigation and municipal uses have a greater average depth than domestic wells. The average well depth for irrigation wells is 321 feet. The average well depth for municipal wells is 466 feet.

Figure 11 shows the cumulative frequency distribution of well depths for domestic wells in the Sacramento Valley Region. A total of 5,484 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 14 to 860 feet.

Figure 11.
Cumulative Frequency Distribution of Domestic Wells,
Sacramento Valley Portion of Butte County.



The histogram bars in Figure 11 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the domestic well depth data is skewed slightly to the right toward deeper well depths. Right-skewed distribution of domestic well data indicates that average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the Sacramento Valley Region shows that:

- 50% of the domestic wells are installed to a depth of 120 feet or less,
- 20% of the wells are installed to a depth of 80 feet or less, and
- 10% of the wells are installed to a depth of 60 feet or less.

Figure 12 illustrates the cumulative frequency distribution of irrigation well depth data in the Sacramento Valley Region. A total of 2,198 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of irrigation wells range from 28 to 1,050 feet.

The histogram in Figure 12 shows that the distribution of irrigation well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the Sacramento Valley Region and that no dominant well depth preference exists.

The cumulative frequency curve of irrigation well depth data for the Sacramento Valley Region shows that:

- 50% of the irrigation wells are installed to a depth of 275 feet or less,
- 20% of the wells are installed to a depth of 150 feet or less, and
- 10% of the wells are installed to a depth of 110 feet or less.

Figure 12.
Cumulative Frequency Distribution of Irrigation Wells,
Sacramento Valley Portion of Butte County

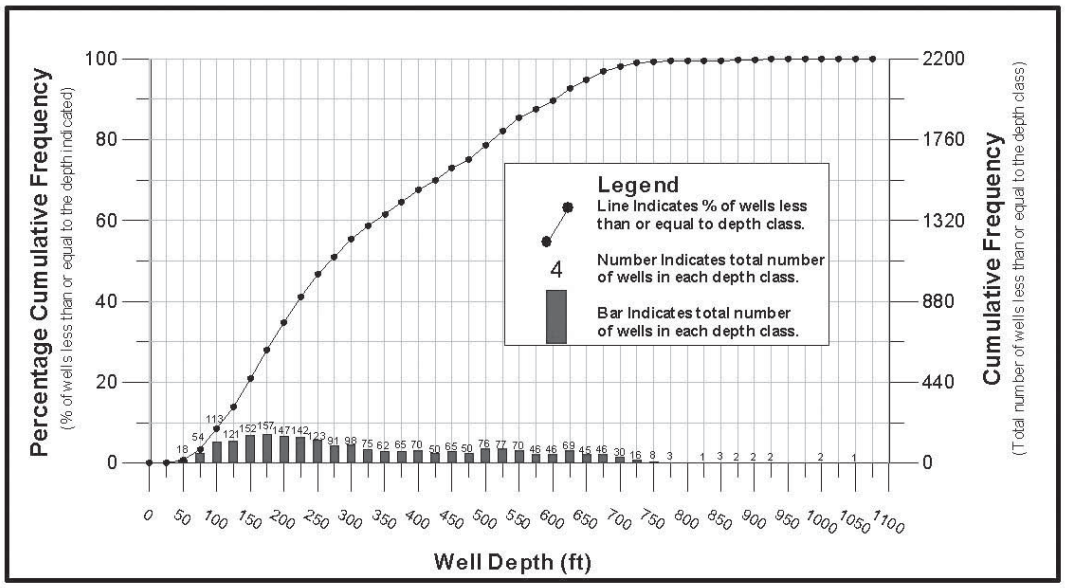


Figure 13 illustrates the cumulative frequency distribution of municipal well depth data in the Sacramento Valley Region. A total of 112 municipal wells were evaluated in terms of cumulative frequency distribution with respect to well depths. Municipal well depths range from 36 to 924 feet.

The histogram bars in Figure 13 show that the distribution of municipal well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the municipal well depth data indicates that there is a wide range of municipal well depths within the Sacramento Valley Region and that no dominant well depth preference exists.

The cumulative frequency curve of municipal well depth data for the Sacramento Valley Region shows that:

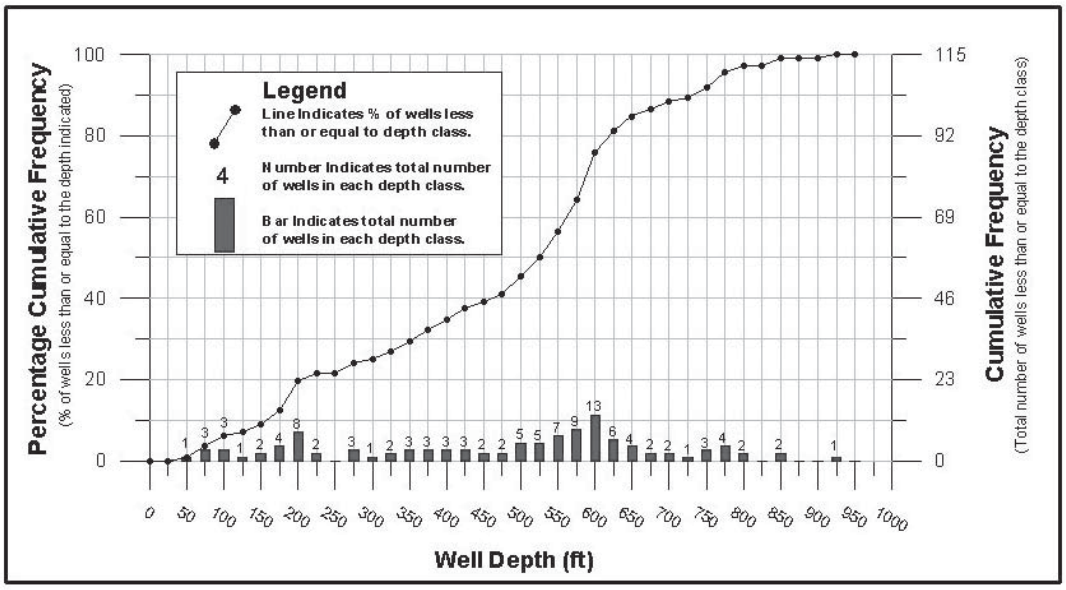
- 50% of the municipal wells are installed to a depth of 485 feet or less,
- 20% of the wells are installed to a depth of 375 feet or less, and
- 10% of the wells are installed to a depth of 190 feet or less.

Well Yield

Well yield estimates for Butte County were evaluated based on well completion reports filed with DWR, published and unpublished investigations, and from utility pump records. The utility records represent pump test data from primarily municipal and agricultural wells within the Sacramento Valley Region of Butte County. A further explanation of well yield data is provided in Section 1. A summary of well yield data, by inventory unit, is provided in Table 6, Appendix B.

About 2,300 municipal and irrigation well completion reports for the Sacramento Valley Region of Butte County are on file at DWR. Of these reports, only 85 have well yield data. Table 6, Appendix B, indicates that the average well yield, reported from well completion reports, in the Sacramento Valley Region of Butte County is about 1,900 gallons per minute (gpm). Well yield data reported in well completion reports filed with DWR are derived using a variety of methods. In some cases, the

Figure 13.
Cumulative Frequency Distribution of Municipal Wells,
Sacramento Valley Portion of Butte County



well yield value listed in the well completion reports is more a function of the particular testing method, rather than an accurate indication of maximum well yield for a given area. Well yield data from well completion reports should serve only as a general guide to local well productivity.

Butte County well yield estimates were also developed from analysis of over 2,600 utility pump test records taken between 1989 and 1998. Utility pump tests represent data from municipal and agricultural wells that were developed by using the well's existing pump and motor. Utility pump tests generally provide an accurate estimate of a well's true yield. Utility pump test data listed in Table 6, Appendix B, represent data from 2,662 pump tests performed on 944 wells between 1989 and 1998. Table 6 shows that the average well yields in the valley area range from a low of 976 gpm in the North Yuba Inventory Unit to a high of 1,602 gpm in the East Butte Inventory Unit. The average well yield for the entire valley region is 1,325 gpm.

In 1961, Olmsted and Davis of the U.S. Geological Survey (USGS) compiled utility pump test records for 21 areas within the Sacramento Valley. Three of these areas - Chico, Gridley, and Honcut - are located almost entirely in the Butte County portion of the Sacramento Valley. The Chico area corresponds to the sum of the entire Vina and West Butte inventory units and the East Butte Inventory Unit north of Nelson. The Gridley area corresponds to the East Butte Inventory Unit south of Nelson. The Honcut area corresponds to the entire North Yuba Inventory Unit. The 1961 USGS utility data listed in Table 6, Appendix B, represent 640 pump tests taken prior to 1959. Table 6 shows that the average well yields in the valley area range from a low of 840 gpm in the Honcut area to a high of 1,000 gpm in the Chico area. The average well yield for the entire valley region was estimated at 990 gpm.

Specific Capacity

Specific capacity estimates for Butte County were evaluated based on published and unpublished investigations and utility pump test records. The utility data are primarily from pump tests performed on municipal and agricultural wells within the Sacramento Valley Region of Butte County between 1989 and 1998. A further

explanation of specific capacity data is provided in Section 1. A summary of the specific capacity data derived from utility pump test records is provided in Table 7, Appendix B.

Over 2,600 utility pump test records were analyzed to estimate specific capacity at the inventory unit level within the Sacramento Valley Region of Butte County. Of these pump test records, about 950 tests provided enough data to accurately calculate specific capacity. The data in Table 7, Appendix B, represent 974 pump tests performed on 433 wells between 1989 and 1998. Table 7 shows that the average specific capacity for the valley inventory units range from a low of 48 gallons per minute per foot (gpm/ft) in the North Yuba Inventory Unit to a high of 87 gpm/ft in the Vina Inventory Unit. The average specific capacity for the entire valley region is 78 gpm/ft.

In 1961, the USGS (Olmsted and Davis 1961) compiled utility pump test records for 21 areas within the Sacramento Valley. Three of these areas - Chico, Gridley, and Honcut - are located almost entirely in the Butte County portion of the Sacramento Valley. The Chico area corresponds to the sum of the entire Vina and West Butte inventory units and the East Butte Inventory Unit north of Nelson. The Gridley area corresponds to the East Butte Inventory Unit south of Nelson. The Honcut area corresponds to the entire North Yuba Inventory Unit. The 1961 USGS utility data listed in Table 7, Appendix B, represent 640 pump tests taken prior to 1959. Table 7 shows that the average specific capacity figures for the valley area range from a low of 51 gpm/ft in the Chico area, to a high of 60 gpm/ft in the Honcut area. The average specific capacity for the entire valley region was estimated at 53 gpm/ft.

Groundwater Storage Capacity

For the purposes of this investigation, groundwater storage capacity is defined as the maximum volume of fresh groundwater capable of being stored within an aquifer beneath a given area. Estimates of storage capacity were calculated by multiplying the inventory unit area by the maximum saturated thickness and the average specific yield of the freshwater portion of the aquifer. A further explanation of groundwater storage capacity estimates is provided in Section 1. Estimates of maximum groundwater storage capacity are listed in Table 8, Appendix B.

Table 8, Appendix B, shows that the Sacramento Valley Region of Butte County covers an area of about 398,000 acres. Maximum groundwater storage capacity estimates in Table 8 assume uniform aquifer saturation from a depth of 10 feet, down to the average base of freshwater at a depth of about 1,350 feet, and an average specific yield of 6.8%. Based on the above assumptions, the estimated maximum groundwater storage capacity for the valley area is 35,900 taf.

Groundwater in Storage

Groundwater in storage is defined as the volume of water contained within the aquifer system at the time of measurement. Groundwater in storage in the Sacramento Valley Region of Butte County was examined using three scenarios:

- the estimated volume of groundwater currently in storage over the entire freshwater portion of the aquifer system,
- the estimated seasonal decline in groundwater levels associated with the removal of groundwater in storage during a normal water year, and
- the estimated seasonal decline in groundwater levels associated with the removal of groundwater in storage during a drought water year.

The estimated amounts of groundwater in storage are listed in Table 9, Appendix B. The estimated seasonal declines in groundwater levels during normal and drought years are provided in Table 10, Appendix B. A further explanation of groundwater in storage estimates was provided in Section 1.

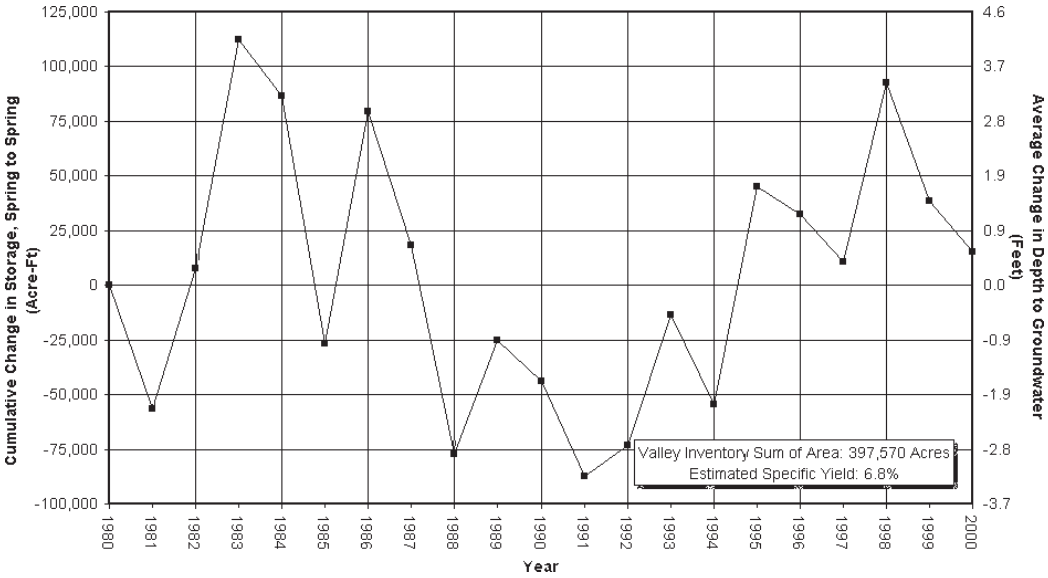
- **Estimated Volume of Groundwater in Storage.** The Sacramento Valley Region of Butte County covers an area of about 398,000 acres. Groundwater in storage estimates for the valley assume uniform aquifer saturation from an average depth of 20 feet down to the average base of freshwater at a depth of about 1,335 feet. The average depth to groundwater for the valley area is based on spring 1997 groundwater level measurements. The average specific yield for the valley area is estimated at 6.8%. Based on the above assumptions, the volume of groundwater in storage for the valley area is estimated at 35,585 taf. A comparison of groundwater storage capacity and groundwater in storage estimates listed in Tables 8 and 9, Appendix B, indicates that the valley aquifer system is close to maximum capacity during normal water years.
- **Estimated Seasonal Decline of Groundwater in Storage associated with Normal-Year Extraction.** Seasonal groundwater extraction is estimated at 100% of the summer agricultural extraction, plus 70% of the annual municipal extraction, minus 30% of the annual deep percolation of applied surface water and groundwater. Based on the above assumptions, the seasonal groundwater demand in the valley area during a normal year is estimated at about 342 taf. The average seasonal decline in groundwater levels associated with a normal-year extraction of 342 taf in the valley region is estimated at 13 feet.
- **Estimated Seasonal Decline of Groundwater in Storage associated with Drought-Year Extraction.** Seasonal groundwater extraction is estimated at 100% of the summer agricultural extraction, plus 70% of the annual municipal extraction, minus 30% of the annual deep percolation of applied surface water and groundwater. Based on the above assumptions, the seasonal groundwater demand in the valley area during a drought year is estimated at about 510 taf. The average seasonal decline in groundwater levels associated with a drought-year extraction of 510 taf in the valley region is about 19 feet.

Changes in the Volume of Groundwater in Storage

The annual spring-to-spring changes in the volume of groundwater in storage for the Sacramento Valley Region of Butte County were calculated over a 20-year period from 1980 to 2000. The changes in the volume of groundwater in storage are based on groundwater contour maps developed from spring groundwater level measurements in the upper portion of the aquifer. Changes in the volume of groundwater in storage data are provided in Table 11, Appendix B, and illustrated in Figure 14. A further explanation of the methodology for estimating changes in the volume of groundwater in storage is provided in Section 1.

Table 11, Appendix B, lists the annual changes in the volume of groundwater in storage, the cumulative changes in the volume of groundwater in storage, and the changes in groundwater levels associated with the cumulative changes in the volume of groundwater in storage. Table 11 shows that the largest single-year decline in spring-to-spring volume of groundwater in storage for the valley area was about 113 taf in 1984-85. The largest single-year increase in the volume of groundwater in storage was about 106 taf in 1985-86. Figure 14 shows that the volume of groundwater in storage during spring 2000 was greater than that of spring 1980 for

Figure 14.
Estimated Cumulative Changes in Spring-to-Spring Storage,
Sacramento Valley Portion of Butte County.



the East Butte and North Yuba inventory units, less than that of 1980 for the West Butte Inventory Unit, and relatively the same for the Vina Inventory Unit. The changes in storage data for the entire Sacramento Valley area indicate that the volume of groundwater in storage during spring 2000 was slightly greater than that of spring 1980.

The cumulative spring-to-spring changes in storage for the Sacramento Valley area are illustrated in Figure 14. The spring-to-spring changes in the graph start with a baseline of zero for spring 1980 and illustrate the cumulative changes from 1980 to 2000. Figure 14 shows that the groundwater in storage increases during the wet years of 1983 and 1986, decreases during the drought of the early 1990s, and then gradually recovers over the next five years. Overall, the amount of groundwater in storage during spring 2000 was about 15 taf greater than that of 1980. The fluctuation in the volume of groundwater in storage between the peak in 1983 and the low in 1991 is estimated at 200 taf.

Conclusions and Recommendations

An inventory analysis of the aquifer system beneath the Sacramento Valley Region of Butte County indicates that the aquifer has fully recovered from the extended drought of the late 1980s and early 1990s, and the amount of annual groundwater extraction is currently within the sustainable yield of the aquifer. Other conclusions include:

- the annual groundwater demands range between 434 and 635 taf for normal and drought years;
- during normal to wet years, the aquifer system typically recharges to maximum storage capacity by the following spring;
- during normal and wet years, the aquifer system has the ability to recharge at a rate of at least 435 to 535 taf per year (recovery of normal-year extraction plus an additional 100 taf);
- about 90 to 100 taf of the annual recharge comes from applied groundwater;
- about 110 to 120 taf of the annual recharge comes from applied surface water;

- the seasonal decline in groundwater level averages between 15 and 25 feet for areas of the valley dependent on groundwater for agricultural and municipal uses;
- a year-round groundwater level depression of 5 to 10 feet exists within the Chico Urban area;
- a long-term comparison of spring-to-spring groundwater levels in the Chico Urban area indicates a 10- to 15-foot decline in groundwater levels since the 1950s, with most of the decline occurring during the 1987-94 drought. The annual decline in groundwater levels in this area has stabilized since 1995; and
- a long-term comparison of groundwater in storage indicates that the amount of groundwater in storage during Spring 2000 was slightly greater than during Spring 1980.

Recommendations at this time are to:

- increase the number of dedicated groundwater monitoring wells within the urban areas of Chico and Oroville;
- collect, inventory, and analyze the existing groundwater quality data for the valley portion of Butte County, and write a report summarizing the data findings;
- conduct additional investigations to delineate and quantify the groundwater recharge and discharge areas for the aquifer system beneath the valley portion of Butte County; and
- conduct groundwater modeling to determine impacts of future urban and agricultural groundwater demand based on projected development identified within the Butte County General Plan.

Vina Inventory Unit

The Vina Inventory Unit covers about 75,000 acres in the northern Sacramento Valley Region of Butte County (Plate 1, Appendix A). It is bordered by Tehama County to the north, Big Chico Creek to the south, the Sacramento River to the west, and the foothills to the east. In a normal water year, about 50% of the Vina Inventory Unit is in summer agricultural production supported by groundwater. Another 10% of the inventory unit is within the CWSC area, which uses groundwater as the municipal water source for much of the Chico urban area. The remaining portion of the CWSC area is within the West Butte Inventory Unit. A separate sub-inventory unit was developed for the CWSC area. Groundwater and well data for the California Water Service Sub-inventory Unit will be presented later in this report. The groundwater and well data presented in the Vina Inventory Unit section includes only that part of the California Water Service Sub-inventory Unit that is within the larger Vina Inventory Unit.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number, types, dates of installation, and distribution of wells in the Vina Inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data by area and by installation date is provided in Tables 1 and 2, Appendix B.

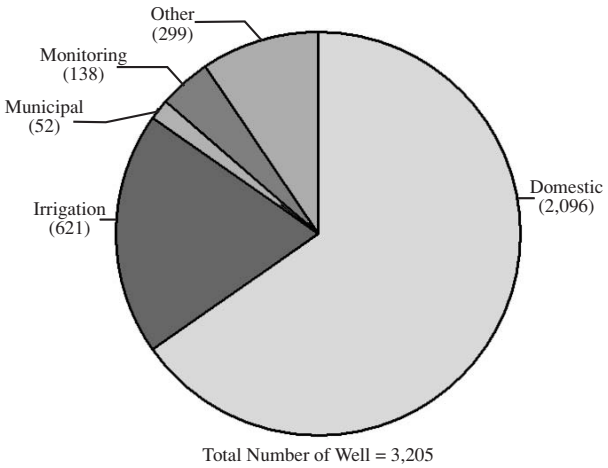
There are an estimated 3,205 wells in the Vina Inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that about 2,096 are listed as domestic, 621 are

listed as irrigation, 51 are listed as municipal, 138 are listed as monitoring, and 299 are listed as other. Figure 15 illustrates the breakdown of wells by use for the Vina Inventory Unit.

Wells in the Vina Inventory Unit were also analyzed to determine the number and types of wells installed over time. Examination of the number and types of wells drilled over time can help offer perspective on the average age of the existing infrastructure and the approximate number of wells installed during normal and drought years. Table 2, Appendix B, lists the annual number and types of wells drilled in the Vina Inventory Unit between 1975 and 1999. The wells in Table 2 are divided into domestic, irrigation, miscellaneous, and total. Table 2, Appendix B, shows that 1,142 wells were drilled in the Vina Inventory Unit between 1975 and 1999.

The number of wells drilled per year in the Vina Inventory Unit ranges from a low of 26 in 1997 to a high of 135 in 1977, with an average of about 46 wells per year. About 77% of the wells drilled during 1997 are listed as domestic and 15% are listed as irrigation. About 81% of the wells drilled during 1977 are listed as domestic and 16% are listed as irrigation. Figure 16 illustrates the number of well completion reports filed per year for the Vina Inventory Unit.

Figure 15.
Number of Wells by Use, Vina Inventory Unit



Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 15 wells within the Vina Inventory Unit. The monitoring wells consist of a mixture of domestic, irrigation, observation and stock wells. Table 4 lists the current monitoring wells along with the annual fluctuations in groundwater levels during normal and drought years. Table 4 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. The locations of groundwater monitoring wells are shown on Plate 6, Appendix A.

Historic groundwater level data for the Vina Inventory Unit indicate that the annual fluctuations in groundwater levels in the unconfined portion of the aquifer system are about 5 to 7 feet during years of normal precipitation and up to 16 feet during years of drought. Annual fluctuations in groundwater levels in the confined or semi-confined portions of the aquifer system are about 7 to 25 feet during normal years and up to 30 feet during drought years.

Figure 16.
Number of Well Completion Reports Filed Per Year, Vina Inventory Unit

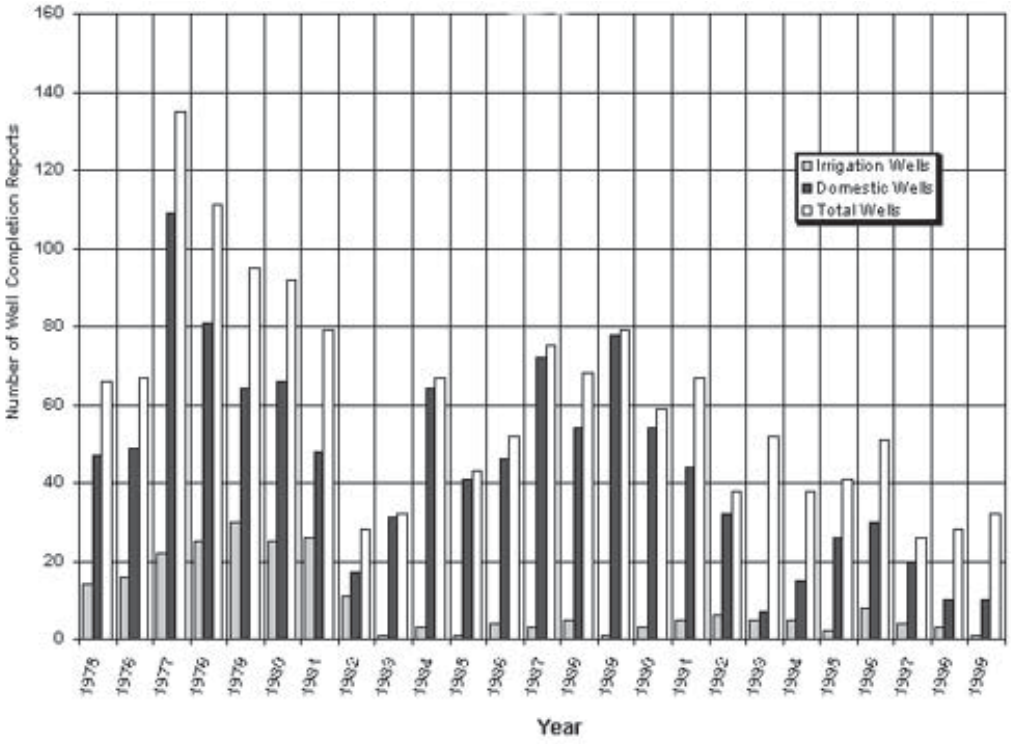


Table 4.
Current Groundwater Monitoring Wells and Estimated Annual Fluctuations in Groundwater Levels, Vina Inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
22N/01E-09J02M	Domestic	Unconfined	1948-2000	5-7	10-16
22N/01E-20K01M	Domestic	Composite	1960-2000	5-10	12-16
22N/01E-28J01M	Observation	Confined	1957-2000	15-20	20-30
22N/01E-28J03M	Observation	Confined	1957-2000	15-20	20-25
22N/01E-28J05M	Observation	Confined	1957-2000	15-20	20-30
22N/01E-28J06M	Domestic	Semi-Confined	1994-2000	20-25	N/A
22N/01W-05M01M	Irrigation	Composite	1946-2000	4-8	10-15
23N/01E-18A01M	Domestic	Composite	1976-2000	3-4	15
23N/01E-29P02M	Domestic	Composite	1990-2000	10-15	N/A
23N/01W-09E01M	Irrigation	Confined	1946-2000	7-10	13-18
23N/01W-09J01M	Irrigation	Confined	1947-2000	10-15	15
23N/01W-14R02M	Stock	Composite	1949-1986	5	15
23N/01W-27L01M	Domestic	Confined	1975-2000	7-19	20-27
23N/01W-36P01M	Domestic	Composite	1959-2000	5-15	25
23N/02W-25C01M	Irrigation	Composite	1966-2000	5-9	10-15

Groundwater hydrographs illustrate changes in groundwater levels over time. Two hydrographs representing the seasonal and long-term changes in groundwater levels for the unconfined and confined aquifer systems in the Vina Inventory Unit are presented in Figures 17 and 18. Additional hydrographs will be presented later in this section during the discussions of groundwater levels at the sub-inventory unit level. Detailed discussions of groundwater level data, hydrograph interpretation, and on-line access to hydrographs for all Butte County groundwater monitoring wells were presented in Section 1.

Figure 17 is a hydrograph for Well 23N/01W-09E01M in the northern Vina Inventory Unit area. The area surrounding this well is characterized by rural and agricultural land uses supported by groundwater. Well 23N/01W-09E01M is an irrigation well constructed in the confined portion of the aquifer system, for which groundwater level measurements date back to the mid-1940s. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until the mid-1970s, on a monthly basis from the mid-1970s to 1996, and are currently monitored four times a year during March, July, August, and October.

Figure 17 shows the seasonal and long-term changes in groundwater levels over time. At first glance, it appears that the annual fluctuations in groundwater levels have increased since 1976. However, prior to 1976, summer groundwater level data were not collected. A comparison of the seasonal fluctuations in groundwater levels using spring to fall data indicates little change since the 1960s.

A long-term comparison of spring-to-spring groundwater levels in Well 23N/01W-09E01M shows a decline in groundwater levels associated with the 1976-77 and 1986-94 droughts, followed by a recovery in groundwater levels to predrought conditions. An overall comparison of the spring-to-spring groundwater level data in Figure 17 indicates that this portion of the basin fully recharges during years of normal precipitation, and there has been little change in groundwater levels in this area since the 1950s and 1960s.

Figure 18 is a hydrograph for Well 22N/01E-09J02M located off Eaton Road just north of Chico. This area is on the northern edge of the CWSC area and is characterized primarily as low density residential. Well 22N/01E-09J02M is a domestic well constructed in the unconfined portion of the aquifer system, for which groundwater level measurements date back to the late 1940s. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until the mid-1990s and are currently monitored four times a year during March, July, August, and October.

Figure 18 shows that the average seasonal fluctuation in groundwater levels is about 10 feet during years of normal precipitation. A long-term comparison of spring-to-spring groundwater levels in Well 22N/01E-09J02M shows a decline in groundwater levels associated with the 1976-77 and 1986-94 droughts, followed by a recovery in groundwater levels to predrought conditions of the early 1970s. A further long-term comparison of spring-to-spring groundwater levels also indicates a 10- to 15-foot decline in groundwater levels since the 1950s.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Groundwater levels for 1997 are considered representative of a normal water year. Spring groundwater levels are commonly the highest of the year and, in areas unaffected by municipal use of

groundwater, reflect the natural groundwater table distribution and direction of movement. Plate 7 shows that the spring groundwater elevations in the Vina Inventory Unit range from an elevation of about 130 feet in the southwestern portion of the inventory unit to an elevation of about 200 feet in the northeast.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. Plate 8 shows that the seasonal groundwater elevation fluctuations for a normal year in the Vina Inventory Unit range from 10 to 20 feet.

Figure 17.
Groundwater Hydrograph for Well 23N/01W-09E01M, Vina Inventory Unit.

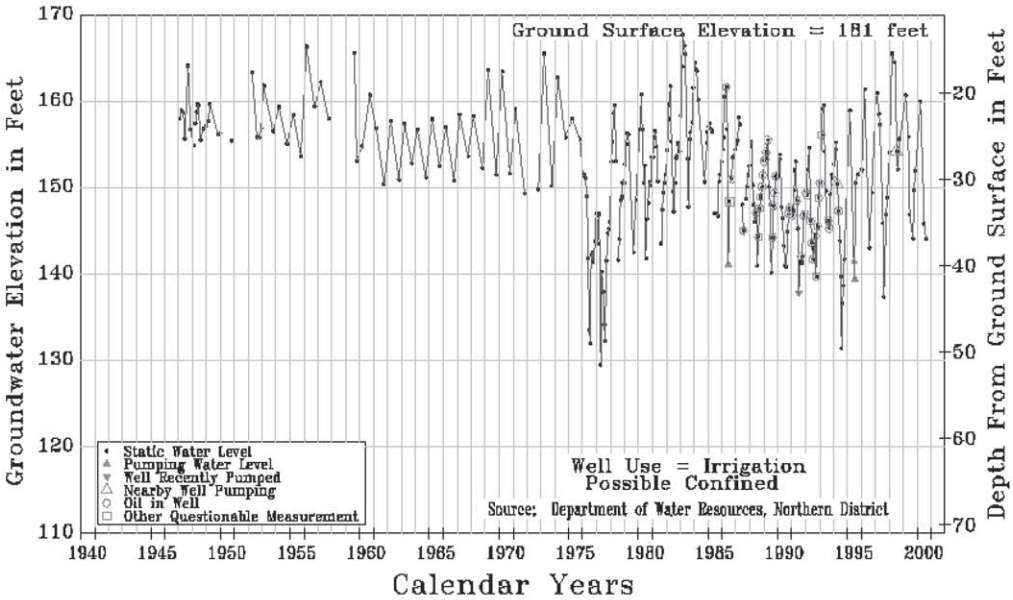
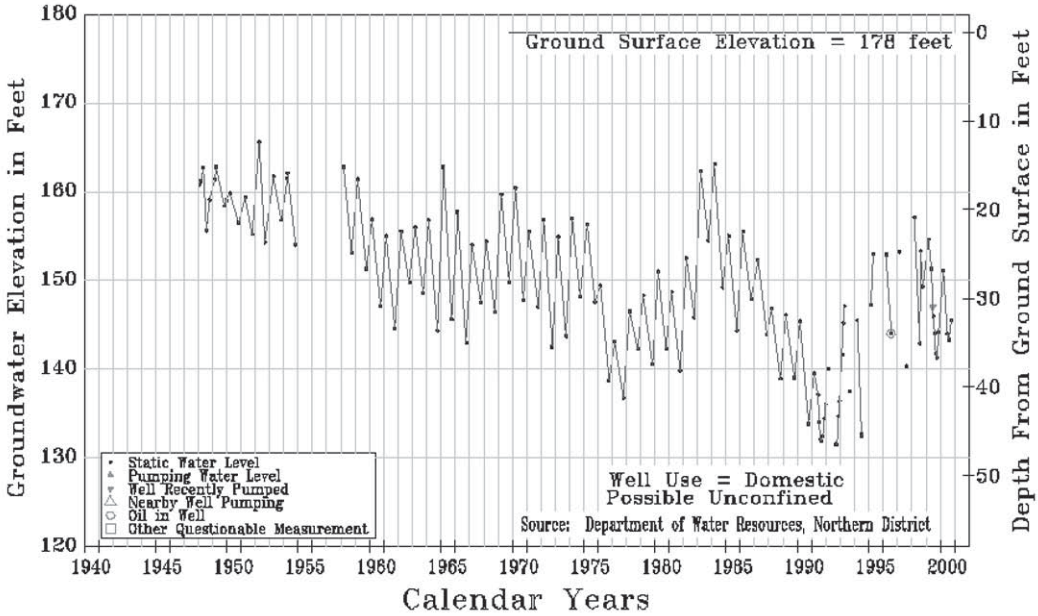


Figure 18.
Groundwater Hydrograph for Well 22N/01E-09J02M, Vina Inventory Unit.



The areas of greatest groundwater elevation decline in the Vina Inventory Unit correlate to those areas dependent on groundwater for agricultural and municipal uses. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). Plate 7 shows that the regional pattern of spring groundwater movement in the Vina Inventory Unit is in a southwesterly direction toward the Sacramento River. Locally, the movement of groundwater fluctuates in the municipal water service area surrounding Chico. Year-round extraction of groundwater for municipal use in the Chico area causes several small groundwater depressions that tend to alter the natural southwestward movement of groundwater in this area.

Groundwater Extraction

Estimates of groundwater extraction in the Vina Inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are summarized in Tables 3 and 4, Appendix B. Groundwater extraction estimates are divided into summer and winter agricultural use, annual municipal and industrial uses, and annual wildlife refuge use. The annual deep percolation estimates are divided into agricultural, municipal, and industrial uses.

The estimated amounts of normal-year groundwater extraction, by type of use, are presented in Table 3, Appendix B, and illustrated in Figure 19. The figure shows that the normal-year groundwater extraction for the Vina Inventory Unit is estimated at about 138 taf. Groundwater extraction of 138 taf represents about 32% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 138 taf of groundwater extracted during a normal year, about 118 taf are for summer agricultural use and about 20 taf are for annual municipal use. Table 3, Appendix B, shows that during a normal year, summer agricultural groundwater is applied to about 35,800 acres for an applied water average of 3.3 af/acre. Table 3 also shows that about 27 taf of the extracted groundwater return to the aquifer via deep percolation during a normal year.

The estimated amounts of drought-year groundwater extraction, by type of use, are presented in Table 4, Appendix B, and illustrated in Figure 20. Figure 20 shows that drought-year groundwater extraction in the Vina Inventory Unit is estimated at about 165 taf, an increase of about 20% over the normal-year extraction estimate. Of the 165 taf of groundwater extracted during a drought year, about 143 taf are for summer agricultural use and about 22 taf are for annual municipal and industrial uses. Table 4, Appendix B, shows that during a drought year, summer agricultural groundwater is applied to about 35,800 acres, for an applied water average of 4 af/acre. Table 4 also shows that about 32 taf of the extracted groundwater return to the aquifer via deep percolation during a drought year.

Figure 19.
Estimated Amounts of Normal-Year Groundwater Extraction by Type of Use, Vina Inventory Unit

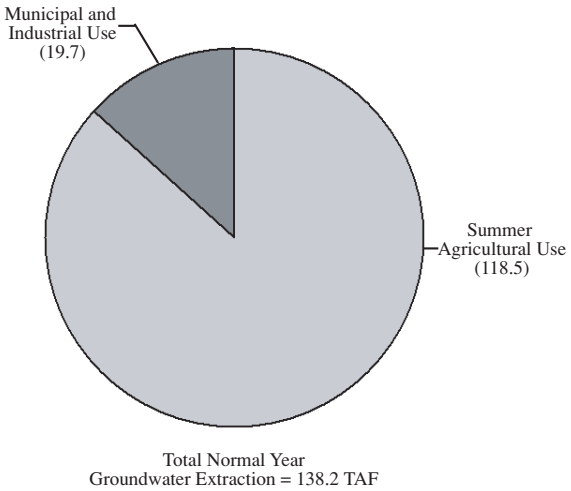
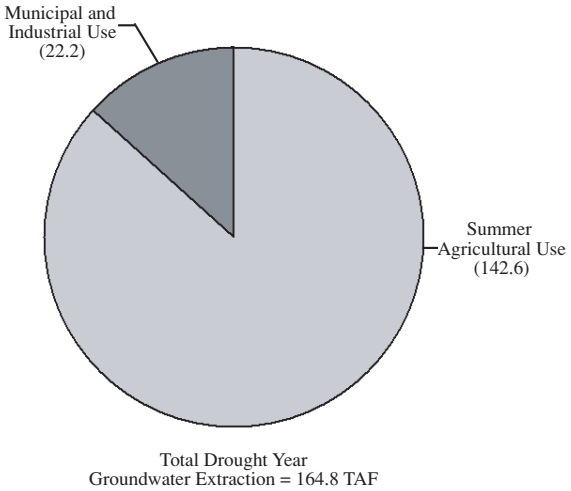


Figure 20.
Estimated Amounts of Drought-Year Groundwater Extraction by Type of Use, Vina Inventory Unit.



Well Depth

Well depth and well use data for the Vina Inventory Unit were collected from well completion reports filed with DWR. A total of 2,768 well records for the Vina Inventory Unit were evaluated and classified into three well types: domestic, irrigation, and municipal. A summary of the minimum, maximum, and average well depths, listed by well type, is presented in Table 5, Appendix B. A statistical distribution of the well depth data was also evaluated through a series of cumulative frequency distribution curves for domestic and irrigation wells. Cumulative frequency curves associated with the Vina Inventory Unit are presented in Figures 21 and 22. Cumulative frequency curves associated with municipal wells within the Vina Inventory Unit will be presented in the California Water Service Sub-inventory Unit section of this report.

Table 5, Appendix B, shows that the majority of wells in the Vina Inventory Unit are for domestic use. The average domestic well depth is about 145 feet. Table 5 also shows that wells drilled for irrigation and municipal uses tend to be deeper than those for domestic use. The average irrigation well depth for the Vina Inventory Unit is 332 feet. The average municipal well depth is 531 feet.

Figure 21 shows the cumulative frequency distribution of well depths for domestic wells in the Vina Inventory Unit. A total of 2,096 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 14 to 754 feet.

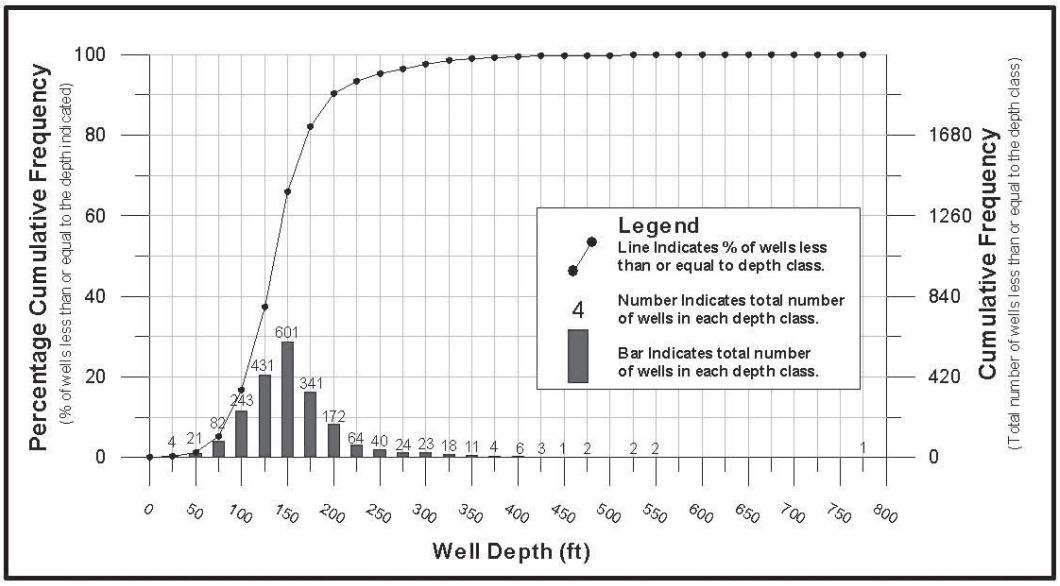
The histogram bars in Figure 21 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the domestic well depth data is fairly symmetrical.

The cumulative frequency curve of domestic well depth data for the Vina Inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 135 feet or less,
- 20% of the wells are installed to a depth of 105 feet or less, and
- 10% of the wells are installed to a depth of 80 feet or less.

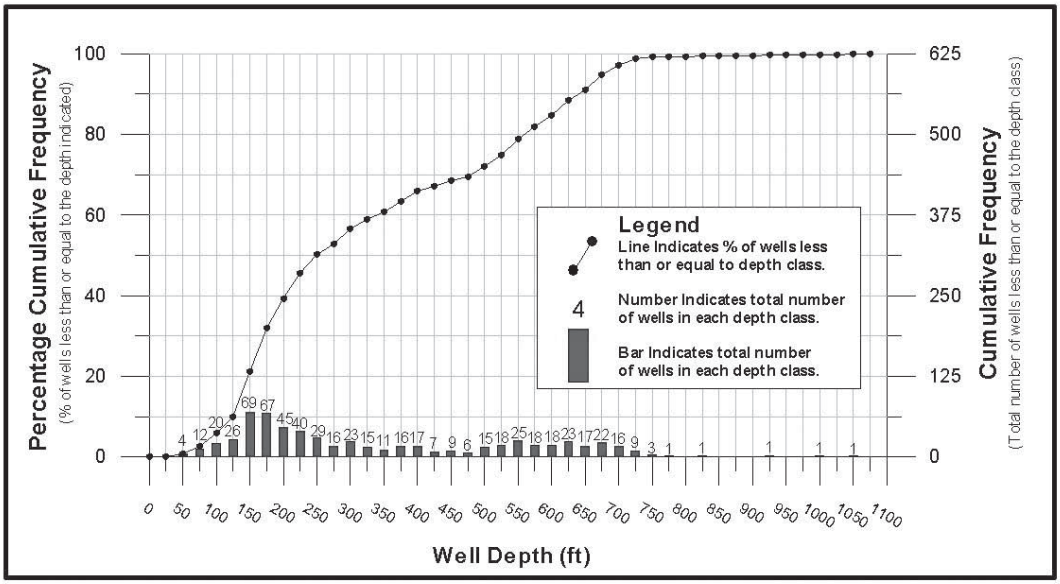
Figure 22 illustrates the cumulative frequency distribution of irrigation well depth data for the Vina Inventory Unit. A total of 621 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 42 to 1,050 feet.

Figure 21.
Cumulative Frequency Distribution of Domestic Wells, Vina Inventory Unit



The histogram bars in Figure 22 show that the distribution of irrigation well depth data is skewed to the right toward deeper well depths. Right-skewed distribution of irrigation well depth data indicates that the average well depth is deeper than the most frequently occurring well depths, or the depth class interval with the greatest number of wells.

Figure 22.
Cumulative Frequency Distribution of Irrigation Wells, Vina Inventory Unit.



The cumulative frequency curve of irrigation well depth data for the Vina Inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 250 feet or less,
- 20% of the wells are installed to a depth of 145 feet or less, and
- 10% of the wells are installed to a depth of 125 feet or less.

Well Yield

Well yield estimates for the Vina Inventory Unit were evaluated based on well completion reports filed with DWR, published and unpublished investigations, and utility pump records from municipal and agricultural wells. A further explanation of well yield data is provided in Section 1. A summary of well yield data is provided in Table 6, Appendix B.

DWR has 676 municipal and irrigation well completion reports on file for the Vina Inventory Unit. Of the 676 reports, only 22 have well yield data. Table 6, Appendix B, shows that the average well yields, based on well completion report data, in the Vina Inventory Unit range from a low of 100 gpm to a high of 3,850 gpm, with an average of 1,227 gpm. Well yield data from well completion reports should serve only as a general guide to local well productivity.

In 1961, Olmsted and Davis of the USGS, compiled utility pump test records for 21 areas within the Sacramento Valley. Three of these areas - Chico, Gridley and Honcut - are located almost entirely in the Butte County portion of the Sacramento Valley. The Chico area corresponds to the sum of the entire Vina Inventory Unit, the entire West Butte Inventory Unit, and the East Butte Inventory Unit north of Nelson. The 1961 USGS utility data listed in Table 6, Appendix B, represent 498 pump tests taken in the Chico area prior to 1959. Table 6 shows that the average well yield in the Chico area, as reported in the 1961 USGS report, is 1,000 gpm.

Estimates of well yield for the Vina Inventory Unit were also evaluated from utility pump test data. The well yield estimates for the Vina Inventory Unit, shown in Table 6, Appendix B, represent data from 788 pump tests performed on 314 wells between

1989 and 1998. Table 6, Appendix B, shows that the well yields for the Vina Inventory Unit range from a low of 88 gpm to a high of 4,473 gpm, with an average well yield of 1,395 gpm. Utility pump tests are generally used to provide an accurate estimate of well yield.

Specific Capacity

Specific capacity estimates for the Vina Inventory Unit were evaluated based on utility pump test records and on published investigations. The utility records represent pump test data from primarily municipal and agricultural wells. An explanation of specific capacity is provided in Section 1. A summary of specific capacity data is provided in Table 7, Appendix B. Table 7, Appendix B, shows that the specific capacity estimates from utility pump test records for the Vina Inventory Unit range from a low of 9 gpm/ft to a high of 244 gpm/ft. The average specific capacity in the Vina Inventory Unit, as estimated from utility pump test data, is 87 gpm/ft. The specific capacity estimates shown in Table 7 represent 284 pump tests performed on 155 wells between 1989 and 1998. Utility pump tests are generally considered to provide a good estimate of specific capacity.

In 1961, Olmsted and Davis of the USGS, compiled utility pump test records for 21 areas within the Sacramento Valley. Three of these areas - Chico, Gridley and Honcut - are located within Butte County portion of the Sacramento Valley. The Chico area corresponds to the sum of the entire Vina Inventory Unit, the entire West Butte Inventory Unit, and the East Butte Inventory Unit north of Nelson. The 1961 USGS utility data listed in Table 7, Appendix B, represent 498 pump tests taken in the Chico area prior to 1959. Table 7 shows that the average specific capacity for the Chico area, as reported in the 1961 USGS report, is 51 gpm/ft.

Groundwater Storage Capacity

For the purposes of this investigation, groundwater storage capacity is defined as the maximum volume of fresh groundwater capable of being stored within an aquifer beneath a given area. Estimates of storage capacity were calculated by multiplying the area of the Vina Inventory Unit by the maximum saturated thickness and the average specific yield of the freshwater portion of the aquifer. A further explanation of groundwater storage estimates is provided in Section 1. Estimates of maximum groundwater storage capacity are listed in Table 8, Appendix B.

Table 8, Appendix B, shows that the Vina Inventory Unit covers an area of about 75,000 acres. Groundwater storage capacity estimates for the Vina Inventory Unit assume uniform aquifer saturation from a depth of 10 feet, down to the average base of freshwater at a depth of about 1,600 feet, and an average specific yield of 7.1%. Based on the above assumptions, the estimated maximum groundwater storage capacity for the Vina Inventory Unit is about 8,500 taf.

Groundwater in Storage

Groundwater in storage is defined as the volume of water contained within the aquifer system at the time of measurement. Estimates of groundwater in storage in the Vina Inventory Unit were examined using three scenarios:

- the estimated volume of groundwater currently in storage over the entire freshwater portion of the aquifer system,
- the estimated seasonal decline in groundwater levels associated with the removal of groundwater in storage during a normal water year, and

- the estimated seasonal decline in groundwater levels associated with the removal of groundwater in storage during a drought water year.

The estimated amounts of groundwater in storage are listed in Table 9, Appendix B. The estimated seasonal declines in groundwater levels during normal and drought years are provided in Table 10, Appendix B. A further explanation of groundwater in storage is provided in Section 1.

- Estimated Volume of Groundwater in Storage. The Vina Inventory Unit covers an area of about 75,000 acres. Groundwater in storage estimates for the Vina Inventory Unit assume uniform aquifer saturation from an average depth of 26 feet, down to the average base of freshwater at a depth of about 1,600 feet, and an average specific yield of 7.1%. The average depth of groundwater in the Vina Inventory unit is based on spring 1997 groundwater level measurements. Using the above assumptions, the volume of groundwater in storage for the Vina Inventory Unit is estimated at 8,400 taf. A comparison of groundwater storage capacity and groundwater in storage estimates in Tables 8 and 9, Appendix B, indicates that groundwater in storage in the Vina Inventory Unit is slightly less than maximum capacity during normal water years.
- Estimated Seasonal Decrease of Groundwater in Storage associated with Normal-Year Extraction. In the Vina Inventory Unit, seasonal groundwater extraction is estimated at 100% of the summer agricultural extraction, plus 70% of the annual municipal extraction, minus 30% of the annual deep percolation. Based on the above assumptions, the seasonal groundwater demand for the Vina Inventory Unit during a normal year is estimated at about 124 taf. The average seasonal decline in groundwater levels associated with a normal-year groundwater extraction is estimated at 23 feet.
- Estimated Seasonal Decrease of Groundwater in Storage associated with Drought-Year Extraction. The drought-year groundwater demand for the Vina Inventory Unit was adjusted to reflect seasonal use during a drought water year. Seasonal groundwater extraction is estimated at 100% of the summer agricultural extraction, plus 70% of the annual municipal extraction, minus 30% of the annual deep percolation. Based on the above assumptions, the seasonal groundwater demand in the Vina Inventory Unit during a drought year is estimated at about 149 taf. The average seasonal decline in groundwater levels associated with a drought-year groundwater extraction is about 28 feet.

Changes in the Volume of Groundwater in Storage

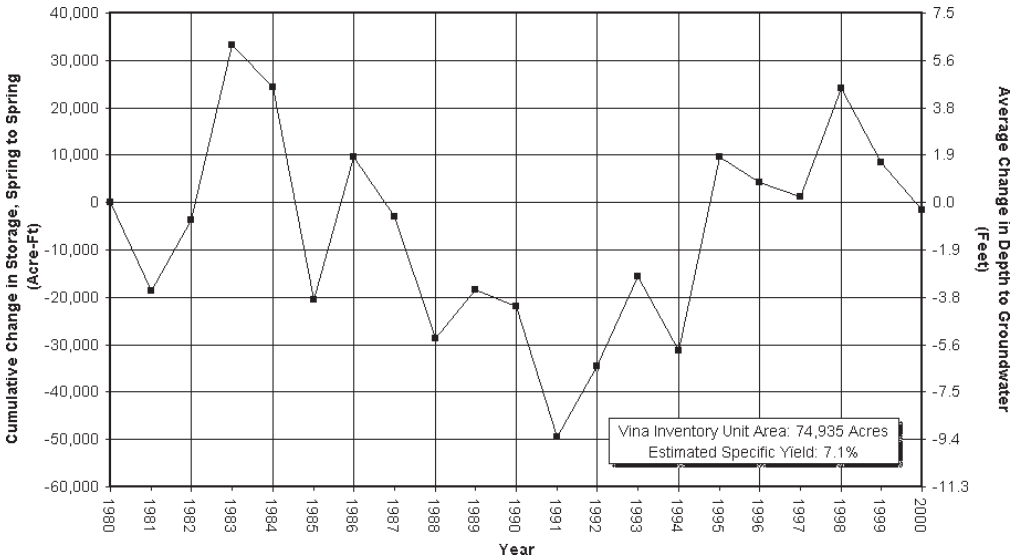
The annual spring-to-spring changes in the volume of groundwater in storage for the Vina Inventory Unit were calculated over a 20-year period from 1980 to 2000. The changes in the volume of groundwater in storage are based on groundwater contour maps developed from spring groundwater level measurements in the upper portion of the aquifer. Changes in the volume of groundwater in storage data for the Vina Inventory Unit are provided in Table 11, Appendix B, and illustrated in Figure 23 below. A further explanation of methods for estimating changes in groundwater in storage is provided in Section 1.

Table 11, Appendix B, lists the annual changes in the volume of groundwater in storage, the cumulative changes in the volume of groundwater in storage and the changes in groundwater levels associated with the cumulative changes in the volume of groundwater in storage for the Vina Inventory Unit. Table 11 shows that the largest single-year decline in spring-to-spring volume of groundwater in storage for the Vina

Inventory Unit was about 45 taf in 1984-85. The largest single-year increase in the volume of groundwater in storage was about 41 taf in 1994-95.

The cumulative spring-to-spring changes in storage for the Vina Inventory Unit are illustrated in Figure 23. The spring-to-spring changes in storage graph starts with a baseline of zero for spring 1980 and shows cumulative changes from 1980 to 2000. Figure 23 shows that the groundwater in storage increased during the wet years of 1983 and 1986, decreased during the drought of the early 1990s, and then gradually recovered over the next 5 years. The fluctuation in groundwater in storage between the peak in 1983 and the low in 1991 is estimated at about 83 taf. Overall, the amount of groundwater in storage in the Vina Inventory Unit during spring 2000 was about the same as during the of spring 1980.

Figure 23.
Estimated Cumulative Changes in Spring-to-Spring Storage, Vina Inventory Unit



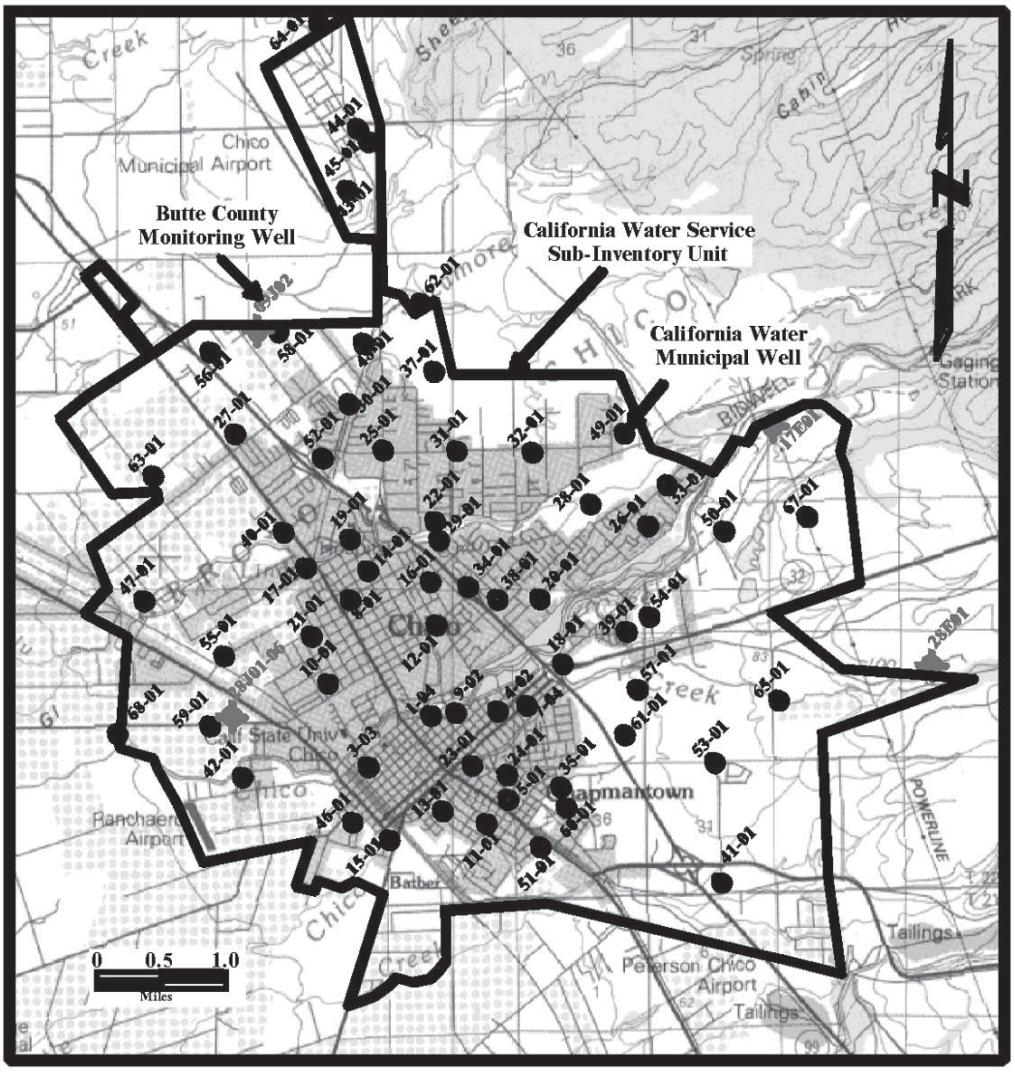
California Water Service Sub-inventory Unit

The California Water Service Sub-inventory Unit covers an area of about 15,400 acres in the greater Chico urban area and is split between the Vina and West Butte inventory units (see Plate 1, Appendix A). The sub-inventory unit boundary corresponds roughly to the municipal water service area for the City of Chico, which is operated by the CWSC. The company supplies groundwater to the Chico area through the operation of about 66 groundwater wells. Those wells, along with DWR and Butte County monitoring wells, are shown below in Figure 24 and in Plate 6, Appendix A.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the California Water Service Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

Figure 24.
Municipal and Monitoring Well Locations,
California Water Service Sub-inventory Unit



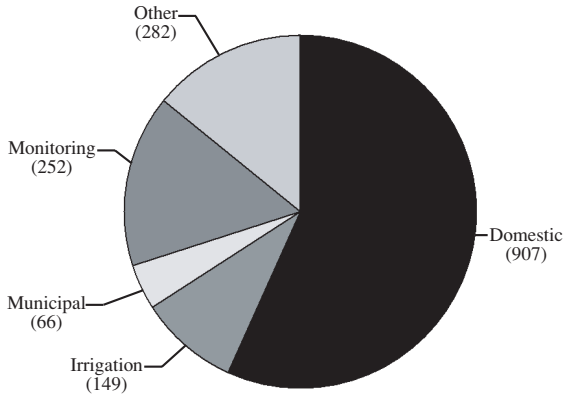
There are about 1,600 wells in the California Water Service Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 907 wells are listed as domestic, 149 are listed as irrigation, 66 are listed as municipal, 252 are listed as monitoring, and 228 are listed as other. Figure 25 illustrates the breakdown of wells by use for the California Water Service Sub-inventory Unit.

Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 7 wells within the California Water Service Sub-inventory Unit. The monitoring wells consist of domestic and observation wells. Table 5 lists the current monitoring wells along with the annual fluctuations in groundwater levels during normal and drought years. Table 5 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record.

Data from the Butte County monitoring grid in Table 5 shows that the annual fluctuations in groundwater levels in the unconfined portion of the aquifer system are

Figure 25.
Number of Wells by Use, California Water Service Sub-inventory Unit



Total Number of Wells = 1602

Table 5.
Current DWR and Butte County Monitoring Wells,
California Water Service Sub-inventory Unit

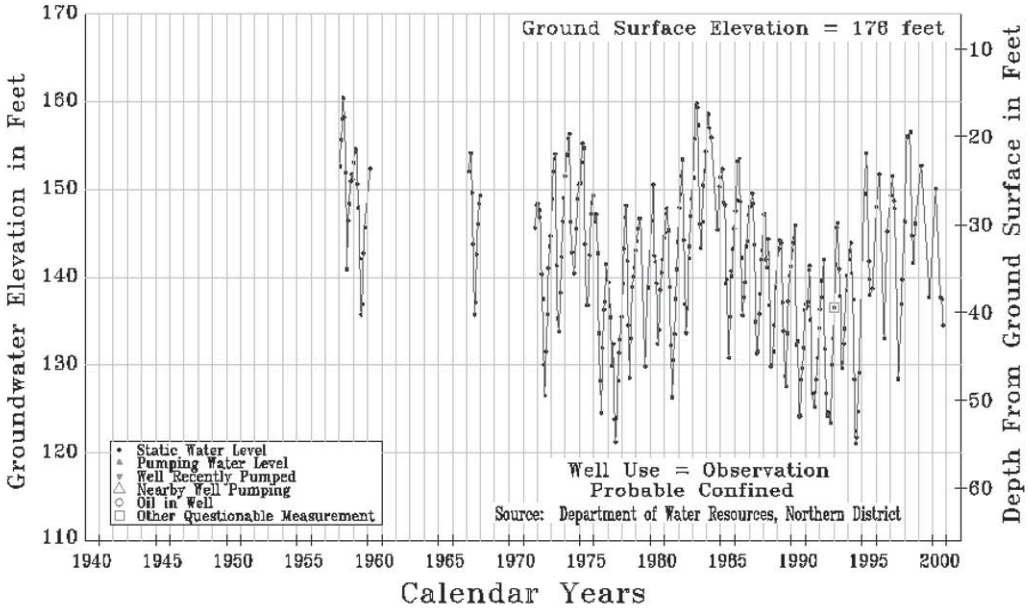
State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
22N/01E-09J02M	Domestic	Unconfined	1948-2000	5-7	10-16
22N/01E-28J01M	Observation	Confined	1957-2000	15-20	20-30
22N/01E-28J03M	Observation	Confined	1957-2000	15-20	20-25
22N/01E-28J05M	Observation	Confined	1957-2000	15-20	20-30
22N/01E-28J06M	Domestic	Semi-Confined	1994-2000	20-25	N/A
22N/02E-17E01M	Domestic	Confined	1953-1999	3-7	N/A
22N/02E-28E01M	Domestic	Confined	1995-2000	3-5	N/A

about 5 to 7 feet during years of normal precipitation and up to about 16 feet during years of drought. Annual fluctuations in groundwater levels in the confined or semi-confined portions of the aquifer system are 15 to 25 feet during normal years and up to 30 feet during drought years.

Groundwater hydrographs illustrate seasonal and long-term changes in groundwater levels over time. Figure 26 is a hydrograph for Well 22N/01E-28J03M located in the western portion of the California Water Service Sub-inventory Unit, which is monitored by DWR and BCDWRC. This well is located in a medium-density residential area. Well 22N/01E-28J03M is an observation well constructed in the confined portion of the aquifer system, for which groundwater level measurements date back to the late 1950s. The groundwater levels in this well were monitored on a monthly basis until about 1996 and are currently monitored four times a year during March, July, August, and October.

Figure 26 shows that the seasonal fluctuation in groundwater levels during a normal year is about 20 feet. A long-term comparison of spring-to-spring groundwater levels in Well 22N/01E-28J03M shows a decline in groundwater levels associated with the 1976-77 and 1986-94 droughts, followed by a recovery in groundwater levels to the

Figure 26.
Groundwater Hydrograph for Well 22N/01E-28J03M,
California Water Service Sub-inventory Unit



predrought conditions of the 1970s. A further long-term comparison of spring-to-spring groundwater levels indicates a 5- to 10-foot decline in groundwater levels since the 1950s.

In addition to the groundwater level monitoring conducted by BCDWRC and DWR, the CWSC currently measures monthly groundwater levels in about 66 municipal groundwater supply wells in the Chico urban area. CWSC wells are typically constructed to produce from the middle to lower portion of the aquifer system.

Groundwater hydrographs for CWSC monitoring wells were developed using static groundwater level data. However, it should be noted that the effects from the recent pumping of these production wells could result in groundwater level readings that are deeper than stable static conditions. Hydrographs from five CWSC wells in the California Water Service Sub-inventory Unit are illustrated in Figures 27 through 32.

Overall analysis of the seasonal fluctuations in groundwater levels in CWSC wells indicates a rather consistent seasonal fluctuation of 15 to 20 feet during normal years. An analysis of seasonal groundwater levels during drought years shows a wide range of fluctuations depending on the individual well. Many wells show little or no seasonal changes between wet, normal and dry years, while others show large differences. The wide range of responses to seasonal changes in normal versus drought years is likely due to the wide range of operational scenarios that can be imposed on these municipal wells.

Long-term changes in groundwater levels in the California Water Service Sub-inventory Unit were determined through evaluation of 45 CWSC wells, for which groundwater level measurements date back to 1978. Using the 1978 to 2000 data, hydrographs were developed and a trend line through the groundwater measurements was calculated. The slope of the trend line illustrates the average changes in groundwater levels per well over the 20-year period. For reference, the average annual precipitation between 1978 and 2000 was also reviewed and determined to be about 8% higher than the 130-year average for the area.

Figure 27.
Groundwater Hydrograph for CWSC Well 1-04

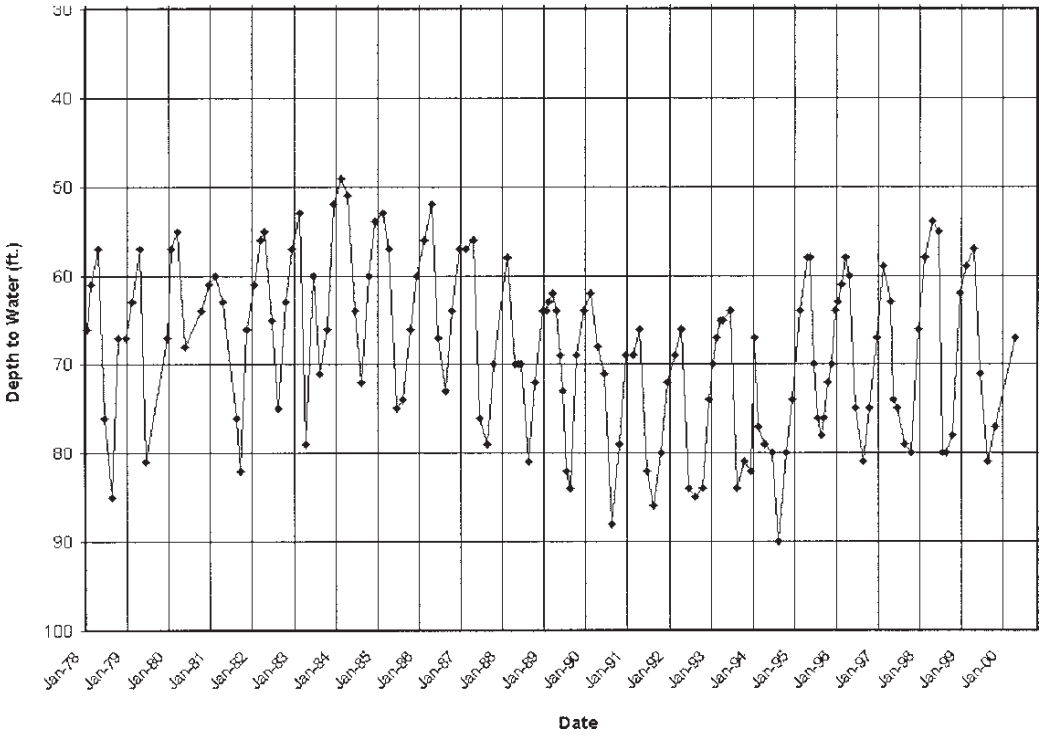


Figure 28.
Groundwater Hydrograph for CWSC Well 27-01

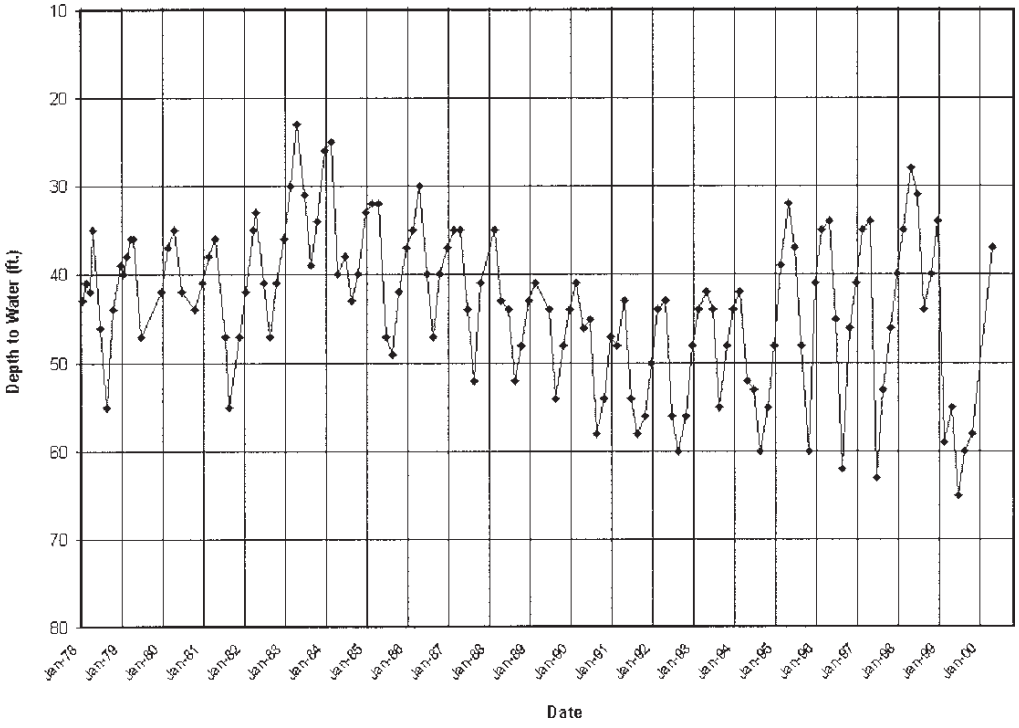


Figure 29.
Groundwater Hydrograph for CWSC Well 33-01

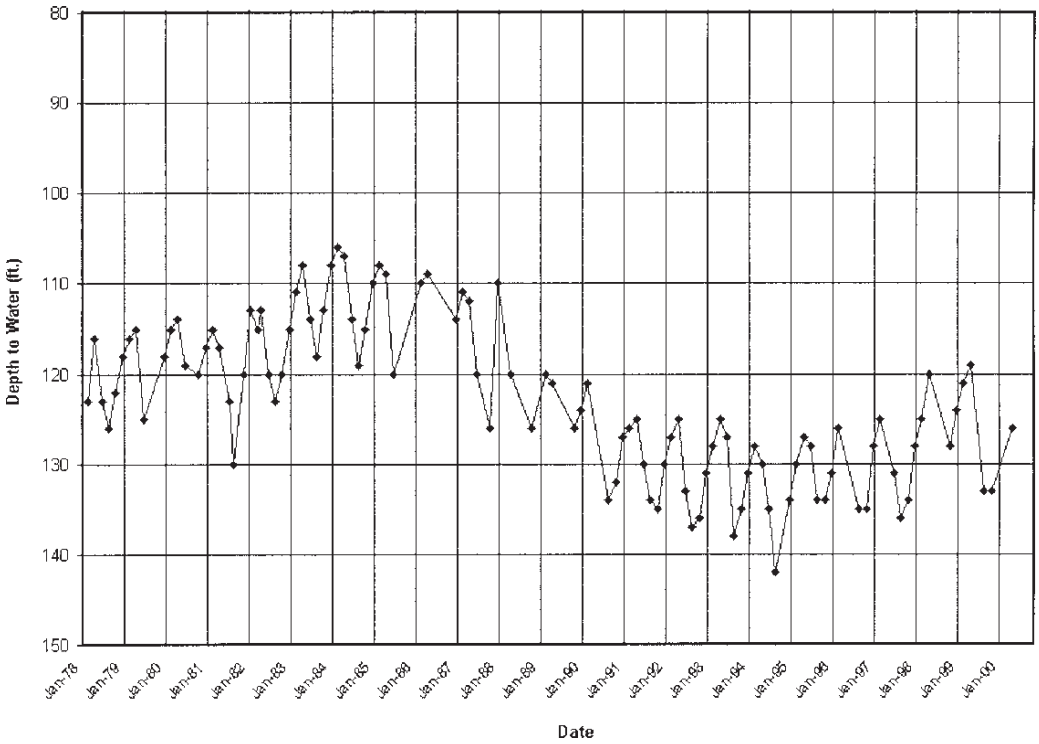


Figure 30.
Groundwater Hydrograph for CWSC Well 34-01

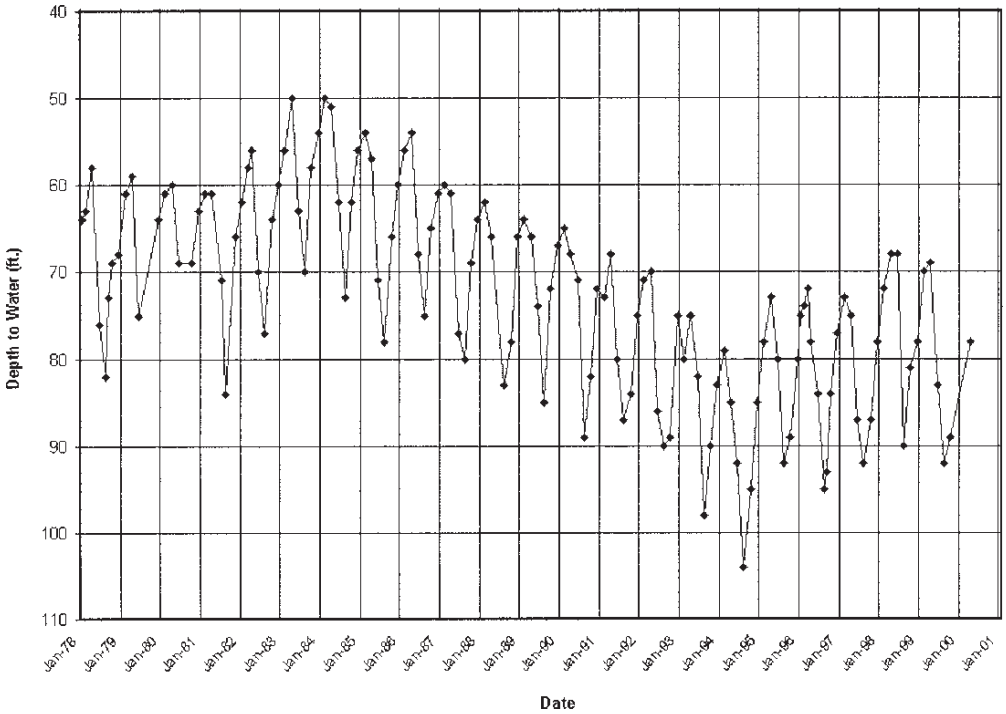


Figure 31.
Groundwater Hydrograph for CWSC Well 41-01

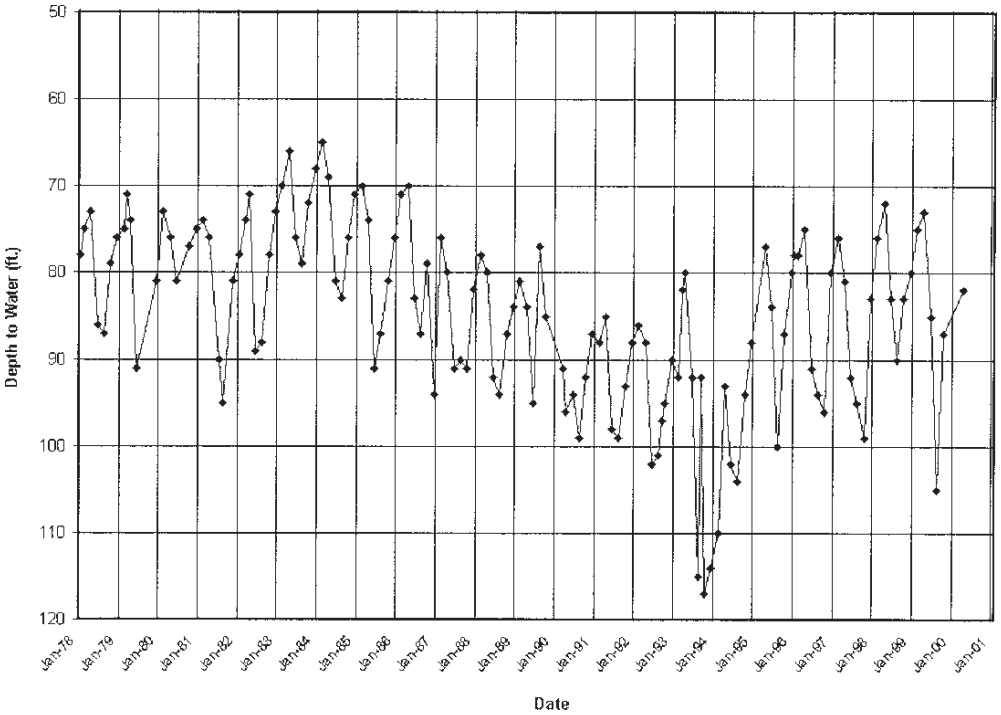
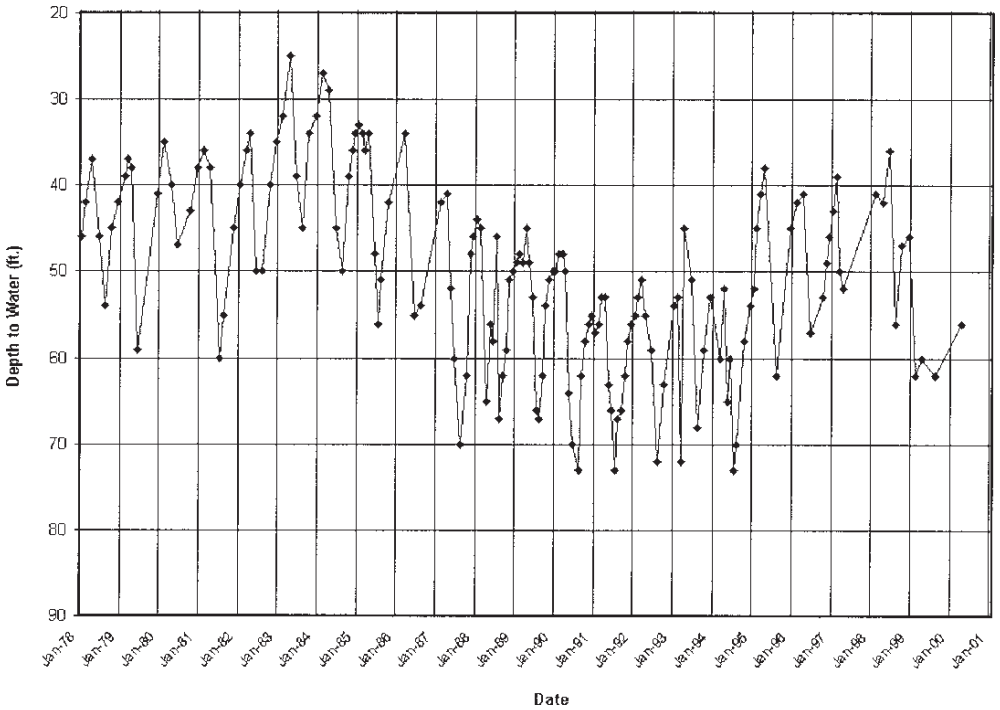


Figure 32.
Groundwater Hydrograph for CWSC Well 46-01



The results of the groundwater level trend line analysis varied significantly from well to well. However, overall analysis indicates that groundwater levels in the California Water Service Sub-inventory Unit have declined an average of 12 feet between 1978 and 2000 with most of the decline occurring during the 1987-1994 drought. Of the 45 CWSC wells examined, groundwater levels increased in 1 well, declined by 0 to 5 feet in 7 wells, and declined greater than 5 feet in 37 wells. Of the 37 wells showing a groundwater level decline of greater than 5 feet between 1978 and 2000, 13 wells declined by 5 to 10 feet, 16 wells declined by 10 to 15 feet, and 8 wells declined by greater than 20 feet. An analysis of the hydrograph data also indicates that groundwater levels in the CWSC wells have stabilized since recovery from the early 1990s drought.

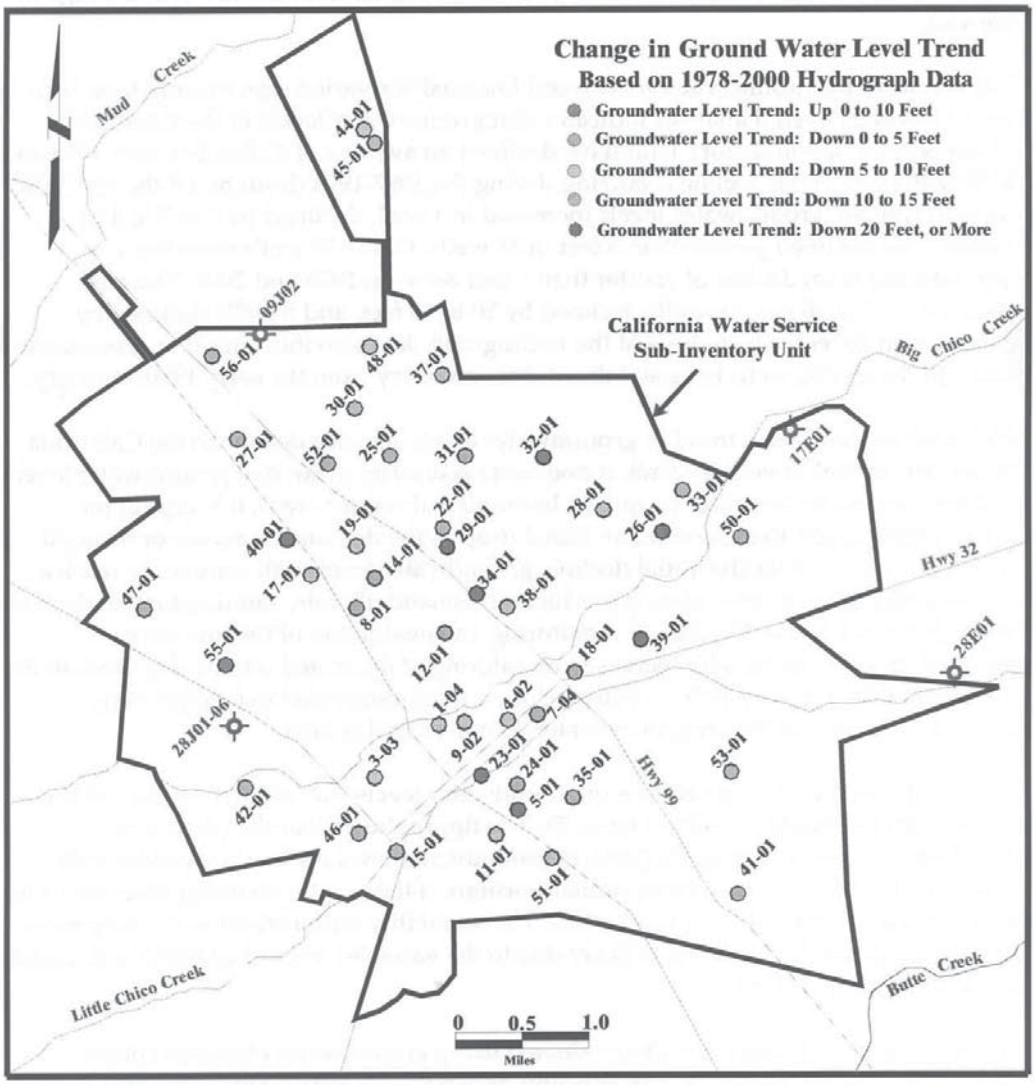
Although the long-term trend of groundwater levels shows a decline in the California Water Service Sub-inventory Unit, it does not necessarily mean that groundwater levels will continue to decline into the future. In municipal service areas, it is typical for groundwater levels to experience an initial drop as the demand increases or drought conditions occur. After the initial decline, groundwater levels will commonly reach a new equilibrium with the existing production demand, thereby limiting further declines in groundwater levels. Continued monitoring and evaluation of the municipal production wells, along with increased monitoring of dedicated monitoring wells in the California Water Service Sub-inventory Unit, are recommended to help properly evaluate and manage future groundwater resources in this area.

A summary of the 20-year changes in groundwater levels was plotted for each of the 45 wells and is shown below in Figure 33. The figure shows that the plan-view distribution of wells having the greatest groundwater level decline is variable, with nearby wells often drawing from similar portions of the aquifer showing little similarity to the changing groundwater level trend. The variability with respect to the long-term changes in groundwater levels is likely due to the variable range of operations imposed on these municipal wells.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. In most portions of the basin, spring groundwater elevations are at their highest point of the year and reflect stable groundwater table conditions. In the California Water Service Sub-inventory Unit, continued use of the aquifer system for municipal water needs results in local variations in the groundwater table throughout the year. Plate 7, Appendix A, shows the variable nature of groundwater elevations in the California Water Service Sub-inventory Unit during spring 1997. The groundwater elevations in this sub-inventory unit generally range from 130 to 150 feet.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. Plate 8 shows that the seasonal groundwater elevation fluctuations for a normal year in the California Water Service Sub-inventory Unit range from 10 to 25 feet. The areas of greatest decline largely coincide with the earliest developed portions of Chico, such as the downtown area, Chapmantown, and the “avenues” area along the Esplanade.

Figure 33.
Historic Changes in Groundwater Levels for CWSC Wells



Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). The plate shows that the regional pattern of spring groundwater movement in the California Water Service Sub-inventory Unit is in a southwesterly direction – toward the Sacramento River. Locally, the movement of groundwater varies in the municipal area surrounding Chico. Year-round extraction of groundwater for municipal use in the Chico area causes several small groundwater depressions that tend to alter the natural southwestward movement of groundwater in this area.

Groundwater Extraction

Estimates of groundwater extraction in the California Water Service Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B.

Table 3, Appendix B, shows that the normal-year groundwater extraction for the California Water Service Sub-inventory Unit is estimated at 30 taf. Groundwater extraction of 30 taf represents 7% of the total amount of groundwater extracted from the valley portion of Butte County during a normal year. All of the groundwater extraction in the California Water Service Sub-inventory Unit is dedicated to municipal and industrial uses. Groundwater extracted for municipal use serves an area of about 15,400 acres. Table 3 also shows that about 9.4 taf of the extracted groundwater return to the aquifer via deep percolation during a normal year.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show drought-year groundwater extraction estimated at 34 taf, an increase of about 13% over normal-year extraction estimate. Table 4 also shows about 10.3 taf of the extracted groundwater return to the aquifer via deep percolation during a drought year.

Well Depth

A total of 1,122 well records for the California Water Service Sub-inventory Unit were evaluated and classified into three well types: domestic, irrigation, and municipal. A summary of the minimum, maximum, and average well depths, listed by well type, is presented in Table 5, Appendix B. A statistical distribution of the well depth data was also evaluated though a series of cumulative frequency distribution curves for domestic, irrigation, and municipal wells. Cumulative frequency distribution curves for the California Water Service Sub-inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the California Water Service Sub-inventory Unit are for domestic use. The average domestic well depth is 138 feet. Table 5 also shows that wells drilled for irrigation and municipal uses tend to be deeper than those for domestic use. The average irrigation well depth for the California Water Service Sub-inventory Unit is 262 feet. The average municipal well depth is 596 feet.

The cumulative frequency distribution of domestic well depths for the California Water Service Sub-inventory Unit is shown in Figure 34. A total of 907 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 14 to 754 feet.

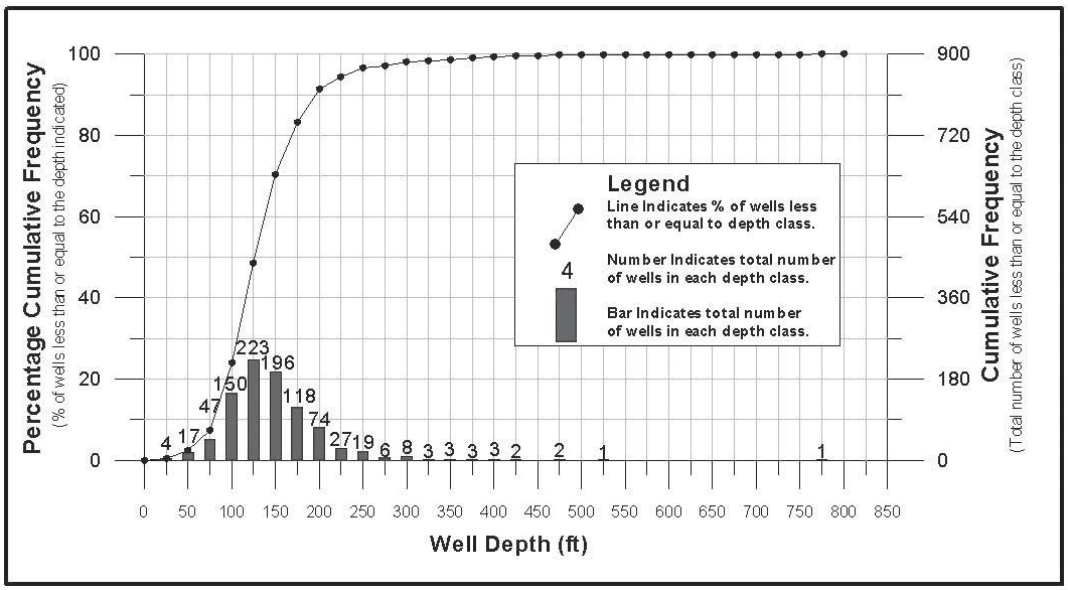
The histogram bars in Figure 34 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the domestic well depth data is fairly symmetrical. Symmetrical distribution of domestic well depth data indicates that an equal number of wells exist on either side of the most frequently occurring well depth.

The cumulative frequency curve of domestic well depth data for the California Water Service Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 130 feet or less,
- 20% of the wells are installed to a depth of 90 feet or less, and
- 10% of the wells are installed to a depth of 70 feet or less.

Figure 35 illustrates the cumulative frequency distribution of irrigation well depth data in the California Water Service Sub-inventory Unit. A total of 149 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 40 to 620 feet.

Figure 34.
Cumulative Frequency Distribution of Domestic Wells,
California Water Service Sub-inventory Unit



The histogram bars in Figure 35 show that the distribution of irrigation well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the California Water Service Sub-inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of irrigation well depth data for the California Water Service Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 235 feet or less,
- 20% of the wells are installed to a depth of 135 feet or less, and
- 10% of the wells are installed to a depth of 100 feet or less.

Figure 36 illustrates the cumulative frequency distribution of municipal well depth data for the California Water Service Sub-inventory Unit. A total of 66 municipal wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The municipal wells range in depths from 380 to 924 feet, with an average depth of 596 feet.

The histogram in Figure 36 shows that the distribution of municipal well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the municipal well depth data indicates that there is a wide range of municipal well depths within the California Water Service Sub-inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of municipal well depth data for the California Water Service Sub-inventory Unit shows that:

- 50% of the municipal wells are installed to a depth of 580 feet or less,
- 20% of the wells are installed to a depth of 500 feet or less, and
- 10% of the wells are installed to a depth of 475 feet or less.

Figure 35.
Cumulative Frequency Distribution of Irrigation Wells,
California Water Service Sub-inventory Unit

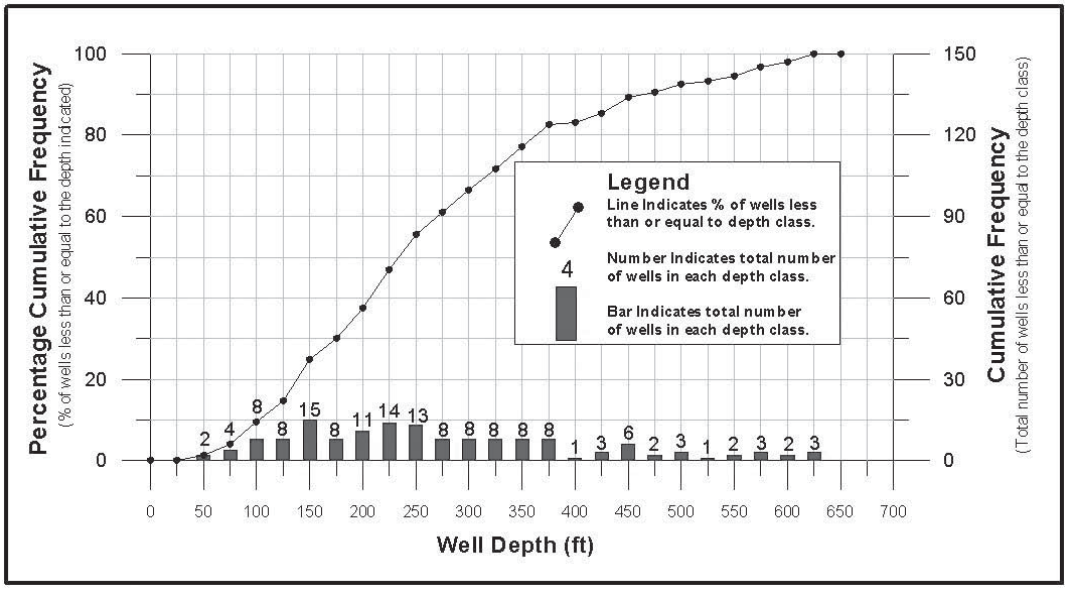
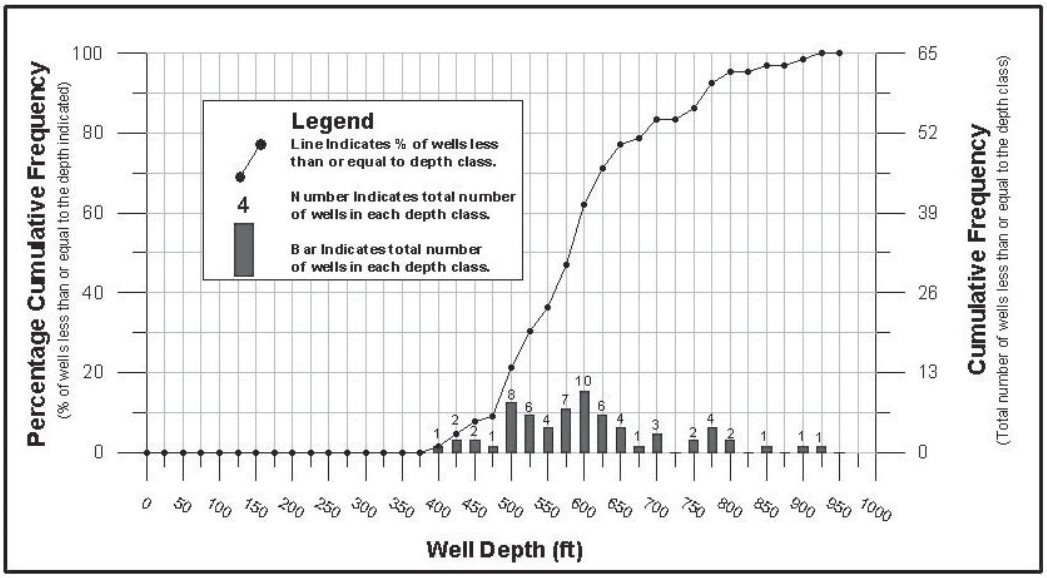


Figure 36.
Cumulative Frequency Distribution of Municipal Wells,
California Water Service Sub-inventory Unit



West Butte Inventory Unit

The West Butte Inventory Unit covers about 86,500 acres in the north-central valley portion of Butte County (Plate 1, Appendix A). It is bordered by Big Chico Creek to the north, Butte Creek to the south, the Sacramento River to the west and the foothills to the east. In a normal year, about 40% of the West Butte Inventory Unit is in summer agricultural production supported by groundwater. Another 8% to 10% of the total area is within the CWSC area, which uses groundwater as a municipal water source for much of the Chico urban area. The West Butte Inventory Unit fully encompasses the Durham-Dayton, M&T, Angel Slough and Llano Seco sub-inventory units. These areas will be presented in detail during discussions of sub-inventory units later in this section. The California Water Service and Western Canal sub-inventory units are only partly contained within the West Butte Inventory Unit and will not be discussed in the West Butte Inventory Unit section of this report. The California Water Service Sub-inventory Unit was presented under the Vina Inventory Unit above, and the Western Canal Sub-inventory Unit will be presented under the East Butte Inventory Unit later in this report. However, the well distribution, well use, and well depth data presented in this section will include all full and partial sub-inventory units that fall within the West Butte Inventory Unit.

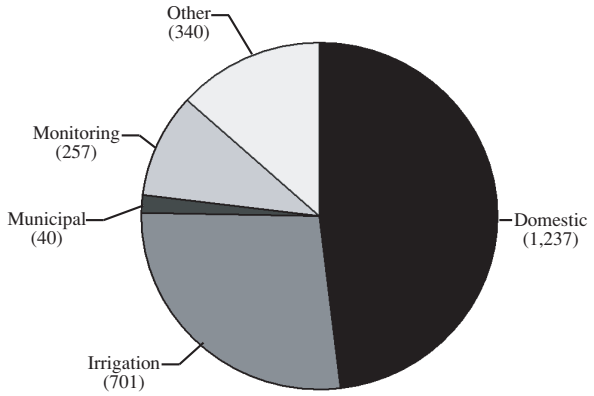
Well Distribution

The well completion report database files at DWR were analyzed to determine the number, types, dates of installation and distribution of wells in the West Butte Inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data by area and by installation date is provided in Tables 1 and 2, Appendix B.

There are 2,575 documented wells in the West Butte Inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 1,237 wells are listed as domestic, 701 are listed as irrigation, 40 are listed as municipal, 257 are listed as monitoring, and 340 are listed as other. Figure 37 illustrates the breakdown of wells by use for the West Butte Inventory Unit.

Wells in the West Butte Inventory Unit were also analyzed to determine the number and types of wells installed over time. Examination of the number and types of wells

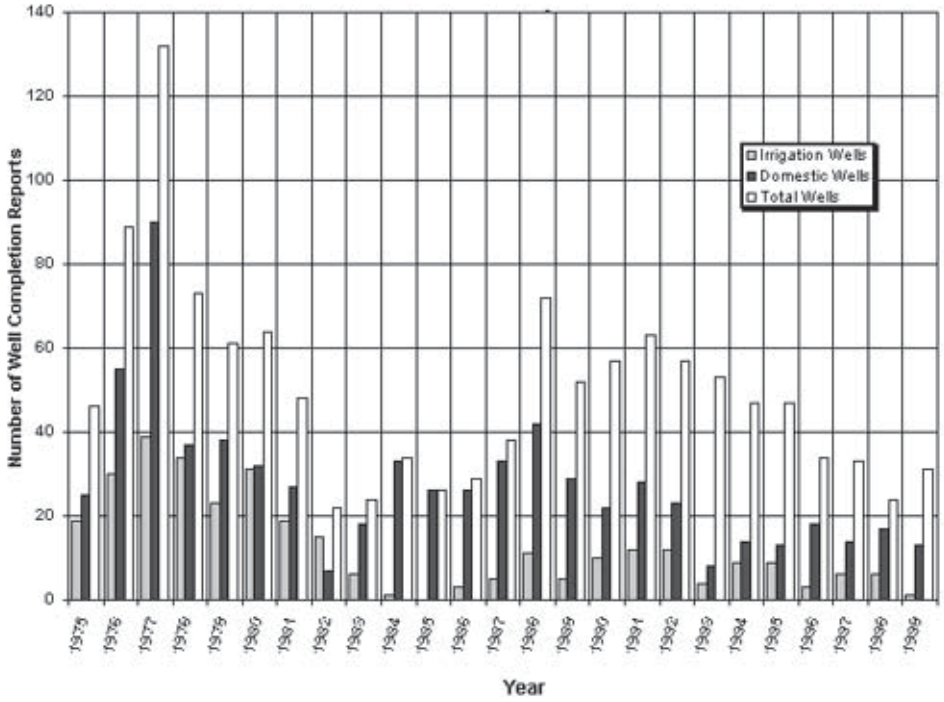
Figure 37.
Number of Wells by Use, West Butte Inventory Unit



Total Number of Wells = 2,575

drilled over time can help offer a perspective on the average age of the existing infrastructure, as well as the approximate number of wells installed during normal and drought years. Table 2, Appendix B, lists the annual number and types of wells drilled in the West Butte Inventory Unit between 1975 and 1999. The wells in Table 2 are divided into domestic, irrigation, miscellaneous, and total. Table 2, Appendix B, shows that 916 wells were drilled in the West Butte Inventory Unit between 1975 and 1999. The number of wells drilled per year range from a low of 22 in 1982, to a high of 132 in 1977, with an average of about 37 wells per year. About 68% of the wells drilled during 1982 are listed as domestic and 30% are listed as irrigation. About 33% of the wells drilled during 1977 are listed as domestic and 67% are listed as irrigation. Figure 38 illustrates the number of well completion reports filed per year for the West Butte Inventory Unit.

Figure 38.
Number of Well Completion Reports Filed Per Year, West Butte Inventory Unit



Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 26 wells within the West Butte Inventory Unit. The monitoring wells consist of a combination of domestic, irrigation, observation, and unused wells. Table 6 lists the current monitoring wells along with the annual fluctuations in groundwater levels during normal and drought years. Table 6 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. The groundwater monitoring wells are shown on Plate 6, Appendix A.

Historic groundwater level data for the West Butte Inventory Unit indicate that the annual fluctuations in groundwater levels in the unconfined portion of the aquifer system are about 3 to 5 feet during years of normal precipitation and up to about 8 feet during years of drought. Composite monitoring wells measure a combined groundwater level in multiple water-bearing zones within the aquifer system. Annual fluctuations in groundwater levels within the composite section of the aquifer system average about 10 feet during normal years and up to 40 feet during years of drought.

Annual fluctuations in groundwater levels in the confined or semi-confined portions of the aquifer system are about 10 to 25 feet during normal years and up to 40 feet during years of drought.

Groundwater hydrographs illustrate changes in groundwater levels over time. Hydrographs showing seasonal and long-term changes in groundwater levels for the unconfined and confined aquifer systems in the West Butte Inventory Unit are presented in Figures 39 and 40. Additional hydrographs will be presented later in this section during discussions of groundwater levels at the sub-inventory unit level. A summary of all of the Butte County hydrographs presented in this report is provided in Appendix D. Detailed discussions of groundwater level data, hydrograph interpretation, and on-line access to hydrographs for all of the Butte County groundwater monitoring wells are presented in Section 1.

Figure 39 is a hydrograph for Well 21N/01E-27D01M located in the Dayton "4-Corners" area. Dayton "4-Corners" is a rural agricultural area largely dependent on groundwater for production of orchards and row crops. Well 21N/01E-27D01M is a domestic well constructed in the semi-confined portion of the upper aquifer system,

Table 6.
Current Groundwater Monitoring Wells and Estimated Annual Fluctuations in Groundwater Levels, West Butte Inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
20N/01E-10C02M	Irrigation	Composite	1947-2000	3-5	8-12
20N/01E-18L01M	Observation	Confined	1999-2000	3-5	8-12
20N/02E-06Q01M	Irrigation	Composite	1947-2000	10-15	10-20
21N/01E-08K02M	Irrigation	Confined	1992-2000	5-9	25
21N/01E-10B03M	Irrigation	Confined	1995-2000	10-13	18-23
21N/01E-12D01M	Irrigation	Composite	1995-2000	*	*
21N/01E-12K01M	Irrigation	Confined	1959-2000	20	30
21N/01E-13F01M	Irrigation	Composite	1995-2000	30	40
21N/01E-14Q02M	Irrigation	Confined	1995-2000	20	40
21N/01E-21C01M	Irrigation	Confined	1995-2000	10	30
21N/01E-22B01M	Domestic	Semi-Confined	1990-2000	20	25
21N/01E-25K01M	Domestic	Semi-Confined	1990-2000	15-25	25-35
21N/01E-26K01M	Irrigation	Confined	1993-2000	15	40
21N/01E-27B01M	Irrigation	Semi-Confined	1993-2000	15	40
21N/01E-27D01M	Domestic	Confined	1946-2000	5-8	25
21N/01E-28F01M	Unused/Irr.	Confined	1999-2000	20	*
21N/01E-33F01M	Unused/Irr.	Confined	1998-2000	4-12	*
21N/01W-23J01M	Irrigation	Unconfined	1941-2000	3-5	6-8
21N/01W-24B01M	Observation	Confined	1995-2000	10	*
21N/01W-35K02M	Irrigation	Composite	1994-1999	4-5	*
21N/02E-07C01M	Irrigation	Confined	1965-2000	10-15	20-25
21N/02E-30L01M	Domestic	Confined	1995-2000	20	30
22N/01E-29R01M	Irrigation	Confined	1947-2000	10	20
22N/01E-32E04M	Domestic	Composite	1992-1997	15	25
22N/02E-17E01M	Domestic	Confined	1953-1999	3-7	*
22N/02E-28E01M	Domestic	Confined	1995-2000	3-5	*

*Insufficient Data

for which groundwater level measurements date back to the 1940s. Groundwater levels in this well were monitored semi-annually (spring and fall) until about 1975, monthly from 1975 to 1979, and semi-annually from 1979 to 1991. Since 1991, the well has been monitored four times a year during March, July, August, and October.

The hydrograph in Figure 39 shows seasonal fluctuations in groundwater levels of about 10 to 15 feet during years of normal precipitation. A long-term comparison of spring-to-spring groundwater levels in Well 21N/01E-27D01M shows a sharp decline and recovery of groundwater levels associated with the 1976-77 drought and a gradual decline and recovery associated with the 1986-94 drought. Overall, spring-to-spring groundwater levels in this portion of the semi-confined aquifer system during years of normal precipitation have changed little since the early-1970s. A further comparison of spring-to-spring groundwater levels shows a trend of slightly declining groundwater levels since the late 1940s and early 1950s.

Figure 39.
Groundwater Hydrograph for Well 21N/01E-27D01M, West Butte Inventory Unit.

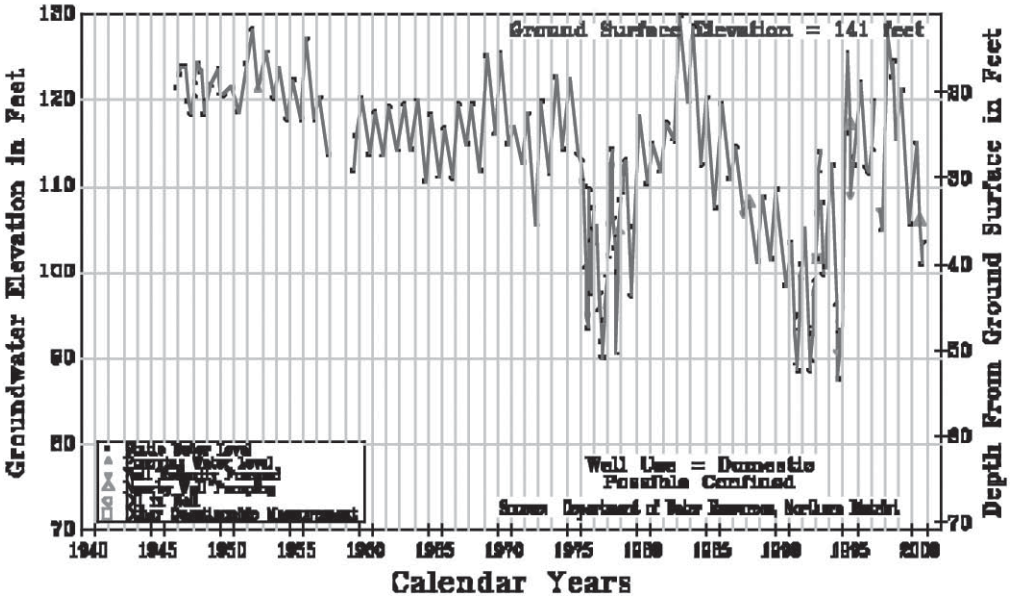


Figure 40 is a hydrograph for Well 21N/01W-23J01M located along Chico River Road north of Ord Ferry Road. The well is located within a rural agricultural area largely dependent on groundwater for production of orchards and row crops. Well 21N/01W-23J01M is a shallow irrigation well that draws groundwater from the unconfined portion of the upper aquifer system. The groundwater level measurement record for Well 21N/01W-23J01M dates back to the late 1940s. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until about the mid-1970s. Groundwater level measurements were taken on a monthly basis from 1976 to about 1979 and again from 1991 to about 1995. Since 1998, this well has been monitored four times a year during March, July, August, and October.

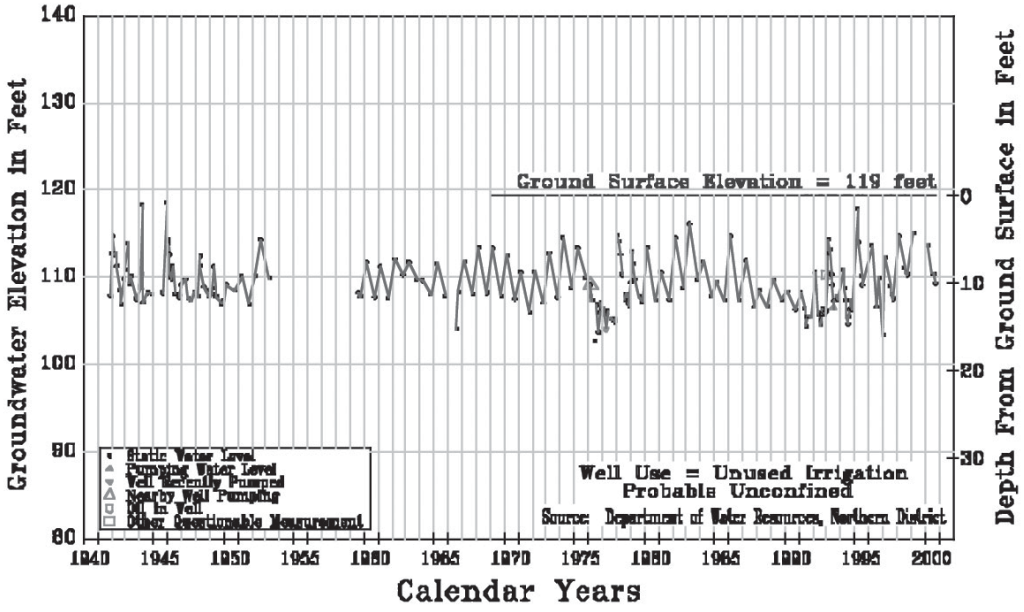
A long-term comparison of spring-to-spring groundwater levels in Well 21N/01W-23J01M shows a slight decline associated with the 1976-77 and 1986-94 droughts followed by a recovery in groundwater levels to predrought conditions. An overall comparison of the spring-to-spring groundwater level data in Figure 40 indicates that this portion of the basin fully recharges during years of normal precipitation. Figure 40 also shows that there has been little change in groundwater levels in this area since measurement of this well began in the early 1940s.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Groundwater elevations for 1997 are considered representative of a normal water year. Spring groundwater elevations are commonly the highest of the year and, in areas unaffected by municipal use of groundwater, reflect the natural groundwater table distribution and direction of movement. Plate 7 shows that the spring groundwater elevations in the West Butte Inventory Unit range from an elevation of about 90 feet in the southwest portion of the inventory unit to an elevation of about 140 feet along the eastern margin of the valley.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. The seasonal fluctuations in groundwater elevations are often dependent on the source of water used for agricultural and municipal land uses. A water source map, based on 1997 land and water use data, is provided on Plate 9, Appendix A.

Plate 8 shows that the seasonal groundwater elevation fluctuations for a normal year in the West Butte Inventory Unit range from 0 to -30 feet, with the largest seasonal declines occurring in the central portion of the Durham-Dayton Sub-inventory Unit. Plate 8 shows that smaller seasonal declines also exist within the California Water Service Sub-inventory Unit. Areas having the greatest seasonal declines in groundwater elevations correlate to regions that are largely dependent on groundwater for agricultural and municipal needs. Plate 8 shows little to no seasonal decline in groundwater elevation in the southwestern portion of the West Butte Inventory Unit where the limited groundwater extraction and the application of agricultural surface water during the summer months compensate for seasonal decline of groundwater elevations.

Figure 40.
Groundwater Hydrograph for Well 21N/01W-23J01M, West Butte Inventory Unit



Groundwater Movement

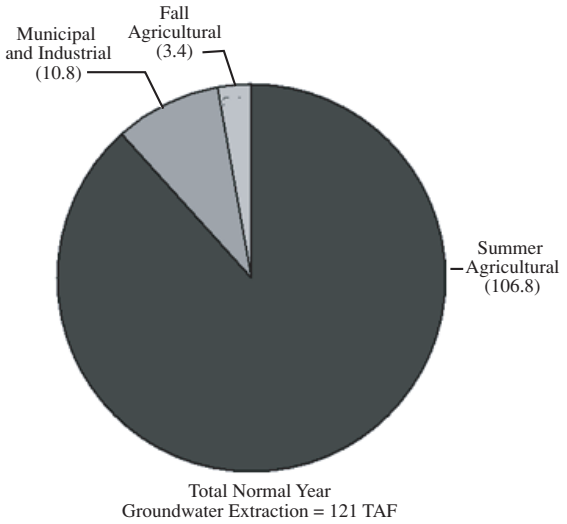
The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). Plate 7 shows that the regional pattern of spring groundwater movement in the West Butte Inventory Unit is in a south-to-southwesterly direction toward the Sacramento River. Localized variations in the region groundwater flow pattern are observed in the municipal area surrounding Chico. Year-round extraction of groundwater for municipal use in the Chico area causes several small groundwater depressions that tend to alter the natural southwestward movement of groundwater in this area.

Groundwater Extraction

Estimates of groundwater extraction in the West Butte Inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are summarized in Tables 3 and 4 in Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A. Groundwater extraction estimates are divided into summer and winter agricultural use, annual municipal and industrial use, and annual wildlife refuge use. The annual deep percolation estimates are divided into agricultural, municipal, and industrial uses.

The estimated amounts of normal-year groundwater extraction, by type of use, are presented in Table 3, Appendix B, and illustrated in Figure 41. Figure 41 shows that normal-year groundwater extraction for the West Butte Inventory Unit is estimated at 121 taf. Groundwater extraction of 121 taf represents about 28% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 121 taf of groundwater extracted during a normal year, about 107 taf are for summer agricultural use, about 11 taf are for annual municipal use and about 3 taf are for fall agricultural use. Table 3, Appendix B, shows that, during a normal year, summer agricultural groundwater is applied to about 34,500 acres, for

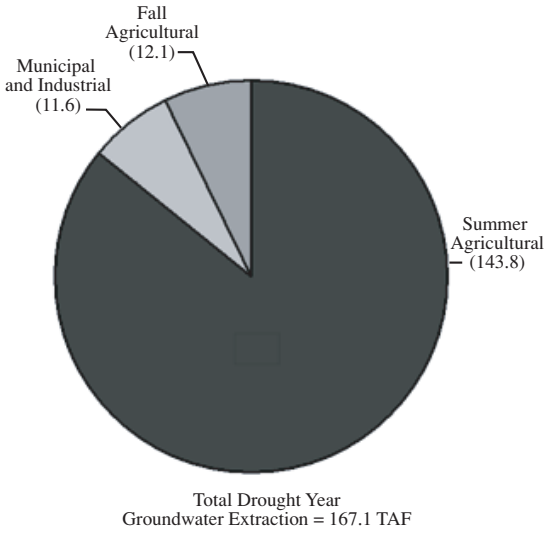
Figure 41.
Estimated Amounts of Normal-Year Groundwater Extraction by Type of Use, West Butte Inventory Unit



an applied water average of 3.1 af/acre. Table 3 also shows that about 23 taf of the extracted groundwater return to the aquifer via deep percolation during a normal year.

The estimated amounts of drought-year groundwater extraction, by type of use, are presented in Table 4, Appendix B, and illustrated in Figure 42. Figure 42 shows that drought-year groundwater extraction in the West Butte Inventory Unit is estimated at 167 taf, an increase of about 38% over the normal-year extraction estimate. Of the 167 taf of groundwater extracted during a drought year, about 143 taf are for summer agricultural use, 12 taf are for annual municipal use, and 12 taf are for fall agricultural use. Of the 167 taf of groundwater extracted during a drought year, about 27 taf are returned to the aquifer via deep percolation. Table 4, Appendix B, shows that in a drought year the groundwater extracted during the summer is applied to about 36,500 acres, for an applied water average of 3.9 af/acre.

Figure 42.
Estimated Amounts of Drought-Year Groundwater Extraction by Type of Use, West Butte Inventory Unit



Well Depth

Well depth and well use data for the West Butte Inventory Unit were collected from well completion reports filed with DWR. A total of 1,926 well records for the West Butte Inventory Unit were evaluated and classified into three well types: domestic, irrigation, and municipal. A summary of the minimum, maximum, and average well depths, listed by well type, is presented in Table 5, Appendix B. A statistical distribution of the well depth data was also evaluated though a series of cumulative frequency distribution curves for domestic, irrigation, and municipal wells. Cumulative frequency curves associated with the West Butte Inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the West Butte Inventory Unit are for domestic use. The average domestic well depth is 134 feet. Table 5 also shows that wells drilled for irrigation and municipal uses tend to be deeper than those for domestic use. The average irrigation well depth for the West Butte Inventory Unit is 342 feet. The average municipal well depth is 511 feet.

The cumulative frequency distribution of well depth data was also evaluated for domestic, irrigation, and municipal wells in the West Butte Inventory Unit. Figure 43

shows the cumulative frequency distribution of well depths for domestic wells in the West Butte Inventory Unit. A total of 1,222 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 15 to 680 feet.

The histogram bars in Figure 43 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of domestic well depth data are slightly skewed to the right toward deeper well depths. Right-skewed distribution of domestic well depth data indicates that the average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the West Butte Inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 120 feet or less,
- 20% of the wells are installed to a depth of 90 feet or less, and
- 10% of the wells are installed to a depth of 75 feet or less.

Figure 43.
Cumulative Frequency Distribution of Domestic Wells, West Butte Inventory Unit

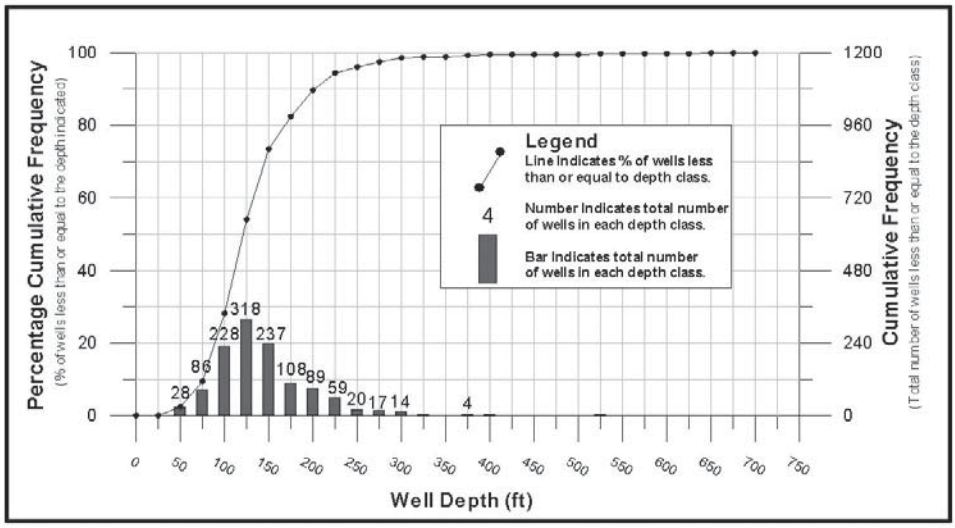


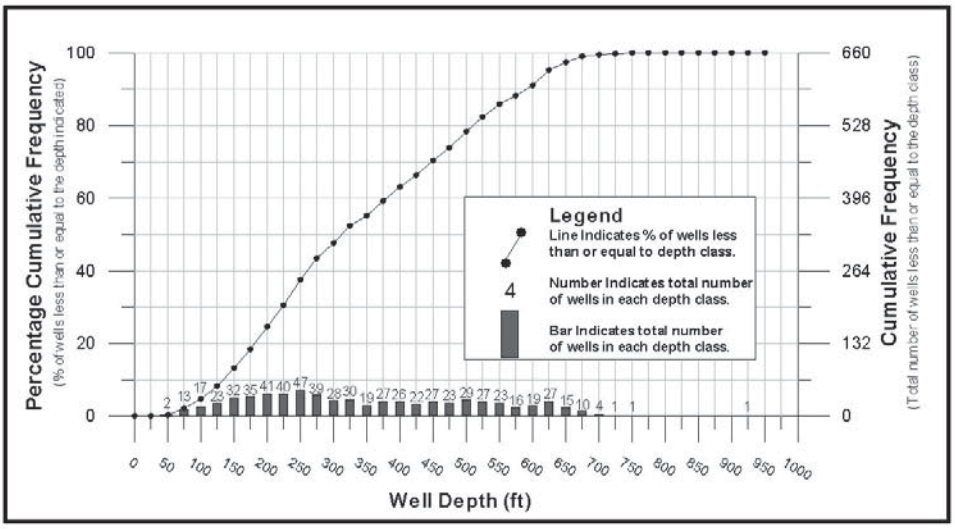
Figure 44 illustrates the cumulative frequency distribution of irrigation well depth data in the West Butte Inventory Unit. A total of 664 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 40 to 920 feet.

The histogram bars in Figure 44 show that the distribution of irrigation well depth data are asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the West Butte Inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of irrigation well depth data for the West Butte Inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 310 feet or less,
- 20% of the wells are installed to a depth of 180 feet or less, and
- 10% of the wells are installed to a depth of 140 feet or less.

Figure 44.
Cumulative Frequency Distribution of Irrigation Wells, West Butte Inventory Unit



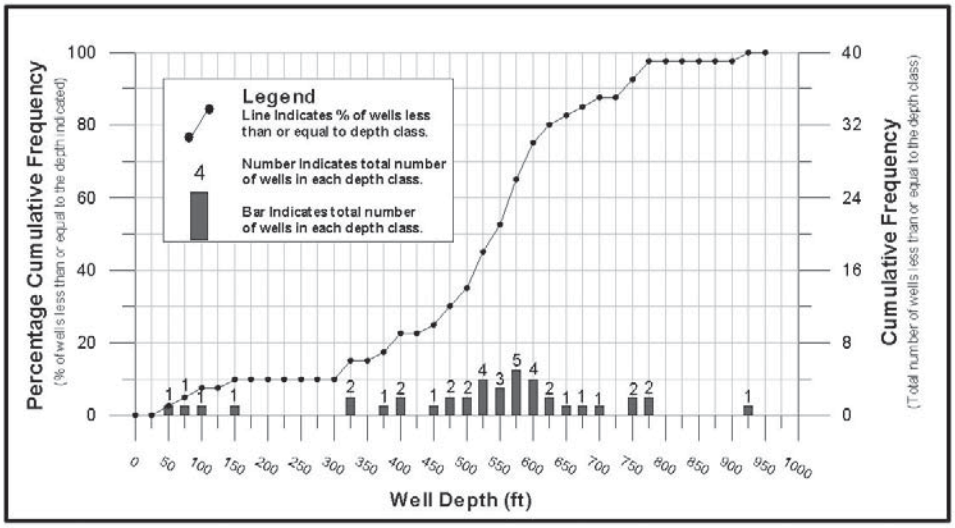
A total of 40 municipal wells in the West Butte Inventory Unit were also evaluated with respect to cumulative frequency distribution curves**.** Depths of the municipal wells range from 36 to 924 feet.

The histogram bars in Figure 45 show that the distribution of municipal well depth data are asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the municipal well depth data indicates that there is a wide range of municipal well depths within the West Butte Inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of municipal well depth data for the West Butte Inventory Unit shows that:

- 50% of the municipal wells are installed to a depth of 540 feet or less,
- 20% of the wells are installed to a depth of 385 feet or less, and
- 10% of the wells are installed to a depth of 300 feet or less.

Figure 45.
Cumulative Frequency Distribution of Municipal Wells, West Butte Inventory Unit



Well Yield

Well yield estimates for the West Butte Inventory Unit were evaluated based on well completion reports filed with DWR, published and unpublished investigations, and utility pump test records from municipal and agricultural wells. A further explanation of well yield data is provided in Section 1. A summary of well yield data is provided in Table 6, Appendix B.

DWR has 705 municipal and irrigation well completion reports on file for the West Butte Inventory Unit. Of the 705 reports, only 19 have well yield data. Table 6, Appendix B, shows that the average well yields from well completion report data for the West Butte Inventory Unit range from a low of 100 gpm to a high of 3,000 gpm, with an average of about 1,700 gpm. Well yield data from well completion reports should serve only as a general guide to local well productivity.

In 1961, Olmsted and Davis of the USGS compiled utility pump test records for 21 areas within the Sacramento Valley. Three of these areas - Chico, Gridley and Honcut are located almost entirely in the Butte County portion of the Sacramento Valley. The Chico area corresponds to the sum of the entire Vina Inventory Unit, the entire West Butte Inventory Unit, and the East Butte Inventory Unit north of Nelson. Well yield data from the 1961 USGS investigation are summarized in Table 6, Appendix B. The 1961 USGS utility data for the Chico area represents 498 pump tests taken prior to 1959. Table 6, Appendix B, shows that the average well yield in the Chico area, as reported in the 1961 USGS report, is 1,000 gpm.

Well yield estimates for the West Butte Inventory Unit were also evaluated using data from utility pump test records. The well yield estimates for the West Butte Inventory Unit, shown in Table 6, Appendix B, represent 822 pump tests performed on 319 wells between 1989 and 1998. Table 6, Appendix B, shows that the well yields for the West Butte Inventory Unit range from a low of 53 gpm to a high of 5,382 gpm, with an average well yield of 1,152 gpm. Utility pump tests are generally considered to provide an accurate estimate of well yield.

Specific Capacity

Specific capacity estimates for the West Butte Inventory Unit were evaluated based on utility pump test records and on published and unpublished investigations. The utility records represent pump test data from primarily municipal and agricultural wells. A further explanation of specific capacity data is provided in Section 1. The specific capacity estimates shown in Table 7 represent 291 pump tests performed on 143 wells between 1989 and 1998. A summary of specific capacity data is

also provided in Table 7, Appendix B. Table 7 shows that specific capacity estimates from utility pump test records for the West Butte Inventory Unit range from a low of 9 gpm/ft to a high of 299 gpm/ft. The average specific capacity in the West Butte Inventory Unit, estimated from utility pump test data, is 71 gpm/ft. Utility pump tests are generally considered to provide a good estimate of specific capacity.

In 1961, Olmsted and Davis of the USGS compiled utility pump test records for 21 areas within the Sacramento Valley. Three of these areas - Chico, Gridley and Honcut - are located within Butte County portion of the Sacramento Valley. The Chico area corresponds to the sum of the entire Vina Inventory Unit, the entire West Butte Inventory Unit, and the East Butte Inventory Unit north of Nelson. Specific

capacity data from the 1961 USGS investigation are summarized in Table 7, Appendix B. The 1961 USGS utility data for the Chico area represent 498 pump tests taken prior to 1959. Table 7 shows that the average specific capacity for the Chico area, as reported in the 1961 USGS report, is 51 gpm/ft.

Groundwater Storage Capacity

For the purposes of this investigation, groundwater storage capacity is defined as the maximum volume of fresh groundwater capable of being stored within an aquifer, beneath a given area. Estimates of storage capacity were calculated by multiplying the area of the West Butte Inventory Unit by the maximum saturated thickness and the average specific yield of the freshwater portion of the aquifer. Groundwater storage capacity estimates are summarized in Table 8, Appendix B. A further explanation of groundwater in storage is provided in Section 1.

Table 8, Appendix B, shows that the West Butte Inventory Unit covers an area of about 86,500 acres. Groundwater storage capacity estimates for the West Butte Inventory Unit listed in Table 8 assume uniform aquifer saturation from a depth of 10 feet, down to the average base of freshwater at a depth of about 1,500 feet, and an average specific yield of 6.6%. Based on the above assumptions, the estimated maximum groundwater storage capacity for the West Butte Inventory Unit is about 8,550 taf.

Groundwater in Storage

Groundwater in storage is defined as the amount of water contained within the aquifer system at the time of measurement. Groundwater in storage in the West Butte Inventory Unit was examined using three scenarios:

- the estimated volume of groundwater currently in storage over the entire freshwater portion of the aquifer system,
- the estimated seasonal decline in groundwater levels associated with the removal of groundwater in storage during a normal water year, and
- the estimated seasonal decline in groundwater levels associated with the removal of groundwater in storage during a drought water year.

The estimated amounts of groundwater in storage are summarized in Table 9, Appendix B. A further explanation of groundwater in storage is provided in Section 1.

- Estimated Volume of Groundwater in Storage. The West Butte Inventory Unit covers an area of about 86,500 acres. Groundwater in storage estimates for the West Butte Inventory Unit assume uniform aquifer saturation from an average depth of 22 feet, down to the average base of freshwater at a depth of about 1,500 feet, and an average specific yield of 6.6%. The average depth of groundwater is based on monitoring data collected in spring 1997. Based on the above assumptions, the volume of groundwater in storage for the West Butte Inventory Unit is estimated at 8,500 taf. A comparison of groundwater storage capacity and groundwater in storage estimates in Tables 8 and 9, Appendix B, indicates that groundwater in storage in the West Butte Inventory Unit is slightly less than the maximum capacity during normal water years.
- Estimated Seasonal Decline of Groundwater in Storage associated with Normal-Year Extraction. The normal-year groundwater demand for the West Butte

Inventory Unit was adjusted to reflect seasonal use during a normal water year. Seasonal groundwater extraction is estimated at 100% of the summer agricultural extraction, plus 70% of the annual municipal extraction, minus 30% of the annual deep percolation of applied surface water and groundwater. Based on the above assumptions, the seasonal groundwater demand for the West Butte Inventory Unit during a normal year is estimated at about 102 taf. The average seasonal lowering of groundwater levels associated with a normal-year extraction of 102 taf of groundwater in the West Butte Inventory Unit is estimated at 18 feet.

- Estimated Seasonal Decline of Groundwater in Storage associated with Drought-Year Extraction. The drought-year groundwater demand for the West Butte Inventory Unit was adjusted to reflect seasonal use during a drought water year. Seasonal groundwater extraction is estimated at 100% of the summer agricultural extraction, plus 70% of the annual municipal extraction, minus 30% of the annual deep percolation of applied surface water and groundwater. Based on the above assumptions, the seasonal groundwater demand in the West Butte Inventory Unit during a drought year is estimated at about 138 taf. The average seasonal decline in groundwater levels associated with a drought-year extraction of 138 taf in the West Butte Inventory Unit is about 24 feet.

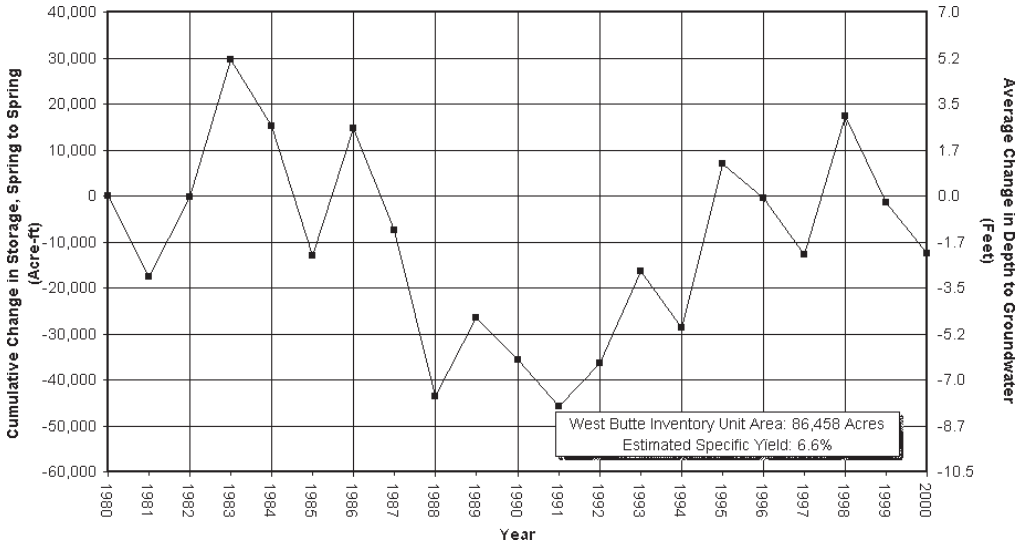
Changes in the Volume of Groundwater in Storage

The annual spring-to-spring changes in the volume of groundwater in storage for the West Butte Inventory Unit were calculated over a 20-year period from 1980 to 2000. The changes in the volume of groundwater in storage are based on groundwater contour maps developed from spring groundwater level measurements in the upper portion of the aquifer. A summary of the spring-to-spring changes in the volume of groundwater in storage data is provided in Table 11, Appendix B. The cumulative spring-to-spring changes in the volume of groundwater in storage for the West Butte Inventory Unit are presented in Figure 46. A further explanation of the method for estimating changes in the volume of groundwater in storage is provided in Section 1.

Table 11, Appendix B, lists the annual changes in—the volume of—groundwater in storage, the cumulative changes in—the volume of—groundwater in storage and the changes in groundwater levels associated with the cumulative changes in the volume of groundwater in storage for the West Butte Inventory Unit. Table 11 shows that the largest single-year decline in spring-to-spring volume of groundwater in storage for the West Butte Inventory Unit was about 36 taf in 1987-88. The largest single-year increase in the volume of groundwater in storage was about 36 taf in 1994-95.

The cumulative spring-to-spring changes in the volume of groundwater in storage for the West Butte Inventory Unit are illustrated in Figure 46. The spring-to-spring changes in the volume of groundwater in storage graph starts with a baseline of zero for spring 1980 and shows cumulative changes from 1980 to 2000. Figure 46 shows that the volume of groundwater in storage increases during the wet years of 1983 and 1986, decreases during the drought years of the early 1990s, and then gradually recovers over the next five years. The change in the volume of groundwater in storage between the peak in 1983 and the low in 1991 is estimated at about 66 taf. Overall, the amount of groundwater in storage in the West Butte Inventory Unit during spring 2000 was about 12 taf less than spring 1980.

Figure 46.
Estimated Cumulative Changes in Spring-to-Spring Storage, West Butte Inventory Unit



Durham-Dayton Sub-inventory Unit

The Durham-Dayton Sub-inventory Unit covers an area of about 40,000 acres in the heart of the West Butte Inventory Unit. It is bordered by Big Chico Creek to the north, Butte Creek and the Western Canal Sub-inventory Unit to the south, foothills to the east, and the M&T and Llano Seco sub-inventory units to the west (see Plate 1, Appendix A). In a normal year, 67% of the Durham-Dayton Sub-inventory Unit in summer agricultural production supported by groundwater. In addition, 18% of the sub-inventory unit is within the CWSC area and uses groundwater as a municipal water source. The well data presented in this section represents the entire Durham-Dayton Sub-inventory Unit, including that portion of the California Water Service Sub-inventory Unit that lies within the Durham-Dayton Sub-inventory Unit.

Well Distribution

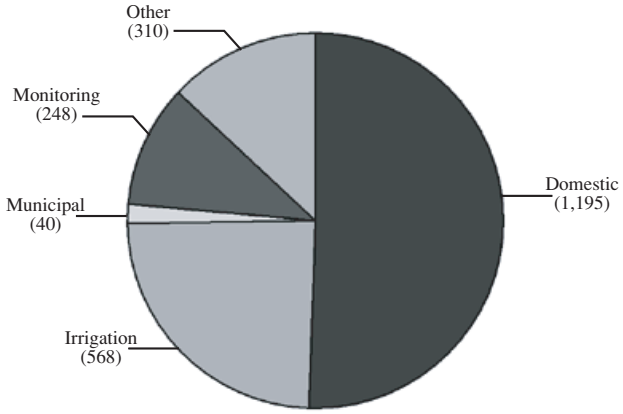
The well completion report database files at DWR were analyzed to determine the number and types of wells in the Durham-Dayton Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are about 2,400 wells in the Durham-Dayton Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that about 1,195 are listed as domestic, 568 are listed as irrigation, 40 are listed as municipal, 248 are listed as monitoring, and 310 are listed as other. Figure 47 illustrates the breakdown of wells by use for the Durham-Dayton Sub-inventory Unit.

Groundwater Level

DWR and BCDWRC currently monitor the groundwater levels in 17 wells within the Durham-Dayton Sub-inventory Unit. Nine of the 17 wells have been added since 1995. Four of these wells are equipped with continuous groundwater level recording devices. The monitoring wells consist of domestic, irrigation, and observation wells. Table 7 lists the current monitoring wells, along with the annual fluctuations in groundwater levels during normal and drought years. Table 7 also lists the well use,

Figure 47.
Number of Wells by Use, Durham-Dayton Sub-inventory Unit



Total Number of Well = 2,361

the aquifer system that is being monitored, and the monitoring period of record. DWR and BCDWRC monitoring wells are shown on Plate 6, Appendix A.

Historic groundwater level data for the Durham-Dayton Sub-inventory Unit indicate that the annual fluctuations in groundwater levels in the confined or semi-confined portions of the aquifer system average about 15 feet during years of normal precipitation and up to 40 feet during years of drought. The annual fluctuations in groundwater levels monitored in a composite section of the aquifer system are highly variable, ranging from 5 to 30 feet during normal years and up to 40 feet during years of drought. Composite monitoring wells measure a combined groundwater level in multiple water-bearing zones within the aquifer system.

Table 7.
Current Groundwater Monitoring Wells and the Estimated Annual Fluctuations in Groundwater Levels, Durham-Dayton Sub-inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
21N/01E-33F01M	Unused/Irr.	Confined	1998-2000	4-12	*
21N/01E-28F01M	Unused/Irr.	Confined	1999-2000	20	*
21N/01E-26K01M	Irrigation	Confined	1993-2000	15	40
20N/01E-10C02M	Irrigation	Composite	1947-2000	3-5	8-12
20N/02E-06Q01M	Irrigation	Composite	1947-2000	10-15	10-20
21N/01E-10B03M	Irrigation	Confined	1995-2000	10-13	18-23
21N/01E-12D01M	Irrigation	Composite	1995-2000	*	*
21N/01E-12K01M	Irrigation	Confined	1959-2000	20	30
21N/01E-13F01M	Irrigation	Composite	1995-2000	30	40
21N/01E-14Q02M	Irrigation	Confined	1995-2000	20	40
21N/01E-21C01M	Irrigation	Confined	1995-2000	10	30
21N/01E-22B01M	Domestic	Semi-Confined	1990-2000	20	25
21N/01E-25K01M	Domestic	Semi-Confined	1990-2000	15-25	25-35
21N/01E-27B01M	Irrigation	Semi-Confined	1993-2000	15	40
21N/01E-27D01M	Domestic	Confined	1946-2000	5-8	25
21N/02E-07C01M	Irrigation	Confined	1965-2000	10-15	20-25
21N/02E-30L01M	Domestic	Confined	1995-2000	20	30

*Insufficient Data

Groundwater hydrographs illustrate changes in groundwater levels over time. Hydrographs that represent the seasonal and long-term changes in groundwater levels for the confined aquifer system in the Durham-Dayton Sub-inventory Unit are presented in Figures 48 and 49. The locations of the monitoring wells are shown on Plate 6, Appendix A.

Figure 48.
Groundwater Hydrograph for Well 20N/02E-06Q01M,
Durham-Dayton Sub-inventory Unit

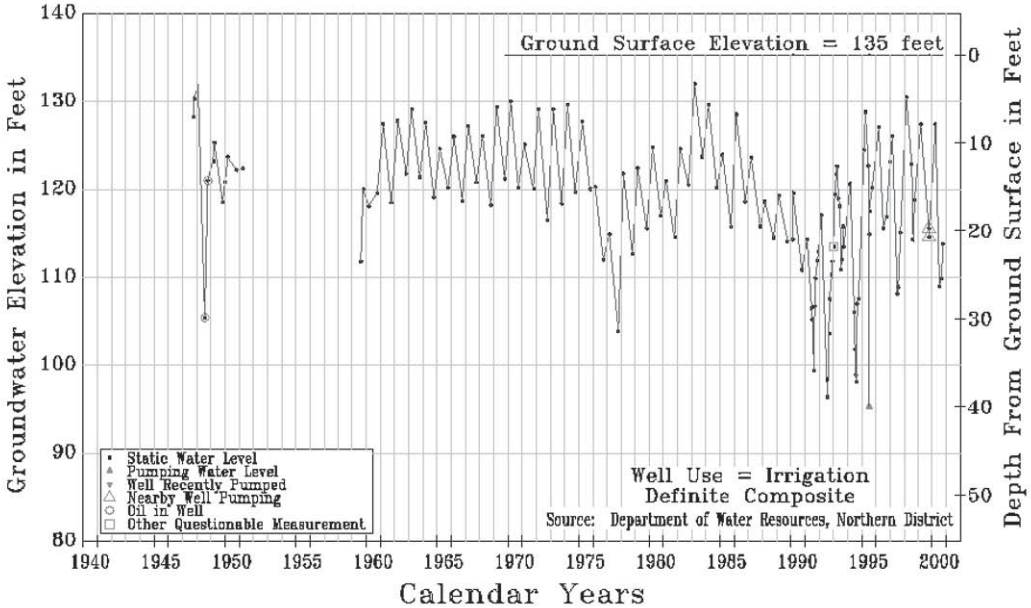


Figure 49.
Groundwater Hydrograph for Well 21N/02E-07C01M,
Durham-Dayton Sub-inventory Unit

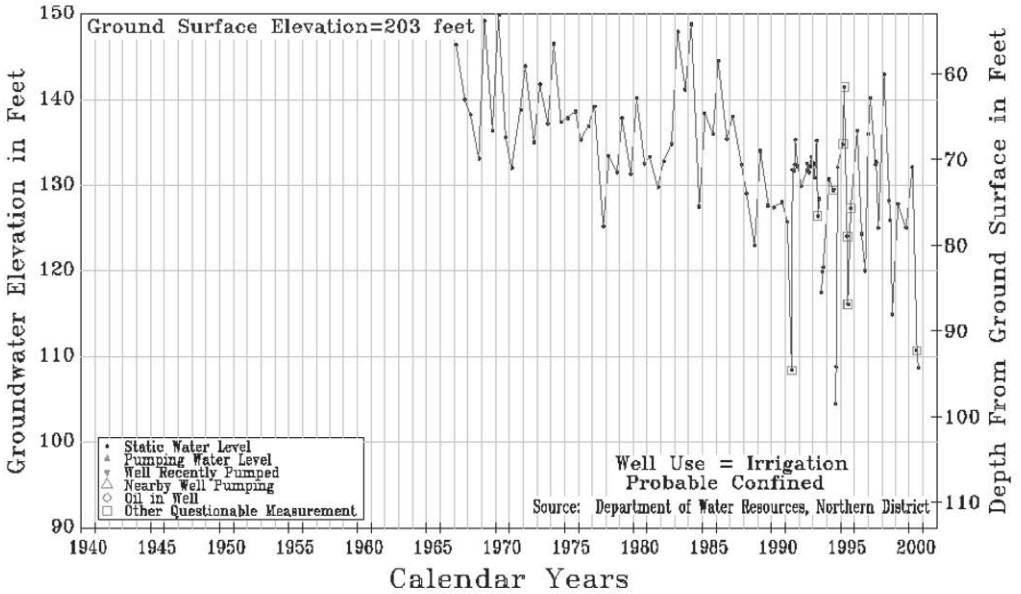


Figure 48 is a hydrograph for Well 20N/02E-06Q01M, located two miles south of Durham adjacent to Butte Creek. This area marks a change in agricultural water use from groundwater in the north to surface water in the south. This well is a deep irrigation well with shallow casing, for which groundwater level measurements date back to the late 1940s. Groundwater levels represent a mixture of the unconfined and confined portions of the aquifer system. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until 1991 and on a monthly basis from 1991 to about 1994. Since 1994, this well has been monitored four times a year during March, July, August, and October.

Figure 48 shows seasonal fluctuations in groundwater levels of about 10 to 15 feet during years of normal precipitation and up to 20 feet during years of drought. A long-term comparison of spring-to-spring groundwater levels in Well 20N/02E-06Q01M shows a decline and recovery of groundwater levels associated with the 1976-77 and 1986-94 droughts. Overall, a comparison of spring-to-spring groundwater levels associated with the composite portion of the aquifer system, during years of normal precipitation, shows they have changed little since the early 1970s.

Figure 49 is a hydrograph for Well 21N/02E-07C01M, located off the Midway, between Chico and Durham. The area surrounding this well is predominantly rural agricultural and largely dependent on groundwater for production of orchards and row crops. This irrigation well was constructed in the confined portion of the aquifer system and had groundwater level measurement records that date back to the late 1960s. Groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until 1991, on a monthly basis from 1991 to about 1994, and are currently monitored four times a year during March, July, August, and October.

Figure 49 shows that the average seasonal fluctuations in groundwater levels are about 10 to 15 feet during years of normal precipitation and up to 25 feet during years of drought. A long-term comparison of spring-to-spring groundwater levels in Well 21N/02E-07C01M shows a small decline in groundwater levels associated with the 1976-77 drought followed by a larger decline associated with the 1986-94 drought. Although the spring 1998 groundwater levels recovered to that of the early 1980s, the long-term spring-to-spring trend indicates a 15- to 20-foot decline in groundwater levels since the late 1960s. It should be noted, however, that difficulties in measuring this well have led to multiple questionable measurements throughout the years. Newly added monitoring wells are helping to provide a more accurate evaluation of the groundwater level trends in this area.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Plate 7 shows that the spring groundwater elevations in the Durham-Dayton Sub-inventory Unit range from an elevation of about 100 feet in the southwestern portion of the sub-inventory unit to an elevation of about 140 feet in the northeastern portion.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. Plate 8 shows that the seasonal groundwater elevation fluctuations for a normal year in the Durham-Dayton Sub-inventory Unit range from 10 to 30 feet, with the largest seasonal declines occurring just west of Durham and southeast of Chico.

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map on Plate 7, Appendix A, by a series of small arrows perpendicular to the groundwater elevation contours. Plate 7 shows that the regional pattern of spring groundwater movement in the Durham-Dayton Sub-inventory Unit is in a south-to-southwesterly direction, at a gradient of about 5 feet per mile, toward the Sacramento River and Butte Creek. The direction of groundwater movement indicates that both the Sacramento River and Butte Creek serve as groundwater drains in the Durham-Dayton Sub-inventory Unit.

Groundwater Extraction

Estimates of groundwater extraction in the Durham-Dayton Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map, based on 1997 land and water use data, is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that the normal-year groundwater extraction for the Durham-Dayton Sub-inventory Unit is estimated at 95 taf. Groundwater extraction of 95 taf represents about 22% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 95 taf of groundwater extracted during a normal year, about 84 taf are for summer agricultural use and about 10 taf are for annual municipal and industrial uses. Groundwater extracted for summer agricultural use in a normal year services an area of about 26,600 acres, for an applied water average of 3.2 af/acre. Table 3 also shows that about 19 taf of the extracted groundwater return to the aquifer via deep percolation in a normal year.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show that drought-year groundwater extraction in the Durham-Dayton Sub-inventory Unit is estimated at 119 taf, an increase of about 25% over the normal-year extraction estimate. Groundwater extracted for summer agricultural use during a drought year serves an area of about 26,900 acres, for an applied water average of 4.0 af/acre. Table 4 shows that about 21 taf of the extracted groundwater return to the aquifer via deep percolation in a drought year.

Well Depth

Well depth and well use data for the Durham-Dayton Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 1,803 well records for the Durham-Dayton Sub-inventory Unit were evaluated and classified into three well types: domestic, irrigation, and municipal. A statistical distribution of the well depth data was also evaluated though cumulative frequency distribution curves for domestic and irrigation wells. Cumulative frequency distribution curves for the Durham-Dayton Sub-inventory Unit are presented below and summarized by inventory and sub-inventory unit in Table 5, Appendix B.

Table 5, Appendix B, shows that the majority of wells in the Durham-Dayton Sub-inventory Unit are for domestic use. The average domestic well depth is about 134 feet. Table 5 also shows that wells drilled for irrigation and municipal uses tend to be

deeper than those for domestic use. The average irrigation well depth for the Durham-Dayton Sub-inventory Unit is 348 feet. The average municipal well depth is 511 feet.

The well depth data were further analyzed by an evaluation of the cumulative frequency distribution of well depths for domestic and irrigation wells in the Durham-Dayton Sub-inventory Unit. Figure 50 shows the cumulative frequency distribution of well depths for domestic wells in the Durham-Dayton Sub-inventory Unit. A total of 1,195 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 15 to 680 feet.

The histogram bars in Figure 50 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the domestic well depth data is fairly symmetrical. Symmetrical distribution of domestic well depth data indicates that an equal number of wells exist on either side of the most frequently occurring well depth.

The cumulative frequency curve of domestic well depth data for the Durham-Dayton Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 120 feet or less,
- 20% of the wells are installed to a depth of 90 feet or less, and
- 10% of the wells are installed to a depth of 75 feet or less.

Figure 50.
Cumulative Frequency Distribution of Domestic Wells,
Durham-Dayton Sub-inventory Unit

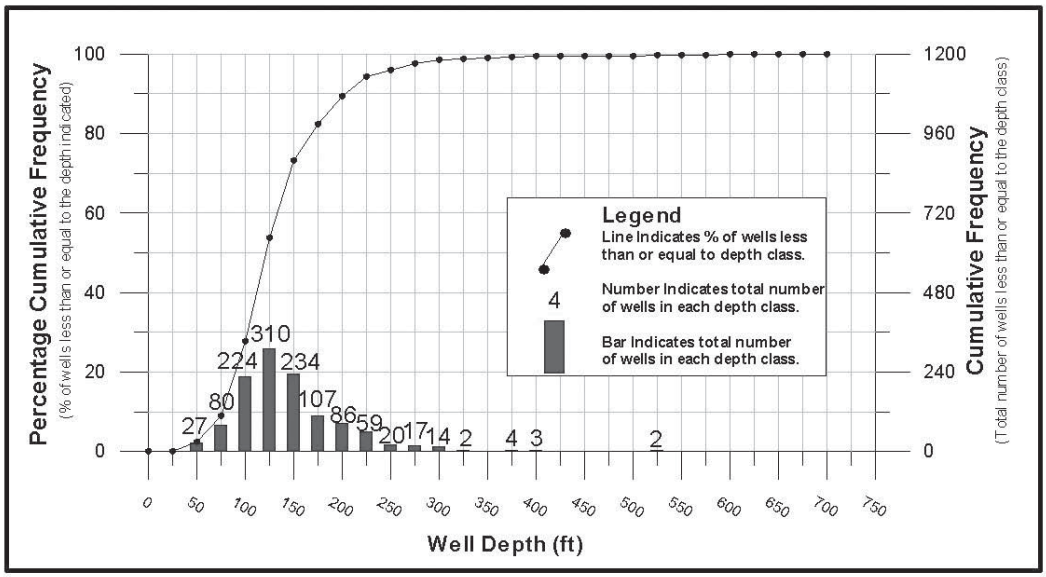


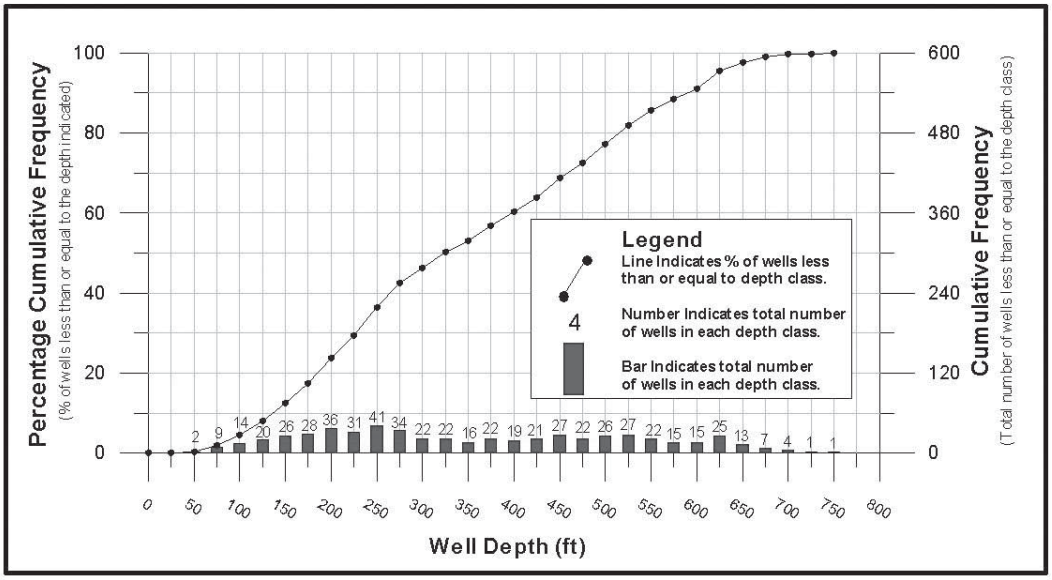
Figure 51 illustrates the cumulative frequency distribution of irrigation well depth data in the Durham-Dayton Sub-inventory Unit. A total of 568 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 40 to 750 feet.

The histogram bars in Figure 51 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the well depth data for irrigation wells is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the Durham-Dayton Sub-inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of irrigation well depth data for the Durham-Dayton Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 325 feet or less,
- 20% of the wells are installed to a depth of 185 feet or less, and
- 10% of the wells are installed to a depth of 135 feet or less.

Figure 51.
Cumulative Frequency Distribution of Irrigation Wells,
Durham-Dayton Sub-inventory Unit



M&T Sub-inventory Unit

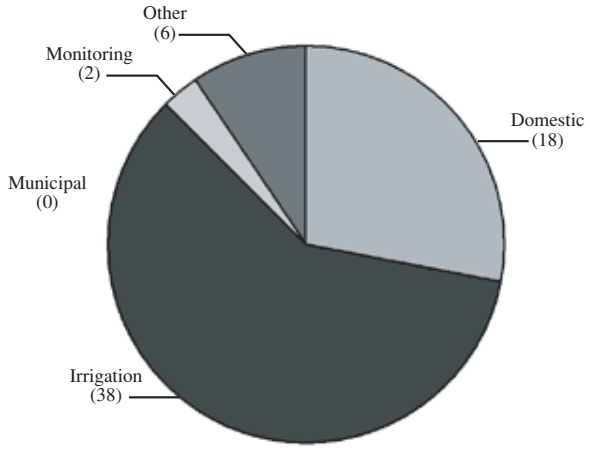
The M&T Sub-inventory Unit covers an area of about 8,200 acres in the northwestern portion of the West Butte Inventory Unit. It is bordered by Big Chico Creek to the north, the Llano Seco and Durham-Dayton sub-inventory units to the south and east, and the Sacramento River and Angel Slough Sub-inventory Unit to the west (see Plate 1, Appendix A). The M&T Sub-inventory Unit corresponds roughly to the water service area of the M&T Chico Ranch. Agricultural land use includes orchards, rice, and row crops supported by groundwater and surface water. In a normal year, about 27% of the M&T Sub-inventory Unit is in summer agricultural production supported by groundwater.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the M&T Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are about 64 wells in the M&T Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other; 18 are listed as domestic, 38 are listed as irrigation, none are listed as municipal, 2 are listed as monitoring, and 6 are listed as other. Figure 52 illustrates the breakdown of wells by use for the M&T Sub-inventory Unit.

Figure 52.
Number of Wells by Use, M&T Sub-inventory Unit



Total Number of Well = 64

Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 5 wells within the M&T Sub-inventory Unit. The monitoring wells consist of domestic, irrigation, and observation wells. Monitoring Wells 21N/01E-08K02M and 21N/01W-35K02M are equipped with continuous groundwater level recording devices, while Well 21N/01W-24B01M is equipped with an extensometer as well. Table 8 lists the current monitoring wells along with the annual fluctuations in groundwater levels during normal and drought years. Table 8 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. DWR and BCDWRC monitoring wells are shown on Plate 6, Appendix B.

Historic groundwater level data for the M&T Sub-inventory Unit indicate that the annual fluctuations in groundwater levels in the confined portion of the aquifer system average about 8 to 10 feet during years of normal precipitation and up to 25 feet during years of drought. The annual fluctuations in groundwater levels in the composite section of the aquifer system are variable, ranging from 4 to 15 feet during normal years and up to 25 feet during drought years. Composite monitoring wells measure a combined groundwater level in multiple water-bearing zones within the aquifer system.

Table 8.
Current Groundwater Monitoring Wells and Estimated Annual Fluctuations in Groundwater Levels, M&T Sub-inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
21N/01E-08K02M	Irrigation	Confined	1992-2000	5-9	25
21N/01W-24B01M	Observation	Confined	1995-2000	10	*
21N/01W-35K02M	Irrigation	Composite	1994-1999	4-5	*
22N/01E-29R01M	Irrigation	Confined	1947-2000	10	20
22N/01E-32E04M	Domestic	Composite	1992-1997	15	25

*Insufficient Data

Groundwater hydrographs illustrate changes in groundwater levels over time. A hydrograph representing the seasonal and long-term changes in groundwater levels for the confined aquifer system in the M&T Sub-inventory Unit is presented in Figure 53. The locations of the monitoring wells are shown on Plate 6, Appendix A.

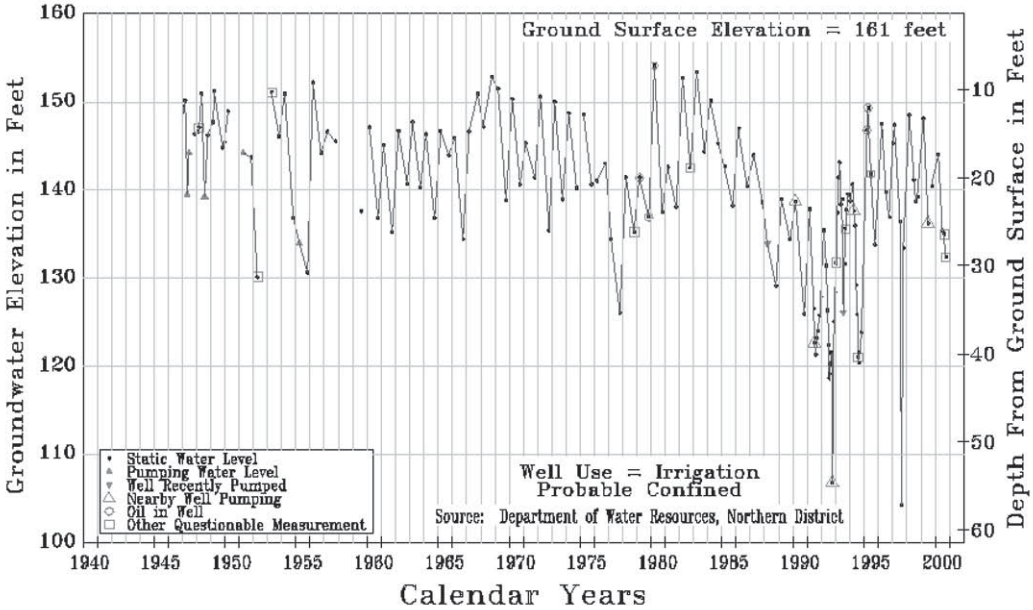
Figure 53 is a hydrograph for Well 22N/01E-29R01M, located just south of Big Chico Creek in the northern portion of the M&T Sub-inventory Unit. The well is surrounded by agricultural orchard production that is supported by groundwater extraction. Well 22N/01E-29R01M is an active irrigation well of intermediate depth, for which groundwater level measurements date back to the late 1940s. Groundwater levels in this well represent the confined portion of the aquifer. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until 1991 and on a monthly basis from 1991 to about 1994. Since 1994, the groundwater levels have been monitored four times a year during March, July, August, and October.

Figure 53 shows that the average seasonal fluctuations in groundwater levels are about 10 feet during years of normal precipitation and up to 20 feet during years of drought. A long-term comparison of spring-to-spring groundwater levels in Well 22N/01E-29R01M shows a small decline in groundwater levels associated with the 1976-77 drought followed by a larger decline associated with the 1986-94 drought.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater elevation contour map for the Sacramento Valley Region of Butte County. Plate 7 shows that the spring groundwater elevations in the M&T Sub-inventory Unit range from an elevation of about 110 feet in the southwestern portion of the sub-inventory unit to an elevation of about 140 feet in the northeastern portion.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. Plate 8 shows that the seasonal groundwater elevation

Figure 53
Groundwater Hydrograph for Well 22N/01E-29R01M, M&T Sub-inventory Unit



fluctuations for a normal year in the M&T Sub-inventory Unit range from 5 to 15 feet, with the largest seasonal declines occurring in the northern portion of the sub-inventory unit just west of Chico.

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). Plate 7, Appendix A, shows that the regional pattern of spring groundwater movement in the M&T Sub-inventory Unit is in a south-to-southwesterly direction toward the Sacramento River and Angel Slough.

Groundwater Extraction

Estimates of groundwater extraction in the M&T Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that the normal-year groundwater extraction for the M&T Sub-inventory Unit is estimated at about 7 taf. Groundwater extraction of about 7 taf represents about 1.5% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Most of the groundwater extracted is for summer agricultural use. The agricultural groundwater in a normal year services an area of about 2,100 acres, for an applied water average of 3.2 af/acre. Table 3 also shows that less than 2 taf of the extracted groundwater return to the aquifer via deep percolation in a normal year.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show that drought-year groundwater extraction in the M&T Sub-inventory Unit is estimated at about 9 taf, an increase of about 20% over the normal-year extraction estimate. Of the approximately 9 taf of groundwater extracted during a drought year, about 2 taf are returned to the aquifer via deep percolation.

Well Depth

Well depth and well use data for the M&T Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 56 well records for the M&T Sub-inventory Unit were evaluated and classified into two well types: domestic and irrigation (no municipal well records were on file). Cumulative frequency distribution curves were also used to evaluate the statistical distribution of the well depth data for irrigation wells. Cumulative frequency distribution curves for the M&T Sub-inventory Unit are presented below and are summarized by inventory and sub-inventory unit in Table 5, Appendix B.

Table 5, Appendix B, shows that the majority of wells drilled in the M&T Sub-inventory Unit are for irrigation use. The average irrigation well depth is about 397 feet. Table 5 also shows that only 18 wells were drilled for domestic use. The average domestic well depth in the M&T Sub-inventory Unit is 147 feet. The domestic wells range in depths from 54 to 640 feet. Further statistical analyses of domestic wells in the M&T Sub-inventory Unit were not developed due to the low number of wells.

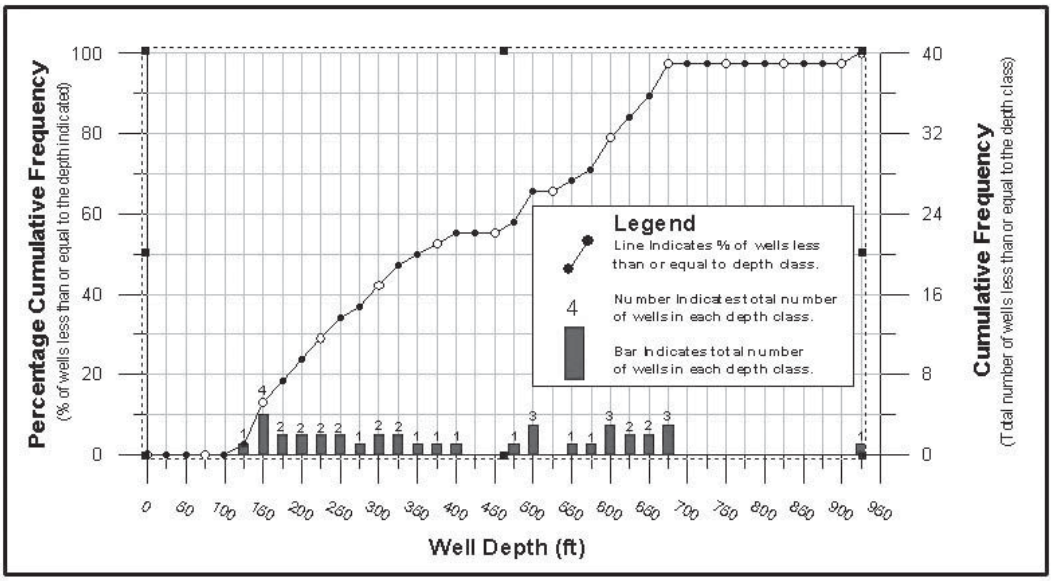
The well depth data for irrigation wells were further analyzed by evaluating the cumulative frequency distribution of well depths. Figure 54 shows the cumulative frequency distribution of well depths for irrigation wells. A total of 38 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 115 to 920 feet.

The histogram bars in Figure 54 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the irrigation well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the data indicates that there is a wide range of irrigation well depths within the M&T Sub-inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of irrigation well depth data for the M&T Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 350 feet or less,
- 20% of the wells are installed to a depth of 190 feet or less, and
- 10% of the wells are installed to a depth of 150 feet or less.

Figure 54.
Cumulative Frequency Distribution of Irrigation Wells, M&T Sub-inventory Unit



Angel Slough Sub-inventory Unit

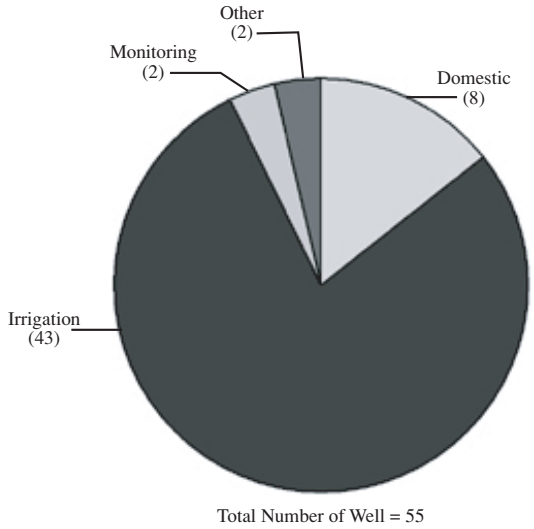
The Angel Slough Sub-inventory Unit covers an area of about 5,400 acres in the western portion of the West Butte Inventory Unit. It is bordered by the M&T Sub-inventory Unit to the north and east, the Llano Seco Sub-inventory Unit to the south, and the Sacramento River to the west (see Plate 1, Appendix A). Agricultural land use consists largely of orchards and row crops supported by both groundwater and surface water. In a normal year, about 70% of the Angel Slough Sub-inventory Unit is in summer agricultural production supported by groundwater.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the Angel Slough Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are about 55 wells in the Angel Slough Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 8 wells are listed as domestic, 43 are listed as irrigation, none are listed as municipal, 2 are listed as monitoring and 2 are listed as other. Figure 55 illustrates the breakdown of wells by use for the Angel Slough Sub-inventory Unit.

Figure 55.
Number of Wells by Use, Angel Slough Sub-inventory Unit.



Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 1 well within the Angel Slough Sub-inventory Unit. The well is located within a rural agricultural area that is largely dependent on groundwater for production of orchards and row crops. Well 21N/01W-23J01M is a shallow irrigation well that draws groundwater from the unconfined portion of the upper aquifer system. The groundwater level measurement record for the well dates back to the late 1940s. Table 9 lists the annual fluctuations in groundwater levels during normal and drought years, the aquifer system that is being monitored, and the monitoring period of record for Well 21N/01W-23J01M. The groundwater hydrograph for this well is presented in Figure 40 under the discussion of groundwater levels in the West Butte Inventory Unit section. DWR and BCDWRC monitoring wells are shown on Plate 6, Appendix A.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Plate 7 shows that the spring groundwater levels in the Angel Slough Sub-inventory Unit are fairly flat, falling between the 90- and 100-foot elevation contours.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater levels between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. Plate 8 shows that the seasonal groundwater level fluctuations for a normal year in the Angel Slough Sub-inventory Unit range from 3 feet in areas near the Sacramento River to -7 feet in areas to the east and adjacent to the Durham-Dayton Sub-inventory Unit.

Table 9.
Current Groundwater Monitoring Well and Estimated Annual Fluctuations in Groundwater Levels, Angel Slough Sub-inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
21N/01W-23J01M	Irrigation	Unconfined	1941-2000	3-5	6-8

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). Plate 7 shows that the regional pattern of spring groundwater movement in the Angel Slough Sub-inventory Unit is in a south-to-southwesterly direction, at a gradient of about 7 feet per mile, toward the Sacramento River and Angel Slough. The direction of groundwater movement indicates that the Sacramento River is serving as a drain for groundwater from the Angel Slough Sub-inventory Unit.

Groundwater Extraction

Estimates of groundwater extraction in the Angel Slough Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that normal-year groundwater extraction for the Angel Slough Sub-inventory Unit is estimated at 10 taf. Groundwater extraction of 10 taf represents about 2.3% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Most of the groundwater extracted in Angel Slough Sub-inventory Unit is for summer agricultural use. The agricultural groundwater in a normal year serves an area of about 3,700 acres, for an applied water average of 2.7 af/acre. Table 1 also shows that less than 2 taf of the extracted groundwater return to the aquifer via deep percolation.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show that drought-year groundwater extraction in the Angel Slough Sub-inventory Unit is estimated at about 13 taf, an increase of about 28% over the normal-year extraction estimate. Of the approximately 13 taf of groundwater extracted during a drought year, about 2 taf are returned to the aquifer via deep percolation.

Well Depth

Well depth and well use data for the Angel Slough Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 51 well records for the Angel Slough Sub-inventory Unit were evaluated and classified into two well types: domestic and irrigation. There are no municipal or industrial well records on file for this sub-inventory unit. A summary of the minimum, maximum, and average well

depths, listed by well type, is presented in Table 5, Appendix B. A cumulative frequency distribution curve was also used to evaluate the statistical distribution of the well depth data for irrigation wells within the sub-inventory unit. The cumulative frequency curve for the Angel Slough Sub-inventory Unit is presented below and the data used to create the curve is summarized in Table 5, Appendix B.

Table 5, Appendix B, shows that the majority of wells in the Angel Slough Sub-inventory Unit are for irrigation use. The average irrigation well depth is 229 feet. Table 5 also shows that only 8 wells were drilled for domestic use. The average domestic well depth for the Angel Slough Sub-inventory Unit is 86 feet. The domestic wells range in depths from 35 to 125 feet. A further statistical analysis of domestic wells in the Angel Slough Sub-inventory Unit was not developed due to the low number of wells.

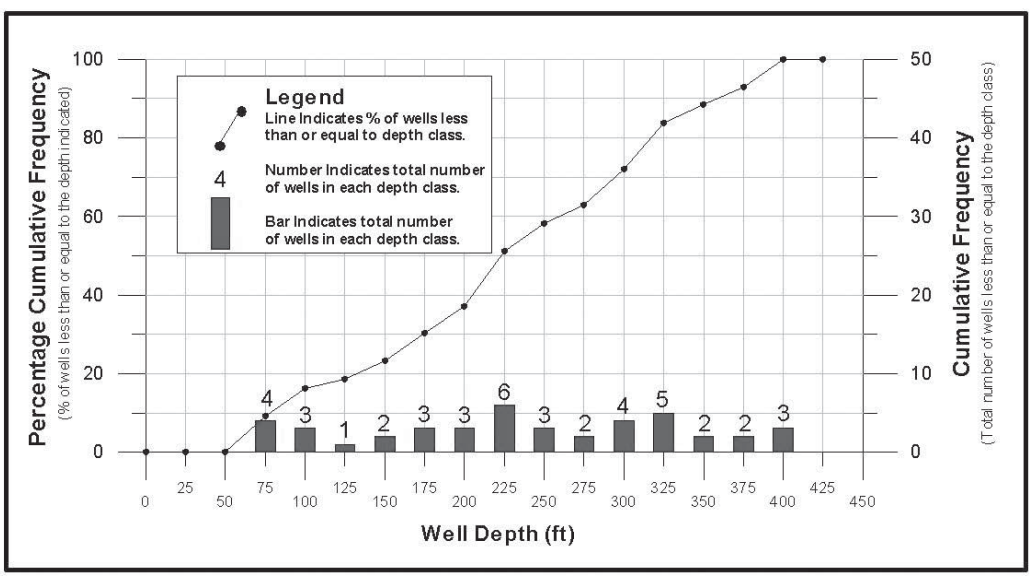
The well depth data for irrigation wells were further analyzed by evaluating the cumulative frequency distribution of well depths. Figure 56 shows the cumulative frequency distribution of well depths for irrigation wells. A total of 43 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 60 to 400 feet.

The histogram bars in Figure 56 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the irrigation well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the Angel Slough Sub-inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of irrigation well depth data for the Angel Slough Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 225 feet or less,
- 20% of the wells are installed to a depth of 130 feet or less, and
- 10% of the wells are installed to a depth of 75 feet or less.

Figure 56.
Cumulative Frequency Distribution of Irrigation Wells,
Angel Slough Sub-inventory Unit



Llano Seco Sub-inventory Unit

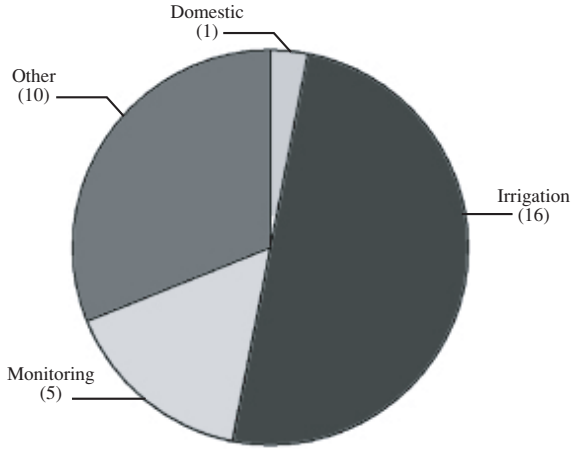
The Llano Seco Sub-inventory Unit covers an area of about 18,400 acres in the southwestern portion of the West Butte Inventory Unit. It is bordered by the M&T and Angel Slough sub-inventory units to the north, Durham-Dayton and Western Canal sub-inventory units to the east, Glenn County to the south, and the Sacramento River to the west (see Plate 1, Appendix A). This sub-inventory unit corresponds roughly to the water service area associated with Rancho Llano Seco. Land uses within the Llano Seco Sub-inventory Unit consist of a mixture of row crops, grain, pasture and native riparian supported by both surface water and groundwater. In a normal year, about 6% of the Llano Seco Sub-inventory Unit is in summer agricultural production supported by groundwater.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the Llano Seco Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are 32 wells in the Llano Seco Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 1 well is listed as domestic, 16 are listed as irrigation, none are listed as municipal, 5 are listed as monitoring, and 10 are listed as other. Figure 57 illustrates the breakdown of wells by use for the sub-inventory unit.

Figure 57.
Number of Wells by Use, Llano Seco Sub-inventory Unit



Total Number of Well = 32

Groundwater Level

There are little groundwater level data available for the Llano Seco Sub-inventory Unit. DWR and BCDWRC are not currently monitoring wells in the Llano Seco Sub-inventory Unit. However, historic groundwater level records for two shallow wells, 20N/01W-26H01M and 20N/01W-26H02M, are available. Frequent nearby pumping and difficulties with measuring these wells resulted in many years of questionable measurements, which led to the removal of 20N/01W-26H02M from the groundwater level monitoring grid in 1994 and removal of 20N/01W-26H01M in 1997.

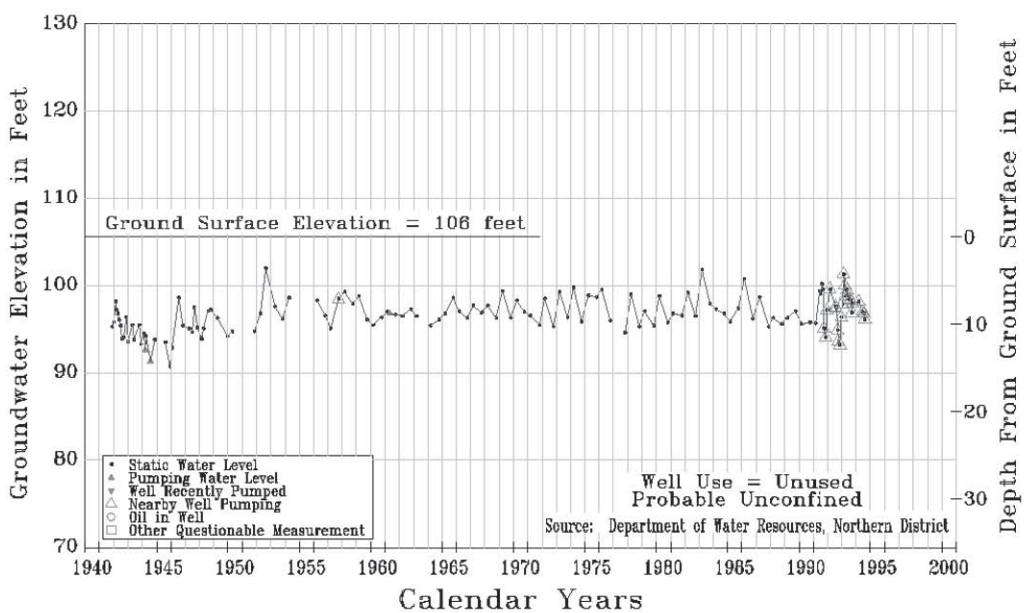
Figure 58 is a hydrograph for Well 20N/01W-26H02M located in the southern portion of the Llano Seco Sub-inventory Unit. The area surrounding this well is characterized by rural and agricultural land uses supported primarily by the application of surface water. Well 20N/01W-26H02M is an unused irrigation well constructed in the unconfined portion of the aquifer system, for which groundwater level measurements date back to the early 1940s. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until 1991 and on a monthly basis from 1991 to about 1994, when it was eliminated from the monitoring grid.

Figure 58 shows that the average seasonal fluctuations in groundwater levels are about 3 to 5 feet during years of normal precipitation. A long-term comparison of spring-to-spring groundwater levels in Well 20N/01W-26H02M shows little, if any, decline in groundwater levels associated with the 1976-77 and 1986-94 droughts. Overall comparison of spring-to-spring groundwater levels in Figure 58 shows that there has been little change in the unconfined aquifer system in this portion of the Llano Seco Sub-inventory Unit since the early 1940s.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Plate 7, Appendix A shows that the spring groundwater elevations in the Llano Seco Sub-inventory Unit are fairly flat and fall between the 90- and 100-foot elevation contours.

Plate 8, Appendix A is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. Plate 8 shows that the seasonal groundwater elevation fluctuations for a normal year in the Llano Seco Sub-inventory Unit range from about 3 feet in areas near the Sacramento River to 7 feet in areas to the northeast and adjacent to the Durham-Dayton Sub-inventory Unit.

Figure 58.
Groundwater Hydrograph for Well 20N/01W-26H02M, Llano Seco Sub-inventory Unit.



Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). Plate 7 shows that the regional pattern of spring groundwater movement in the Llano Seco Sub-inventory Unit is in a south-to-southwesterly direction, at a gradient of about 2 feet per mile, toward the Sacramento River and Angel Slough.

Groundwater Extraction

Estimates of groundwater extraction in the Llano Seco Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that the estimated normal-year groundwater extraction for the Llano Seco Sub-inventory Unit is fairly low at about 2 taf. Groundwater extraction of approximately 2 taf represents about 0.6% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the approximately 2 taf of groundwater extracted during a normal year, most are for summer agricultural use and 0.5 taf is for fall agricultural uses. The agricultural groundwater in a normal year services an area of about 1,100 acres, for an applied water average of 2.3 af/acre. Table 3 also shows that about 0.3 taf of the extracted groundwater returns to the aquifer via deep percolation.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show that drought-year groundwater extraction in the Llano Seco Sub-inventory Unit is estimated at 3.2 taf, an increase of about 39% over the normal-year extraction estimate. Of the 3.2 taf of groundwater extracted during a drought year, about 0.6 taf is returned to the aquifer via deep percolation.

Well Depth

Well depth and well use data for the Llano Seco Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 16 well records for the Llano Seco Sub-inventory Unit were evaluated and classified into two well types: domestic and irrigation. There are no municipal and public well records on file for this sub-inventory unit. A statistical summary is presented in Table 5, Appendix B. Further statistical analyses of domestic and irrigation wells in the Llano Seco Sub-inventory Unit were not developed due to the low number of wells. Table 5, Appendix B, shows that the majority of wells in the Llano Seco Sub-inventory Unit are for irrigation use. Table 1 shows that 15 wells are for irrigation use and 1 well is for domestic use. The irrigation wells range in depths from 110 to 592 feet, with an average depth of 311 feet. The 1 domestic well is listed at a depth of less than 60 feet.

East Butte Inventory Unit

The East Butte Inventory Unit covers about 188,700 acres in the south-central valley portion of Butte County (Plate 1, Appendix A). It is bordered by Butte Creek to the north and west, the Butte County line to the south, foothills to the northeast, and the Feather River to the southeast. Agricultural land use consists primarily of rice production supported by both groundwater and surface water. To a lesser extent, orchards and row crops are also produced in areas having more permeable soils. In a normal year, about 12% of the East Butte Inventory Unit is in summer agricultural production supported by groundwater. During a drought year, about 19% of the inventory unit consists of summer agricultural production supported by groundwater.

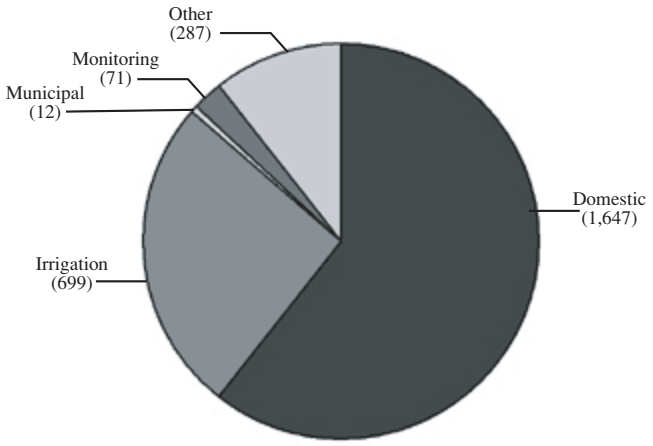
The inventory unit is divided into nine sub-inventory units: Pentz, Esquon, Cherokee, Western Canal, Richvale, Thermalito, Biggs-West Gridley, Butte, and Butte Sink. About one-third of the Western Canal Sub-inventory Unit is located in the West Butte Inventory Unit. Well distribution, use, and depth data presented under the East Butte Inventory Unit includes only that part of the Western Canal Sub-inventory Unit that is within the East Butte Inventory Unit. Detailed discussions of groundwater resources at the sub-inventory unit level will be presented later in this section.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number, types, dates of installation, and distribution of wells in the East Butte Inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data, by area and installation date, is provided in Tables 1 and 2, Appendix B.

There are an estimated 2,716 wells in the East Butte Inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 1,647 wells are listed as domestic, 699 are listed as irrigation, 12 are listed as municipal, 71 are listed as monitoring, and 287 are listed as other. Figure 59 illustrates the breakdown of wells by use for the inventory unit.

Figure 59.
Number of Wells by Use, East Butte Inventory Unit

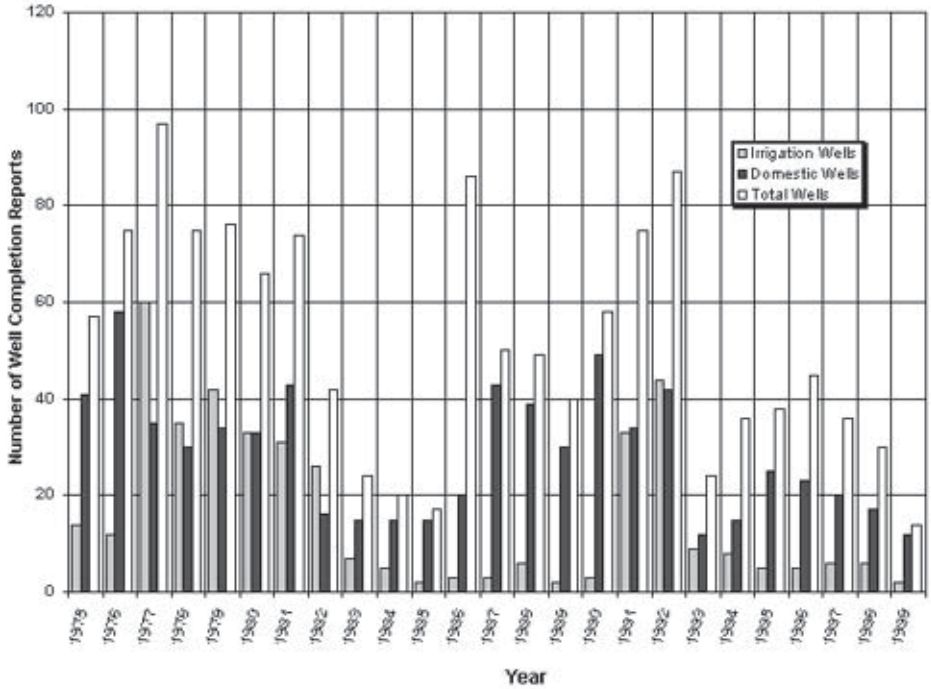


Total Number of Well = 2,716

Wells in the East Butte Inventory Unit were also analyzed to determine the number and types of wells installed over time. Examination of the number and types of wells drilled over time can help offer perspective on the average age of the existing infrastructure and the approximate number of wells installed during normal and drought years. Table 2, Appendix B, lists the annual number and types of wells drilled in the East Butte Inventory Unit between 1975 and 1999. The wells in Table 2 are grouped as domestic, irrigation, miscellaneous, and total.

Table 2, Appendix B, shows that 987 wells were drilled in the East Butte Inventory Unit between 1975 and 1999. The number of wells drilled per year range from a low of 14 in 1999 to a high of 97 in 1977, with an average of 39 wells per year. About 86% of the wells drilled in 1999 are listed as domestic and 14% are listed as irrigation. About 36% of the wells drilled in 1977 are listed as domestic and 61% are listed as irrigation. Figure 60 illustrates the number of well completion reports filed per year for the East Butte Inventory Unit.

Figure 60.
Number of Well Completion Reports Filed Per Year, East Butte Inventory Unit



Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 38 wells within the East Butte Inventory Unit. The monitoring wells consist of a mixture of domestic, irrigation, observation and unused wells. Table 10 lists the currently monitored wells along with the annual fluctuations in groundwater levels during normal and drought years. Table 10 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. The groundwater monitoring wells are shown on Plate 6, Appendix B.

Historic groundwater level data for the East Butte Inventory Unit indicate that the annual fluctuations in groundwater levels in the unconfined portion of the aquifer system are about 2 to 4 feet during years of normal precipitation and up to about 15

feet during drought years. In the confined and composite portions of the aquifer, the increased use of groundwater in the northern portion of the inventory unit results in much wider fluctuations in groundwater levels. In the southern portion of the inventory unit, the composite wells average about 4 feet during normal years and up to 10 feet during drought years. In the northern portion of the inventory unit, the composite wells average about 15 feet during normal years and 30 to 40 feet during drought years. Composite monitoring wells measure a combined groundwater level in multiple water-bearing zones within the aquifer system. In the northern portions of the inventory unit, annual fluctuations in groundwater levels in the confined and semi-confined aquifer systems range from 15 to 30 feet during normal years. To the south, annual fluctuations in the confined and semi-confined aquifer systems average 4 feet during normal years and up to 5 feet during drought years.

Groundwater hydrographs illustrate changes in groundwater levels over time. Hydrographs representing the seasonal and long-term changes in groundwater levels for the unconfined and confined aquifer systems in the East Butte Inventory Unit are presented in Figures 61 and 62. The locations of the monitoring wells are shown on Plate 6, Appendix A. Additional hydrographs will be presented later in this section during discussions of groundwater levels at the sub-inventory unit level. Detailed discussions of groundwater level data, hydrograph interpretation, and on-line access to hydrographs for all of the Butte County groundwater monitoring wells are presented in Section 1.

Figure 61 is a hydrograph for Well 18N/02E-16F01M, located in the basin area between Richvale and Gridley. The area surrounding the well is characterized as a rural agricultural rice production area that is supported in normal years by flood irrigation with surface water. The well is an irrigation well constructed in the upper, unconfined portion of the aquifer system, for which groundwater level measurements date back to the late 1940s. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until about 1991 and on a monthly basis from 1991 to 1996. Since 1996, this well has been monitored four times a year during March, July, August, and October.

Figure 61 shows seasonal fluctuations in groundwater levels of about 3 to 4 feet during years of normal precipitation. The small seasonal fluctuations in groundwater levels are characteristic of shallow wells in areas associated with agricultural application of surface water. A long-term comparison of spring-to-spring groundwater levels in Well 18N/02E-16F01M shows little response to the 1976-77 and 1986-94 droughts. Overall, spring-to-spring groundwater levels in the unconfined portion of the aquifer during years of normal precipitation have changed little since the mid-1940s.

Table 10.
Current Groundwater Monitoring Wells and Estimated Annual Fluctuations in Groundwater Levels, East Butte Inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
17N/01E-10A01M	Domestic	Composite	1952-2000	3-5	6-7
17N/01E-17F01M	Observation	Semi-Confined	1991-2000	3-5	5-8
17N/01E-17F02M	Observation	Confined	1991-2000	4-5	7-8
17N/01E-17F03M	Observation	Confined	1991-2000	4-5	6-9
17N/02E-16C01M	Domestic	Unconfined	1946-2000	1-2	3-5
17N/02E-14A01M	Irrigation	Composite	1946-2000	2-3	5-10
17N/03E-05C01M	Irrigation	Composite	1946-2000	3-5	8-10
17N/03E-08G01M	Domestic	Composite	1952-2000	3-5	5-10
17N/03E-16N01M	Domestic	Confined	1952-2000	3-6	5-10
18N/01E-13M01M	Domestic	Composite	1947-2000	2-3	10
18N/01E-15D02M	Domestic	Composite	1975-2000	2-3	5
18N/02E-16F01M	Irrigation	Unconfined	1946-2000	1-2	2-4
18N/02E-25M01M	Irrigation	Composite	1959-2000	1-2	3-5
18N/02E-32Q02M	Domestic	Composite	1946-2000	2-3	3-4
18N/03E-05K01M	Irrigation	Confined	1993-2000	3-7	5-10
18N/03E-18F01M	Irrigation	Confined	1946-2000	3-5	5-8
18N/03E-21G01M	Irrigation	Composite	1951-2000	5-8	3-5
19N/01E-09Q01M	Irrigation	Confined	1990-2000	5	10
19N/01E-27Q01M	Observation	Confined	1976-2000	2-4	15-25
19N/01E-28R01M	Domestic	Unconfined	1957-2000	3-4	4-5
19N/02E-15N02M	Unused/Irr.	Confined	2000-2000	*	*
19N/02E-17A01M	Domestic	Unconfined	1959-2000	3-4	4-5
19N/03E-05N02M	Domestic	Composite	1976-2000	3-6	15-25
20N/01E-35C01M	Domestic	Confined	1946-2000	2-3	4-8
20N/02E-09L01M	Irrigation	Composite	1952-2000	10-20	30-40
20N/02E-15H01M	Observation	Confined	1995-2000	10-20	*
20N/02E-15H02M	Observation	Unconfined	1995-2000	2-4	*
20N/02E-16P01M	Irrigation	Composite	1990-2000	5	30-40
20N/02E-24C01M	Observation	Semi-Confined	1999-2000	15	*
20N/02E-24C02M	Observation	Semi-Confined	1999-2000	15	*
20N/02E-24C03M	Observation	Confined	1999-2000	12	*
20N/02E-28N01M	Unused/Dom.	Unconfined	1946-2000	2-4	6-8
20N/03E-33L01M	Unused/Irr.	Semi-Confined	1999-2000	25	*
21N/02E-20P01M	Irrigation	Semi-Confined	1995-2000	20-30	*
21N/02E-26E02M	Unused/Dom.	Unconfined	1959-2000	2-4	5
21N/02E-26F01M	Irrigation	Unconfined	1967-2000	5-10	15-20
21N/03E-22C01M	Domestic	Semi-Confined	2000-2000	*	*
21N/03E-32B01M	Unused/Irr.	Unconfined	1999-2000	5	*

*Insufficient Data

Figure 61.
Groundwater Hydrograph for Well 18N/02E-16F01M, East Butte Inventory Unit

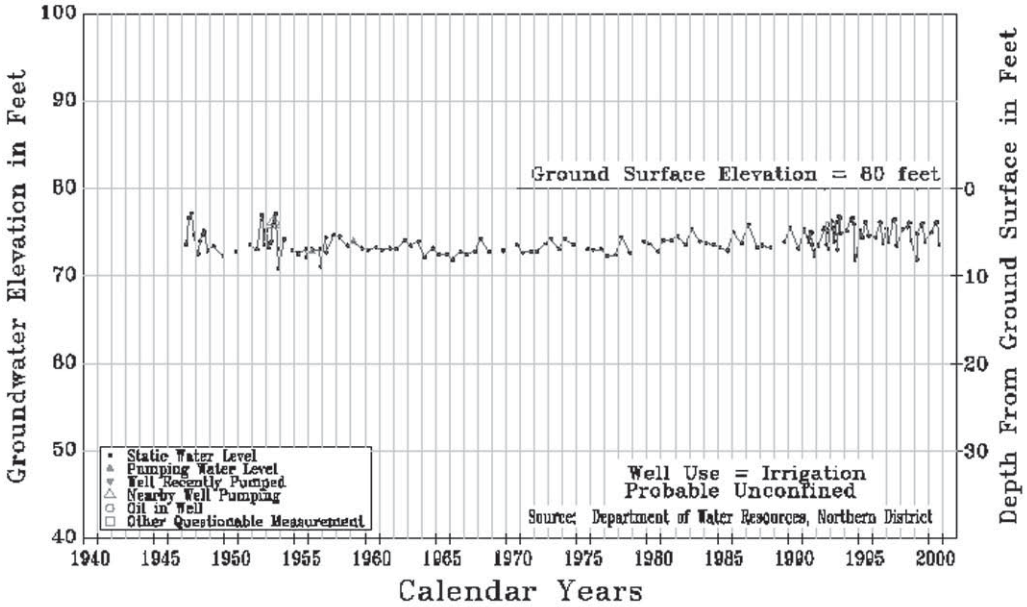
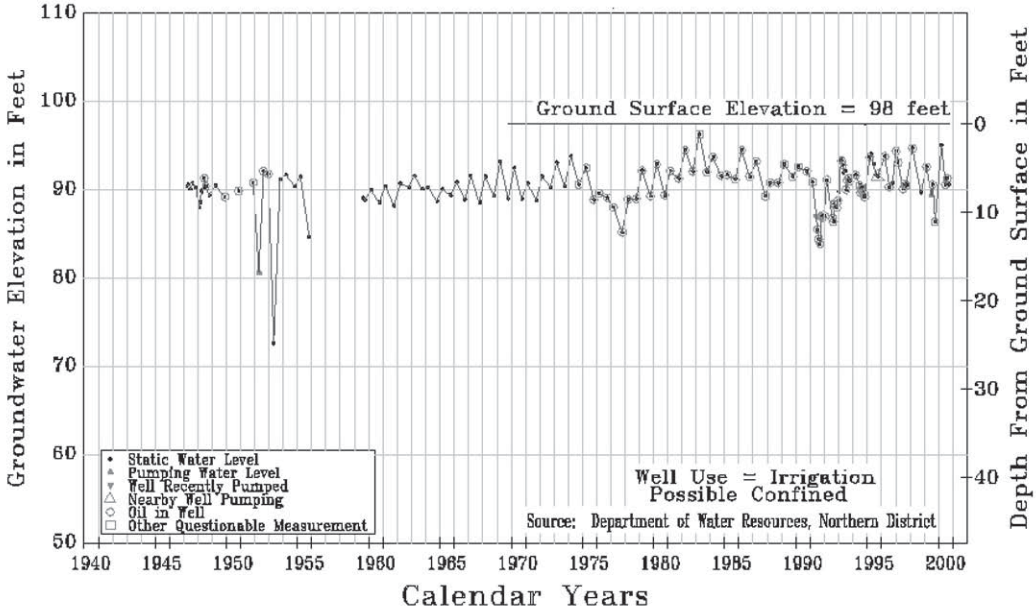


Figure 62 is a hydrograph for Well 18N/03E-18F01M in the eastern portion of the East Butte Inventory Unit. The area surrounding this well is characterized by rural and agricultural land uses that are supported by the application of groundwater on some parcels and the application of surface water on other parcels. The well is an irrigation well constructed so that it draws water from the confined portion of the aquifer system, with a groundwater measurement record dating back to the mid-1940s. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until about 1991 and on a monthly basis from about 1991 to 1995. Since 1995, this well has been monitored four times a year during March, July, August, and October.

Figure 62 shows seasonal fluctuations in groundwater levels of about 3 to 4 feet during years of normal precipitation and 5 to 6 feet during drought periods. A long-term comparison of spring-to-spring groundwater levels in Well 18N/03E-18F01M shows declines in groundwater levels associated with the 1976-77 and 1986-94 droughts, followed by a recovery in levels to predrought conditions. An overall comparison of spring-to-spring groundwater level data indicates that this portion of the basin fully recharges during years of normal precipitation and that there has been a slight increase in groundwater levels in this area since measurement began. This increase is likely the result of an increase in the application of surface water for agriculture and the presence of the Thermalito Afterbay, which recharges groundwater in this area.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Groundwater elevations for 1997 are considered representative of a normal water year. Spring groundwater elevations are commonly the highest of the year and, in areas unaffected by municipal use of groundwater, reflect the natural groundwater table distribution and direction of movement. Plate 7 shows that the spring groundwater elevations in the East Butte Inventory Unit range from an elevation of about 60 feet in the southwestern portion of the inventory unit to an elevation of about 160 feet along the eastern margin of the

Figure 62.
Groundwater Hydrograph for Well 18N/03E-18F01M, East Butte Inventory Unit



valley.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. The seasonal fluctuations in groundwater elevations are often dependent on the sources of water used for agricultural and municipal land uses. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Plate 8, Appendix A, shows that the seasonal groundwater elevation fluctuations for a normal year in the East Butte Inventory Unit range from 0 to 30 feet, with the largest seasonal decline in the western Cherokee Sub-inventory Unit and just south of Durham in the Esquon Sub-inventory Unit. Areas having the greatest seasonal decline in groundwater elevations correlate to regions that are largely dependent on groundwater for agricultural and municipal needs. Plate 8 shows little to no seasonal decline in groundwater elevation for the southwestern half of the East Butte Inventory Unit. In this area, limited groundwater extraction and the application of agricultural water during the summer months compensate for a seasonal decline of groundwater elevations.

Groundwater Movement

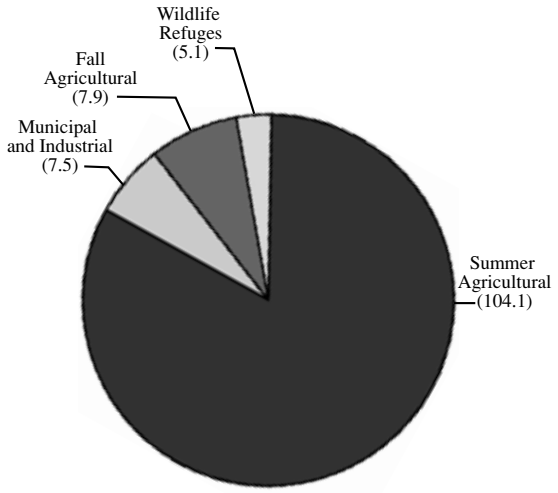
The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). Plate 7 shows that the regional pattern of spring groundwater movement in the East Butte Inventory Unit is in a south-to-southwesterly direction toward the Sacramento River. Regionally, the direction of groundwater movement is fairly uniform. However, local fluctuations in the regional groundwater flow pattern are observed just south of the Thermalito Afterbay due to the recharge of groundwater from this surface water system.

Groundwater Extraction

Estimates of groundwater extraction in the East Butte Inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are summarized in Tables 3 and 4, Appendix B. Groundwater extraction estimates are divided into summer and winter agricultural use, annual municipal and industrial use, and annual wildlife refuge use. The annual deep percolation estimates are divided into agricultural, municipal, and industrial uses. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

The estimated amounts of normal-year groundwater extraction, by type of use, are presented in Table 3, Appendix B, and illustrated in Figure 63. Figure 63 shows that normal-year groundwater extraction for the East Butte Inventory Unit is estimated at 124.6 taf. Groundwater extraction of 124.6 taf represents about 29% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 124.6 taf of groundwater extracted during a normal year, 104.1 taf are for summer agricultural use, 7.5 taf are for annual municipal and public use, 7.9 taf are for fall agricultural use, and 5.1 taf are for wildlife refuge use. Table 3, Appendix B, shows that, during a normal year, summer agricultural groundwater is applied to about 23,500 acres, for an applied water average of 4.4 af/acre. Table 3 also shows that 28.7 taf of the extracted groundwater return to the aquifer via deep percolation during a normal year.

Figure 63.
Estimated Amount of Normal-Year Groundwater Extraction by Type of Use, East Butte Inventory Unit

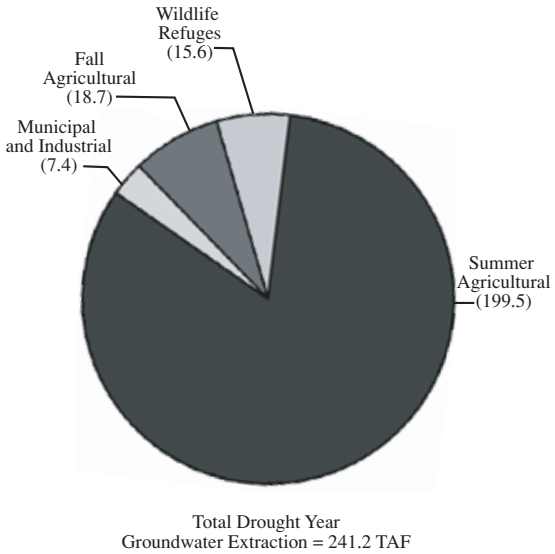


Total Normal Year
Groundwater Extraction = 124.6 TAF

The estimated amounts of drought-year groundwater extraction, by type of use, are presented in Table 4, Appendix B, and illustrated in Figure 64. Figure 64 shows that the drought-year groundwater extraction in the East Butte Inventory Unit is estimated at 241.2 taf, an increase of about 93% over the normal-year extraction estimate. Of the 241.2 taf of groundwater extracted during a drought year, 199.5 taf are for summer agricultural use, 7.4 taf are for annual municipal use, 18.7 taf are for fall agricultural use, and 15.6 taf are for wildlife refuge use. Table 4, Appendix B, shows

that the summer agricultural groundwater in a drought year is applied to about 37,900 acres, for an applied water average of 5.3 af/acre. Table 4 also shows that 42.5 taf of the extracted groundwater return to the aquifer via deep percolation during a drought year.

Figure 64.
Estimated Amount of Drought-Year Groundwater Extraction by Type of Use, East Butte Inventory Unit.



Well Depth

Well depth and well use data for the East Butte Inventory Unit were collected from well completion reports filed with DWR. A total of 2,409 well records for the inventory unit were evaluated and classified into three well types: domestic, irrigation, and municipal. A summary of the minimum, maximum, and average well depths, listed by well type, is presented in Table 5, Appendix B. A statistical distribution of the well depth data was also evaluated though a series of cumulative frequency distribution curves for domestic, irrigation, and municipal wells. Cumulative frequency curves associated with the East Butte Inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the East Butte Inventory Unit are for domestic use. The average domestic well depth is 120 feet. Table 5 also shows that wells drilled for irrigation and municipal uses tend to be deeper than those for domestic use. The average irrigation well depth for the East Butte Inventory Unit is 299 feet. The average municipal well depth is 261 feet.

The cumulative frequency distribution of well depth data was also evaluated for domestic, irrigation, and municipal wells in the East Butte Inventory Unit. Figure 65 shows the cumulative frequency distribution of well depths for domestic wells in the East Butte Inventory Unit. A total of 1,662 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 25 to 860 feet.

The histogram bars in Figure 65 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the domestic well depth data is skewed slightly to the right toward deeper well depths. Right-

skewed distribution of domestic well data indicates that the average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the East Butte Inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 95 feet or less,
- 20% of the wells are installed to a depth of 65 feet or less, and
- 10% of the wells are installed to a depth of 50 feet or less.

Figure 65.
Cumulative Frequency Distribution of Domestic Wells, East Butte Inventory Unit

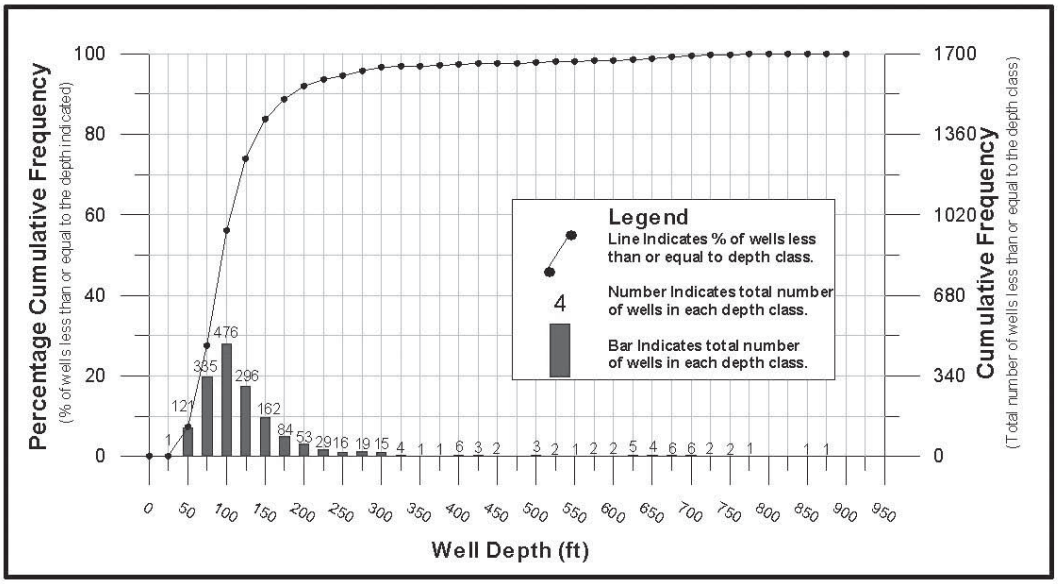


Figure 66 illustrates the cumulative frequency distribution of irrigation well depth data in the East Butte Inventory Unit. A total of 735 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 35 to 883 feet.

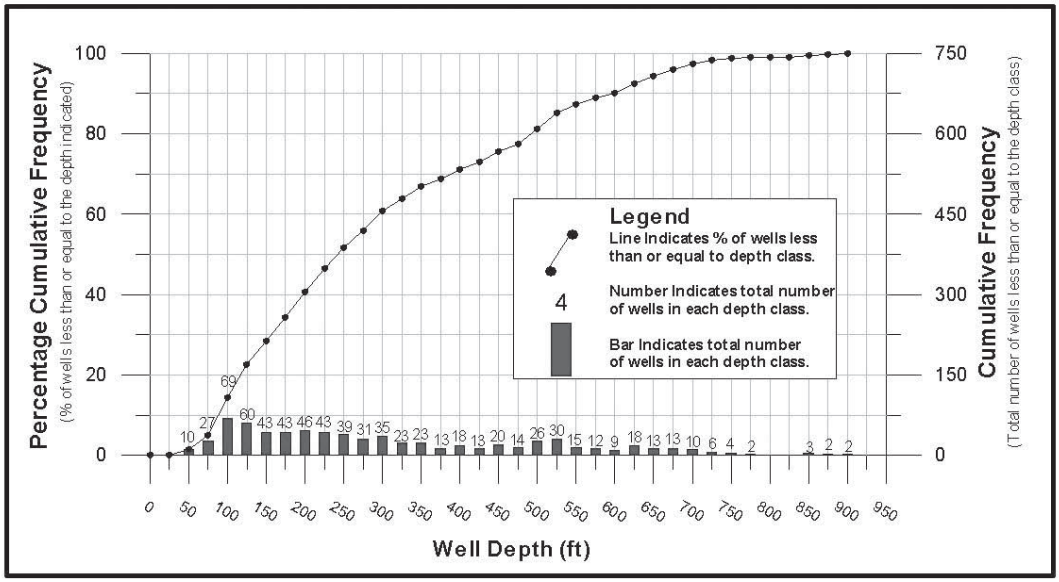
The histogram bars in Figure 66 show that the distribution of irrigation well depth data are asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the East Butte Inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of irrigation well depth data for the East Butte Inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 245 feet or less,
- 20% of the wells are installed to a depth of 115 feet or less, and
- 10% of the wells are installed to a depth of 85 feet or less.

There are 12 municipal wells in the East Butte Inventory Unit. The well depths range from a minimum of 70 feet to a maximum of 381 feet. A cumulative frequency curve was not developed for municipal wells in the inventory unit because the small number of wells tends to limit a statistically meaningful evaluation.

Figure 66.
Cumulative Frequency Distribution of Irrigation Wells, East Butte Inventory Unit



Well Yield

Well yield estimates for the East Butte Inventory Unit were evaluated based on well completion reports filed with DWR, published and unpublished investigations and utility pump records from municipal and agricultural wells. A further explanation of well yield data is provided in Section 1. A statistical summary of well yield data is provided in Table 6, Appendix B.

About 748 municipal and irrigation well completion reports for the East Butte Inventory Unit are on file at DWR. Of the 748 reports, only 38 have well yield data. Table 6, Appendix B, shows that well yields, from well completion report data, in the East Butte Inventory Unit range from a low of 100 gpm to a high of 4,500 gpm, with an average of 2,605 gpm. Well yield data from well completion reports should only serve as a general guide to local well productivity.

In 1961, Olmsted and Davis of the USGS compiled utility pump test records for 21 areas within the Sacramento Valley. Three of these areas - Chico, Gridley, and Honcut - are located almost entirely in the Butte County portion of the Sacramento Valley. The Gridley area corresponds closely to the East Butte Inventory Unit south of Nelson. Well yield data from the investigation are summarized in Table 6, Appendix B. Utility pump test data for the Gridley area represent data from 119 pump tests taken prior to 1959. Table 6 shows that the average well yield in the Gridley area, as reported in the 1961 USGS report, is 980 gpm.

Utility pump test records for the East Butte Inventory Unit were also evaluated for estimates of well yield. The data are summarized in Table 6, Appendix B. The well yield estimates for the East Butte Inventory Unit represent data from 890 pump tests performed on 227 wells between 1989 and 1998. Table 6 shows that the well yields for the East Butte Inventory Unit range from a low of 65 gpm to a high of 5,459 gpm, with an average well yield of 1,602 gpm. Utility pump tests are generally considered to provide an accurate estimate of well yield.

Specific Capacity

Specific capacity estimates for the East Butte Inventory Unit were evaluated based on published investigations and utility pump test records from primarily municipal and agricultural wells. A further explanation of specific capacity data is provided in Section 1. A summary of specific capacity data is provided in Table 7, Appendix B.

Table 7, Appendix B, summarizes specific capacity data from the 1961 Olmsted and Davis (USGS) utility pump test records. Utility pump test data for the Gridley area represent data from 119 pumping tests taken prior to 1959. Table 7 shows that the average specific capacity for the Gridley area, as reported in the 1961 USGS report, is 58 gpm/ft.

Table 7 shows that specific capacity figures from utility pump test records in the East Butte Inventory Unit range from a low of 11 gpm/ft to a high of 340 gpm/ft. The average specific capacity in the East Butte Inventory Unit, estimated using utility pump test data, is 84 gpm/ft. The specific capacity estimates shown in Table 7 represent 335 pump tests performed on 97 wells between 1989 and 1998. Utility pump tests are generally considered to provide a good estimate of specific capacity.

Groundwater Storage Capacity

For the purposes of this investigation, groundwater storage capacity is defined as the maximum volume of fresh groundwater capable of being stored within an aquifer beneath a given area. Estimates of storage capacity were calculated by multiplying the area of the East Butte Inventory Unit by the maximum saturated thickness and the average specific yield of the freshwater portion of the aquifer. Groundwater storage capacity estimates are summarized in Table 8, Appendix B. A further explanation of groundwater in storage is provided in Section 1.

Table 8, Appendix B, shows that the East Butte Inventory Unit covers an area of about 188,600 acres. Groundwater storage capacity estimates for the inventory unit listed in Table 8 assume uniform aquifer saturation from a depth of 10 feet, down to the average base of fresh water at a depth of about 1,400 feet, and an average specific yield of 6.3%. Based on the above assumptions, the estimated maximum groundwater storage capacity for the East Butte Inventory Unit is about 16,416 taf.

Groundwater in Storage

Groundwater in storage is defined as the amount of water contained within the aquifer system at the time of measurement. Groundwater in storage in the East Butte Inventory Unit was examined using three scenarios:

- the estimated volume of groundwater currently in storage over the entire freshwater portion of the aquifer system,
- the estimated seasonal decline in groundwater levels associated with the removal of groundwater in storage during a normal water year, and
- the estimated seasonal decline in groundwater levels associated with the removal of groundwater in storage during a drought water year.

The estimated amounts of groundwater in storage are summarized in Table 9, Appendix B. A further explanation of groundwater in storage is provided in Section 1.

- **Estimated Volume of Groundwater in Storage.** The East Butte Inventory Unit covers an area of about 188,600 acres. Groundwater in storage estimates for the East Butte Inventory Unit assume uniform aquifer saturation from an average

depth of 13 feet, down to the average base of fresh water at a depth of about 1,400 feet, and an average specific yield of 6.3%. The average depth of groundwater is based on monitoring data collected in spring 1997. Based on the above assumptions, the volume of groundwater in storage for the East Butte Inventory Unit is estimated at 16,380 taf. A comparison of groundwater storage capacity and groundwater in storage estimates in Tables 8 and 9, Appendix B, indicates that groundwater in storage in the inventory unit is close to maximum capacity during normal water years.

- Estimated Seasonal Decline of Groundwater in Storage associated with Normal-Year Extraction. The normal-year groundwater demand for the East Butte Inventory Unit was adjusted to reflect seasonal use during a normal water year. Seasonal groundwater extraction is estimated at 100% of the summer agricultural extraction, plus 70% of the annual municipal extraction, minus 30% of the annual deep percolation. Based on the above assumptions, the seasonal groundwater demand for the inventory unit, during a normal year, is estimated at 71.5 taf. The average seasonal decline in groundwater levels associated with a normal-year extraction of 71.5 taf of groundwater in the East Butte Inventory Unit is estimated at 6 feet.
- Estimated Seasonal Decline of Groundwater in Storage associated with Drought-Year Extraction. The drought-year groundwater demand for the East Butte Inventory Unit was adjusted to reflect seasonal use during a drought water year. Seasonal groundwater extraction is estimated at 100% of the summer agricultural extraction, plus 70% of the annual municipal extraction, minus 30% of the annual deep percolation. Based on the above assumptions, the seasonal groundwater demand in the inventory unit during a drought year is estimated at 168.3 taf. The average seasonal decline in groundwater levels associated with drought-year extraction of 168.3 taf in the East Butte Inventory Unit is about 14 feet.

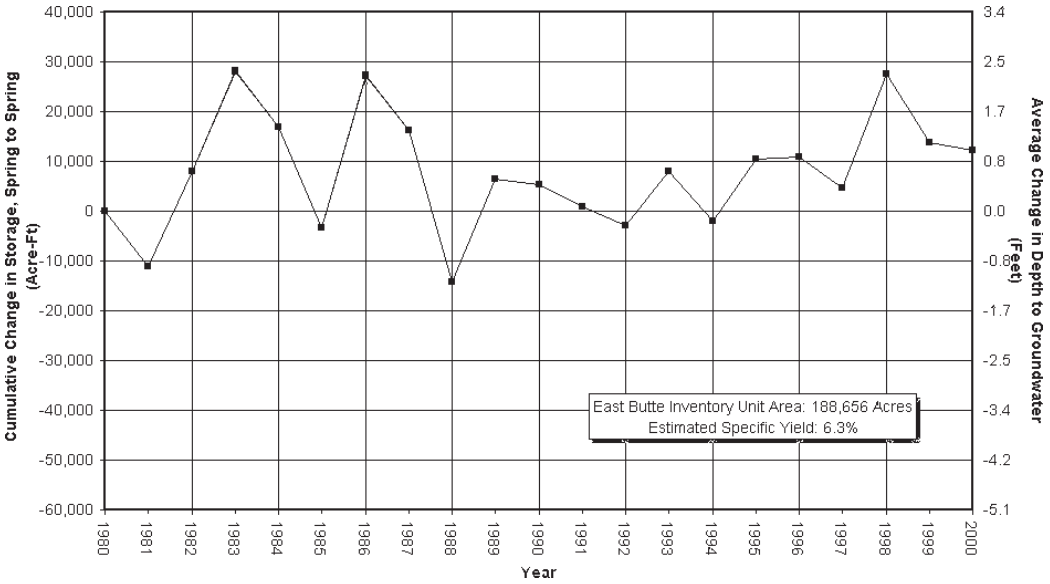
Changes in the Volume of Groundwater in Storage

The annual spring-to-spring changes in groundwater in storage for the East Butte Inventory Unit were calculated over a 20-year period from 1980 to 2000. The changes in the volume of groundwater in storage are based on groundwater contour maps developed from spring groundwater level measurements in the upper portion of the aquifer. A summary of the spring-to-spring changes in the volume of groundwater in storage data is provided in Table 11, Appendix B. The cumulative spring-to-spring changes in the volume of groundwater in storage for the East Butte Inventory Unit are presented in Figure 67. A further explanation of the method for estimating changes in the volume of groundwater in storage is provided in Section 1.

Table 11, Appendix B, lists the annual changes in the volume of groundwater in storage, the cumulative changes in the volume of groundwater in storage, and the changes in groundwater levels associated with the cumulative changes in the volume of groundwater in storage for the East Butte Inventory Unit. Table 11 shows that the largest single-year decline in spring-to-spring volume of groundwater in storage for the East Butte Inventory Unit was about 30.5 taf in 1987-88. The largest single-year increase in the volume of groundwater in storage was about 22.8 taf in 1997-98.

The cumulative spring-to-spring changes in the volume of groundwater in storage for the East Butte Inventory Unit are illustrated in Figure 67. The graph for spring-to-spring changes in the volume of groundwater storage starts with a baseline of zero for spring 1980 and shows cumulative changes from 1980 to 2000. Figure 67 shows that the volume of groundwater in storage increases during the wet years of 1983 and

Figure 67.
Estimated Cumulative Changes in Spring-to-Spring Storage, East Butte Inventory Unit



1986, decreases during 1988, and then increases to stay above the 1980 base storage level over the last five years. The range of the volume of groundwater in storage between the peak in 1983 and the low in 1988 is estimated at about 42.4 taf. Overall, the amount of groundwater in storage in the East Butte Inventory Unit during spring 2000 was about 12 taf more than spring 1980.

Pentz Sub-inventory Unit

The Pentz Sub-inventory Unit covers an area of about 1,900 acres in the northern portion of the East Butte Inventory Unit. It is bordered by Butte Creek to the north, the North Fork of Dry Creek to the south, foothills to the east, and Highway 99 to the west (see Plate 1, Appendix A). The land uses within this sub-inventory unit are nonirrigated native vegetation, pasture, and low density residential. Current groundwater use in the Pentz Sub-inventory Unit is minimal.

Well Distribution

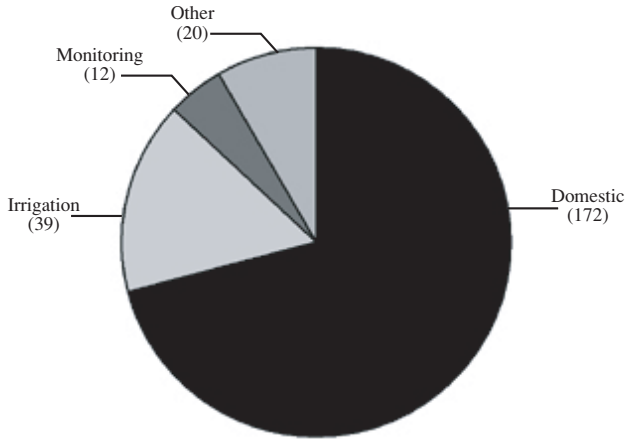
The well completion report database files at DWR were analyzed to determine the number and types of wells in the Pentz Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are about 243 wells in the Pentz Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 172 wells are listed as domestic, 39 are listed as irrigation, none are listed as municipal, 12 are listed as monitoring, and 20 are listed as other. Figure 68 illustrates the breakdown of wells by use for the Pentz Sub-inventory Unit.

Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 2 wells along the western portion of the Pentz Sub-inventory Unit. The monitoring wells consist of unused domestic and irrigation wells. Table 11 lists the current monitoring wells

Figure 68.
Number of Wells by Use, Pentz Sub-inventory Unit



Total Number of Well = 243

along with the annual fluctuations in groundwater levels during normal and drought years. Table 11 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. DWR and BCDWRC monitoring wells are shown on Plate 6, Appendix B.

Historic groundwater level data for the western portion of the Pentz Sub-inventory Unit indicate that the annual fluctuations in groundwater levels in the unconfined portion of the aquifer system average about 2 to 4 feet during years of normal precipitation and about 5 feet during years of drought. The annual fluctuations in groundwater levels associated with monitoring a composite section of the aquifer system average 5 to 10 feet during normal years and up to 20 feet during years of drought. Monitoring wells defined as “composite” measure a combined groundwater level in multiple water-bearing zones within the aquifer system.

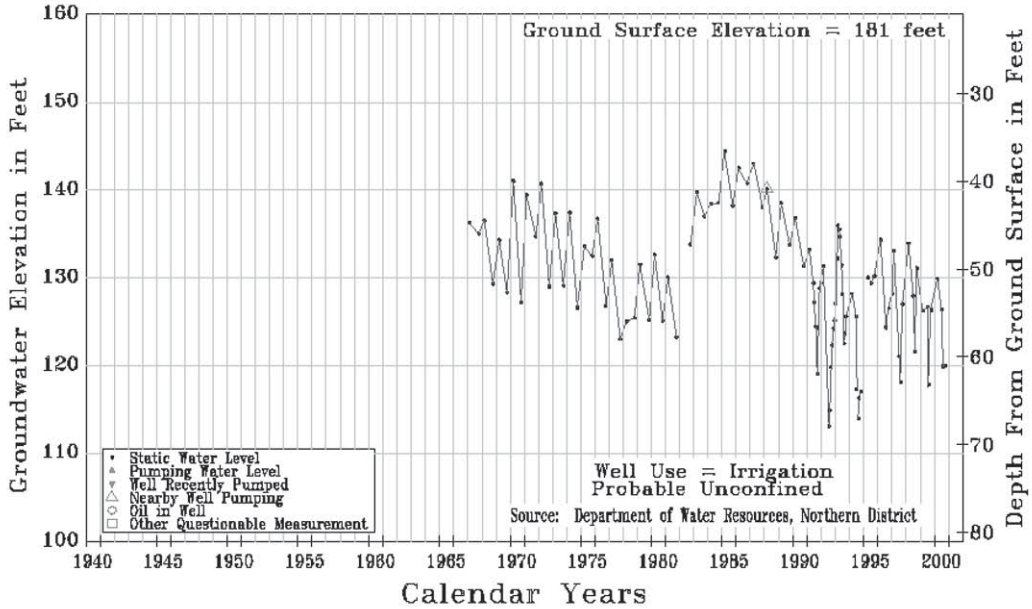
Groundwater hydrographs illustrate changes in groundwater levels over time. A hydrograph representing the seasonal and long-term changes in groundwater levels for the unconfined aquifer system in the western portion of the Pentz Sub-inventory Unit is presented in Figure 69. The locations of the monitoring wells are shown on Plate 6, Appendix B.

Figure 69 is a hydrograph for an active irrigation well, 21N/02E-26F01M, located just west of Highway 99 at the intersection of Durham-Pentz Road. Within a 2-mile radius of the well, groundwater is used to support agricultural production of orchard and row crops and small-scale industrial uses associated with a beverage distribution plant. The well is a deep irrigation well with shallow casing, for which groundwater

Table 11.
Current Groundwater Monitoring Wells and the Estimated Annual Fluctuations in Groundwater Levels, Pentz Sub-inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
21N/02E-26E02M	Unused/Dom.	Unconfined	1959-2000	2-4	5
21N/02E-26F01M	Irrigation	Composite	1967-2000	5-10	15-20

Figure 69.
Groundwater Hydrograph for Well 21N/02E-26F01M, Pentz Sub-inventory Unit



level measurements date back to the mid-1960s. Groundwater levels in this well represent a mixture of the unconfined and confined portions of the aquifer system. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until 1991 and on a monthly basis from 1991 to about 1994. Since 1994 this well has been monitored four times a year during March, July, August, and October.

Figure 69 shows that the average seasonal fluctuations in groundwater levels are about 5 to 10 feet during years of normal precipitation and up to 20 feet during years of drought. A long-term comparison of spring-to-spring groundwater levels in Well 21N/02E-26F01M shows a small decline in groundwater levels associated with the 1976-77 drought, followed by a larger decline associated with the 1986-94 drought. Groundwater levels in this well appear to recover from the 1986-94 drought to groundwater levels similar to those of the early 1980s. However, further long-term analysis of spring-to-spring groundwater levels indicates a 5- to 10-foot decline in groundwater levels since the late 1960s.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Plate 7 shows that the majority of the Pentz Sub-inventory Unit is west of the Sacramento Valley groundwater basin boundary. Interpolation of the groundwater contours in Figure 1 indicates that spring groundwater elevations in the Pentz Sub-inventory Unit range from an elevation of about 140 feet in the western portion of the sub-inventory unit to an elevation of about 200 feet in the eastern portion.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. Plate 8 shows that, in the western portion of the sub-inventory unit, the seasonal groundwater elevations fluctuations for a normal year range from 5 to 15 feet. Not enough groundwater elevation data exist to estimate seasonal groundwater fluctuations in the eastern portion of the Pentz Sub-inventory Unit.

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). Plate 7 shows that the regional pattern of spring groundwater movement in the Pentz Sub-inventory Unit is in a west-to-southwesterly direction. Not enough groundwater level data exist to make an estimate of the local direction of groundwater movement in the sub-inventory unit.

Groundwater Extraction

Estimates of groundwater extraction in the Pentz Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that normal-year groundwater extraction for the Pentz Sub-inventory Unit is estimated at .1 taf. Groundwater extraction of .1 taf represents less than 0.1% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Table 3 also shows that all of the groundwater extracted is used for municipal and industrial uses, primarily domestic water supply.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show that drought-year groundwater extraction in the Pentz Sub-inventory Unit is estimated at .1 taf, or roughly the same as extraction estimates for a normal year.

Well Depth

Well depth and well use data for the Pentz Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 211 well records for this sub-inventory unit were evaluated and classified into two well types: domestic and irrigation. There are no municipal or public well reports for this sub-inventory unit on file with DWR. A statistical summary of the well depth data, listed by well type, is presented in Table 5, Appendix B. Cumulative frequency curves associated with the Pentz Sub-inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the Pentz Sub-inventory Unit are for domestic use. The average domestic well depth is about 245 feet. Table 5 also shows that irrigation wells are slightly deeper. The average irrigation well depth is 299 feet.

The cumulative frequency distribution of well depth data was also evaluated for domestic and irrigation wells in the Pentz Sub-inventory Unit. Figure 70 shows the cumulative frequency distribution of well depths for domestic wells in the sub-inventory unit. A total of 172 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 35 to 860 feet.

The histogram bars in Figure 70 show the total number of domestic wells associated with each 25-foot class interval. The histogram indicates that the distribution of the domestic well depth data is skewed to the right toward deeper well depths. Right-skewed distribution of domestic well data indicates that the average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the Pentz Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 150 feet or less,
- 20% of the wells are installed to a depth of 95 feet or less, and
- 10% of the wells are installed to a depth of 75 feet or less.

Figure 70.
Cumulative Frequency Distribution of Domestic Wells, Pentz Sub-inventory Unit

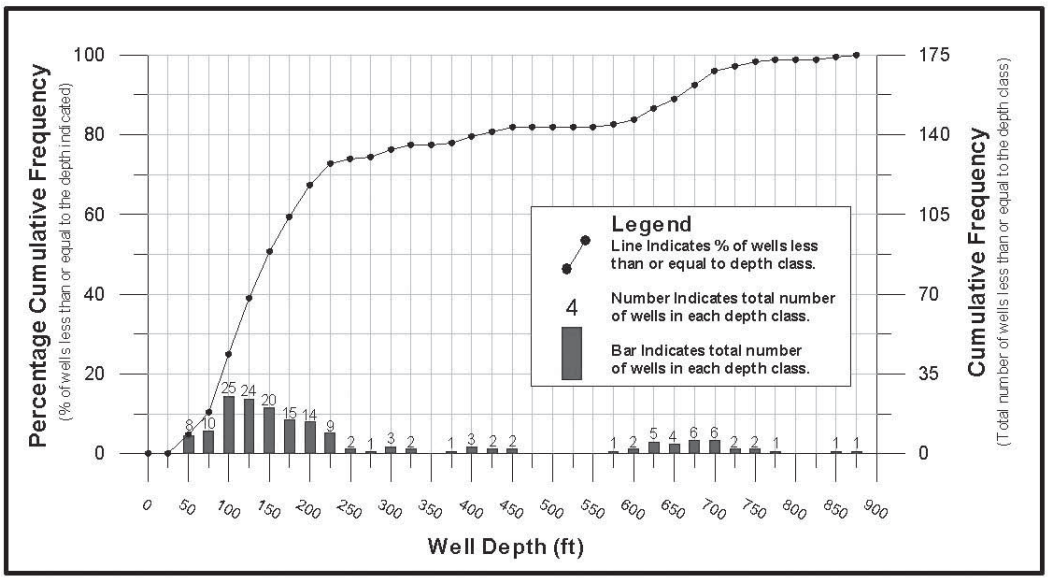


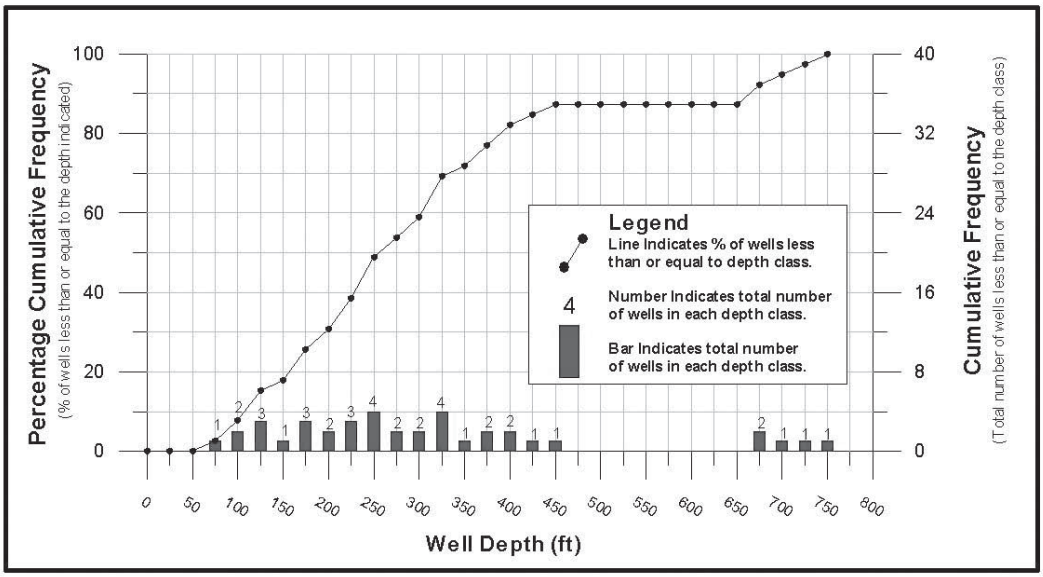
Figure 71 illustrates the cumulative frequency distribution of irrigation well depth data in the Pentz Sub-inventory Unit. A total of 39 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 62 to 740 feet.

The histogram bars in Figure 71 show that the distribution of irrigation well depth data is asymmetrical, showing no noticeable resemblance to normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the East Butte Inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of irrigation well depth data for the Pentz Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 250 feet or less,
- 20% of the wells are installed to a depth of 155 feet or less, and
- 10% of the wells are installed to a depth of 105 feet or less.

Figure 71.
Cumulative Frequency Distribution of Irrigation Wells, Pentz Sub-inventory Unit



Esquon Sub-inventory Unit

The Esquon Sub-inventory Unit covers an area of about 11,600 acres in the northern portion of the East Butte Inventory Unit. It is bordered by the Pentz Sub-inventory Unit to the north, Western Canal Sub-inventory Unit to the south, Cherokee Sub-inventory Unit to the east, and Butte Creek to the west (see Plate 1, Appendix A). The Esquon Sub-inventory Unit almost corresponds to the water service areas associated with the Durham Mutual Water Company and Rancho Esquon. Agricultural land use within the sub-inventory unit includes production of orchards, rice, and grain crops supported by both surface water and groundwater. In a normal year, about 27% of the Esquon Sub-inventory Unit is in summer agricultural production supported by groundwater.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the Esquon Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are about 427 wells in the Esquon Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 291 wells are listed as domestic, 108 are listed as irrigation, none are listed as municipal, 2 are listed as monitoring, and 26 are listed as other. Figure 72 illustrates the breakdown of wells by use for the Esquon Sub-inventory Unit.

Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 2 irrigation wells in the Esquon Sub-inventory Unit. Table 12 lists the wells along with the annual fluctuations in groundwater levels during normal and drought years. Table 12 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. DWR and BCDWRC monitoring wells are shown on Plate 6, Appendix A.

Figure 72.
Number of Wells by Use, Esquon Sub-inventory Unit

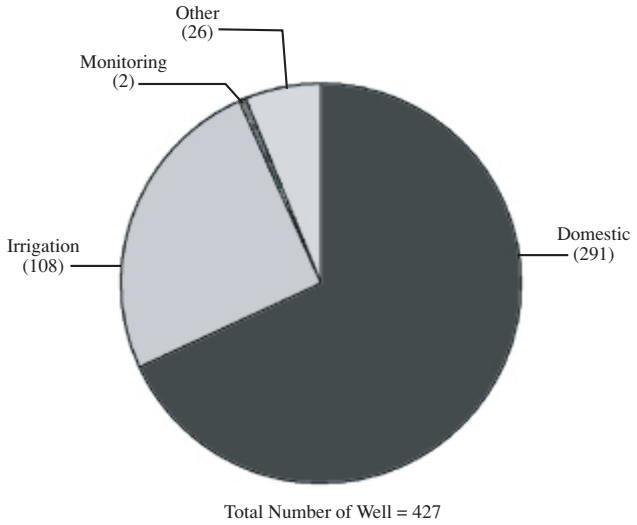


Table 12.
Current Groundwater Monitoring Wells and Estimated Annual Fluctuations in Groundwater Levels, Esquon Sub-inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
20N/02E-09L01M	Irrigation	Composite	1952-2000	10-20	30-40
21N/02E-20P01M	Irrigation	Semi-Confined	1995-2000	20-30	*

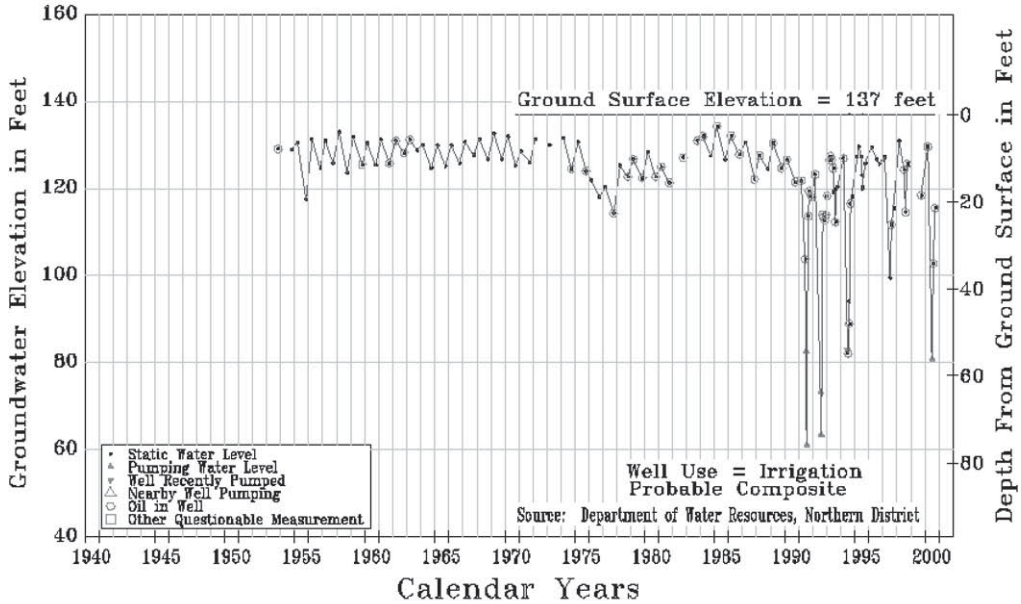
*Insufficient Data

Historic groundwater level data for the western portion of the Esquon Sub-inventory Unit indicate that the annual fluctuations in groundwater levels in the semi-confined portion of the aquifer system average about 20 to 30 feet during years of normal precipitation. The annual fluctuations in groundwater levels associated with monitoring a composite section of the aquifer system average 10 to 20 feet during normal years and up to 40 feet during years of drought. Composite monitoring wells measure a combined groundwater level in multiple water-bearing zones within the aquifer system.

Groundwater hydrographs illustrate changes in groundwater levels over time. A hydrograph representing the seasonal and long-term changes in groundwater levels over a composite section of the aquifer system is presented in Figure 73. The location of the monitoring wells is shown on Plate 6, Appendix A.

Figure 73 is a hydrograph for an active irrigation well, 20N/02E-09L01M, located in the southern portion of the Esquon Sub-inventory Unit. The area surrounding the well consists primarily of rice production using both surface and groundwater. The well is a deep irrigation well with shallow casing, for which groundwater level measurements date back to the 1950s. Groundwater levels in this well represent a

Figure 73.
Groundwater Hydrograph for Well 20N/02E-09L01M, Esquon Sub-inventory Unit



mixture of the unconfined and confined portions of the aquifer system. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until 1991 and on a monthly basis from 1991 to about 1994. Since 1994 this well has been monitored four times a year during March, July, August, and October.

Figure 73 shows that the spring-to-summer fluctuations in groundwater levels average 10 to 20 feet during years of normal precipitation and up to 40 feet during the 1994 drought. A long-term comparison of spring-to-spring groundwater levels in Well 20N/02E-09L01M shows a small decline in groundwater levels associated with the 1976-77 drought, followed by a similar decline associated with the 1986-94 drought. Groundwater levels in this well appear to have recovered from the 1986-94 drought to groundwater levels similar to those of the early 1980s. However, a further long-term analysis of spring-to-spring groundwater levels indicates about a 5-foot decline in groundwater levels since the late 1950s.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Plate 7 shows that the spring groundwater elevations in the Esquon Sub-inventory Unit range from an elevation of about 120 feet in the western portion of the sub-inventory unit to an elevation of about 140 feet in the eastern portion.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. Plate 8 shows that the seasonal groundwater elevation fluctuations in the Esquon Sub-inventory Unit during a normal year range from 10 to 25 feet.

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). Plate 7 shows that the regional pattern of spring

groundwater movement in the Esquon Sub-inventory Unit is in a south-to-southwesterly direction, at a gradient of about 4 feet per mile, adjacent to Butte Creek.

Groundwater Extraction

Estimates of groundwater extraction in the Esquon Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that normal-year groundwater extraction for the Esquon Sub-inventory Unit is estimated at 17.2 taf. Groundwater extraction of 17.2 taf represents about 4% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 17.2 taf of groundwater extracted during a normal year, about 14.2 taf are for summer agricultural use, 0.5 taf is for municipal use, and 2.5 taf are for fall agricultural use. Table 1 shows that, in a normal year, agricultural groundwater services an area of about 3,100 acres, for an applied water average of 4.6 af/acre. Table 3 also shows that about 4.1 taf of the extracted groundwater return to the aquifer via deep percolation in a normal year.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show that drought-year groundwater extraction in the Esquon Sub-inventory Unit is estimated at 29.8 taf, an increase of about 73% over the normal-year extraction estimate. Of the 29.8 taf of groundwater extracted during a drought year, about 24.6 taf are for summer agricultural use, 0.6 taf is for annual municipal use, and 4.6 taf are for fall agricultural use. Table 4 also shows that in a drought year, about 6.8 taf of the extracted groundwater return to the aquifer via deep percolation.

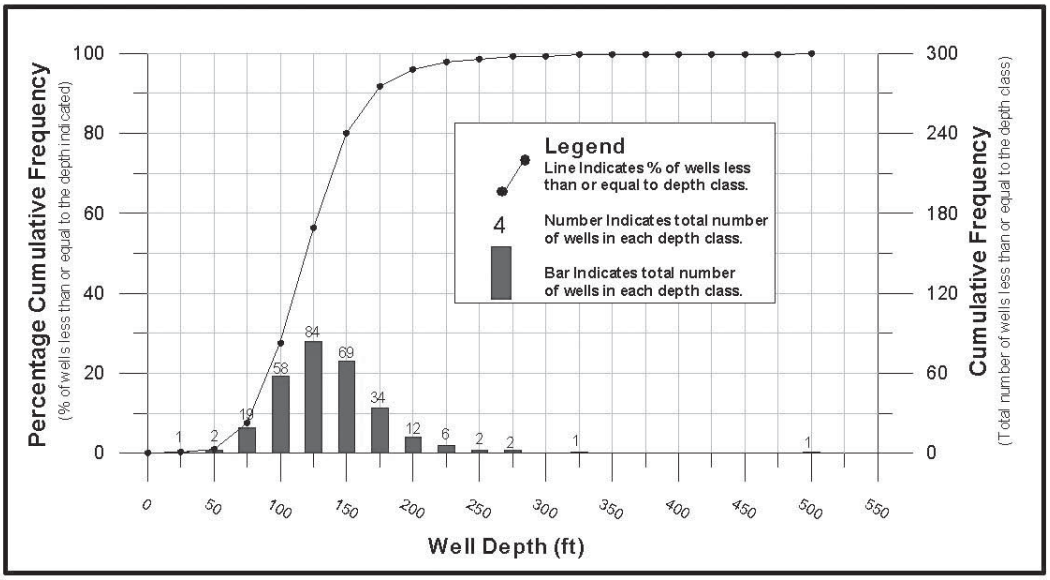
Well Depth

Well depth and well use data for the Esquon Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 399 well records for the Esquon Sub-inventory Unit were evaluated and classified into two well types: domestic and irrigation. There are no municipal well reports for this sub-inventory unit on file with DWR. A statistical summary of the well depth data, listed by well type, is presented in Table 5, Appendix B. Cumulative frequency curves associated with the sub-inventory unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the sub-inventory unit are for domestic use. The average domestic well depth is about 125 feet. Table 5 also shows that the average irrigation well is significantly deeper. The average irrigation well depth is 368 feet.

The cumulative frequency distribution of well depth data was evaluated for domestic and irrigation wells in the Esquon Sub-inventory Unit. Figure 74 shows the cumulative frequency distribution of well depths for domestic wells in the Esquon Sub-inventory Unit. A total of 291 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 25 to 482 feet.

Figure 74.
Cumulative Frequency Distribution of Domestic Wells, Esquon Sub-inventory Unit



The histogram bars in Figure 74 show the total number of domestic wells associated with each 25-foot class interval. The histogram indicates that the distribution of the domestic well depth data is skewed to the right toward deeper well depths. Right-skewed distribution of domestic well data indicates that the average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the Esquon Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 120 feet or less,
- 20% of the wells are installed to a depth of 90 feet or less, and
- 10% of the wells are installed to a depth of 80 feet or less.

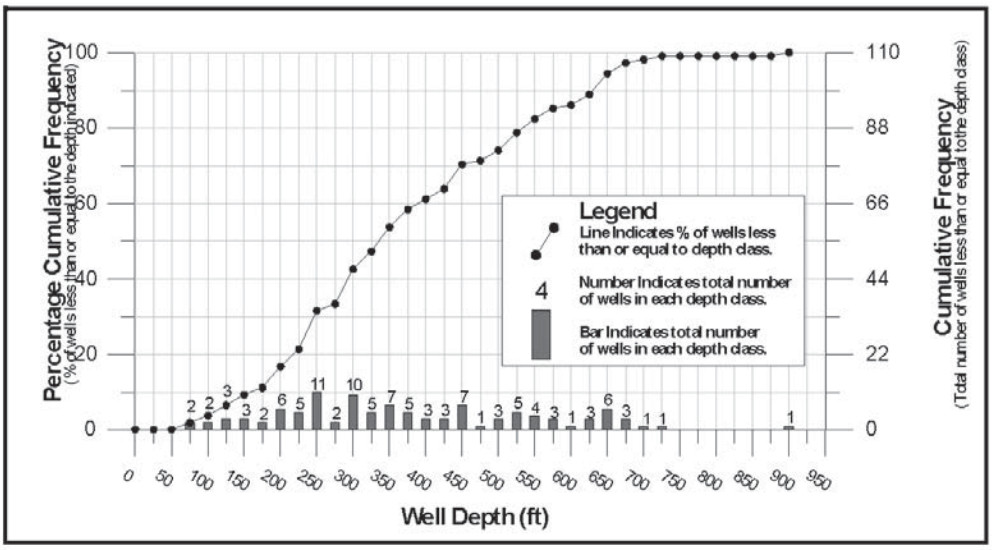
Figure 75 illustrates the cumulative frequency distribution of irrigation well depth data in the Esquon Sub-inventory Unit. A total of 108 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 74 to 883 feet.

The histogram bars in Figure 75 show that the distribution of irrigation well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the Esquon Sub-inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of irrigation well depth data for the Esquon Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 340 feet or less,
- 20% of the wells are installed to a depth of 220 feet or less, and
- 10% of the wells are installed to a depth of 160 feet or less.

Figure 75.
Cumulative Frequency Distribution of Irrigation Wells, Esquon Sub-inventory Unit



Cherokee Sub-inventory Unit

The Cherokee Sub-inventory Unit covers an area of about 14,700 acres in the northern portion of the East Butte Inventory Unit. It is bordered by the Pentz and Esquon Sub-inventory Units to the northwest, Western Canal Sub-inventory Unit to the southwest, Foothill Region on the east, and Thermalito Sub-inventory Unit on the south (see Plate 1, Appendix A). In the eastern portion of the Cherokee Sub-inventory Unit, the land uses consist primarily of non-irrigated native vegetation, along with some pasture and rural residential. In the western portion of the sub-inventory unit, agricultural land use includes rice and orchards crops supported by both surface water and groundwater. In a normal year, about 33% of the Cherokee Sub-inventory Unit is in summer agricultural production supported by groundwater.

Well Distribution

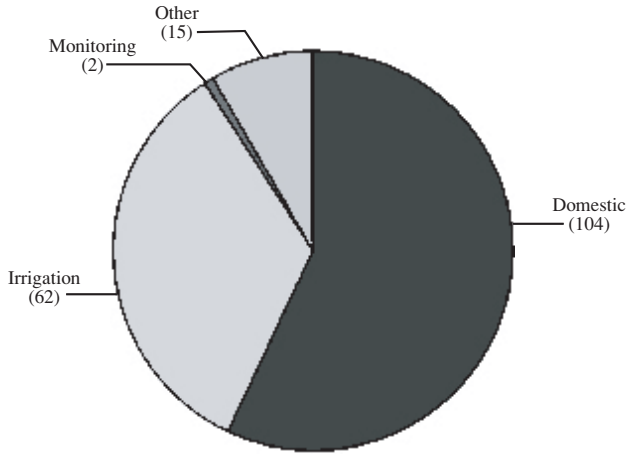
The well completion report database files at DWR were analyzed to determine the number and types of wells in the Cherokee Sub-inventory Unit. Detailed descriptions of the source and accuracy of well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are about 183 wells in the Cherokee Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 104 wells are listed as domestic, 62 are listed as irrigation, none are listed as municipal, 2 are listed as monitoring, and 15 are listed as other. Figure 76 illustrates the breakdown of wells by use for the Cherokee Sub-inventory Unit.

Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 6 wells in the Cherokee Sub-inventory Unit. Three of the 6 wells consist of a nested set of dedicated observation wells with continuous groundwater recording equipment. The wells are constructed in the upper, intermediate, and lower portions of the aquifer system. Two of the remaining monitoring wells are unused irrigation wells; the other well is an active domestic well.

Figure 76.
Number of Wells by Use, Cherokee Sub-inventory Unit



Total Number of Well = 183

Table 13 lists the wells along with the annual fluctuations in groundwater levels during normal and drought years. Table 13 shows that none of the current monitoring wells have long groundwater level measurement histories. However, DWR does have historic groundwater level data from 1991 through 1996 for several wells in the sub-inventory unit. Frequent pumping and nearby pumping activity resulted in numerous questionable measurements and the removal of these wells from the current groundwater level monitoring grid. A hydrograph for Well 20N/02E-13E02M (monitoring discontinued) is presented in Figure 77, below. The current Butte County groundwater monitoring grid is shown on Plate 6, Appendix B.

The groundwater level monitoring grid in Table 13 shows that the annual fluctuations in groundwater levels in the unconfined portion of the aquifer system averages about 5 feet during years of normal precipitation. The annual fluctuations in groundwater levels associated with monitoring a confined or semi-confined section of the aquifer system range from 15 to 25 feet during normal years.

Table 13.
Current Groundwater Monitoring Wells and Estimated Annual Fluctuations in Groundwater Levels, Cherokee Sub-inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
20N/02E-24C01M	Observation	Semi-Confined	1999-2000	15	*
20N/02E-24C02M	Observation	Semi-Confined	1999-2000	15	*
20N/02E-24C03M	Observation	Confined	1999-2000	12	*
20N/03E-33L01M	Unused/Irr.	Semi-Confined	1999-2000	25	*
21N/03E-22C01M	Domestic	Semi-Confined	2000-2000	*	*
21N/03E-32B01M	Unused/Irr.	Unconfined	1999-2000	5	*

*Insufficient Data

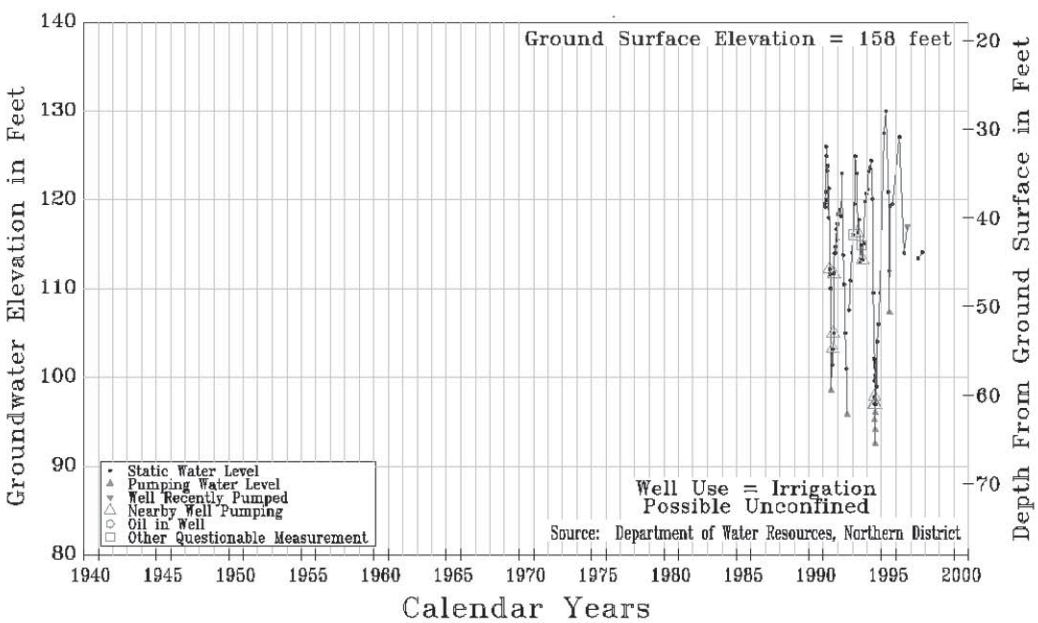
Figure 77 is a hydrograph for Well 20N/02E-13E02M, located in the western portion of the Cherokee Sub-inventory Unit. The area surrounding this well is characterized by agricultural production of orchard, rice, and row crops supported by both groundwater and surface water. The well is a shallow irrigation well constructed in the unconfined portion of the aquifer system. The groundwater levels in this well were monitored on a monthly basis from 1991 to 1995 and four times a year during March, July, August, and October from 1995 to 1996.

Due to active pumping within the monitoring well and pumping of nearby surrounding wells, the seasonal fluctuations in static groundwater levels in Well 20N/02E-13E02M are difficult to accurately determine. In general, Figure 77 shows that the spring-to-summer fluctuations in groundwater levels average about 10 to 12 feet during years of normal precipitation (1993 and 1995) and up to 25 feet during years of drought. Insufficient groundwater level measurement data exist to evaluate the long-term groundwater level trends in this area.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Plate 7 shows that much of the Cherokee Sub-inventory Unit is outside of the Sacramento Valley groundwater basin boundary. Interpolation of the groundwater contours in Plate 7 indicates that spring groundwater elevations in the sub-inventory unit range from an elevation of about 130 feet in the western portion of the sub-inventory unit to an elevation of about 160 feet in the eastern portion. Plate 7 also indicates a groundwater elevation plateau or slight depression of groundwater elevations in the southeastern portion of the sub-inventory unit just east of Highway 99.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. Plate 8 shows that the seasonal groundwater elevation

Figure 77.
Groundwater Hydrograph for Well 20N/02E-13E02M, Cherokee Sub-inventory Unit



fluctuations for a normal year range from 0 feet in the eastern portion of the sub-inventory unit to 25 feet in the southwestern portion of the sub-inventory unit area west of Highway 99 and east of Western Canal Sub-inventory Unit. The Cherokee strip area consists of orchard and rice crops supported primarily by groundwater extraction.

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). The graphic shows that the regional pattern of spring groundwater movement in the Cherokee Sub-inventory Unit is in a southwesterly direction, at a gradient of about 8 feet per mile, adjacent to Butte Creek and Dry Creek.

Groundwater Extraction

Estimates of groundwater extraction in the Cherokee Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that normal-year groundwater extraction for the Cherokee Sub-inventory Unit is estimated at 24 taf. Groundwater extraction of 24 taf represents about 5% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 24 taf of groundwater extracted during a normal year, about 23.1 taf are for summer agricultural use, 0.4 taf is for municipal use, and 0.5 taf is for fall agricultural use. Table 3 shows that, in a normal year, summer agricultural groundwater services an area of about 4,900 acres, for an applied water average of 4.7 af/acre. Table 3 also shows that about 6.1 taf of the extracted groundwater return to the aquifer via deep percolation in a normal year.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show that drought-year groundwater extraction in the Cherokee Sub-inventory Unit is estimated at 27.2 taf, an increase of about 13% over the normal-year extraction estimate. Of the 27.2 taf of groundwater extracted during a drought year, about 26.2 taf are for summer agricultural use, 0.5 taf is for annual municipal use, and 0.5 taf is for fall agricultural use. Table 4 also shows that in a drought year, about 6.8 taf of the extracted groundwater return to the aquifer via deep percolation.

Well Depth

Well depth and well use data for the Cherokee Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 166 well records for the sub-inventory unit were evaluated and classified into two well types: domestic and irrigation. There are no municipal well reports for this sub-inventory unit on file with DWR. A statistical summary of the well depth data, listed by well type, is presented in Table 5, Appendix B. Cumulative frequency curves associated with the Cherokee Sub-inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the Cherokee Sub-inventory Unit are for domestic use. The average domestic well depth is 181 feet. Table 5 also shows that the average irrigation well is significantly deeper. The average irrigation well depth is 446 feet.

The cumulative frequency distribution of well depth data was also evaluated for domestic and irrigation wells in the Cherokee Sub-inventory Unit. Figure 78 shows the cumulative frequency distribution of well depths for domestic wells in the sub-inventory unit. A total of 104 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 35 to 575 feet.

The histogram in Figure 78 shows that the distribution of domestic well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the domestic well depth data indicates that there is a wide range of domestic well depths within the Cherokee Sub-inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of domestic well depth data for the Cherokee Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 165 feet or less,
- 20% of the wells are installed to a depth of 90 feet or less, and
- 10% of the wells are installed to a depth of 75 feet or less.

Figure 78.
Cumulative Frequency Distribution of Domestic Wells, Cherokee Sub-inventory Unit

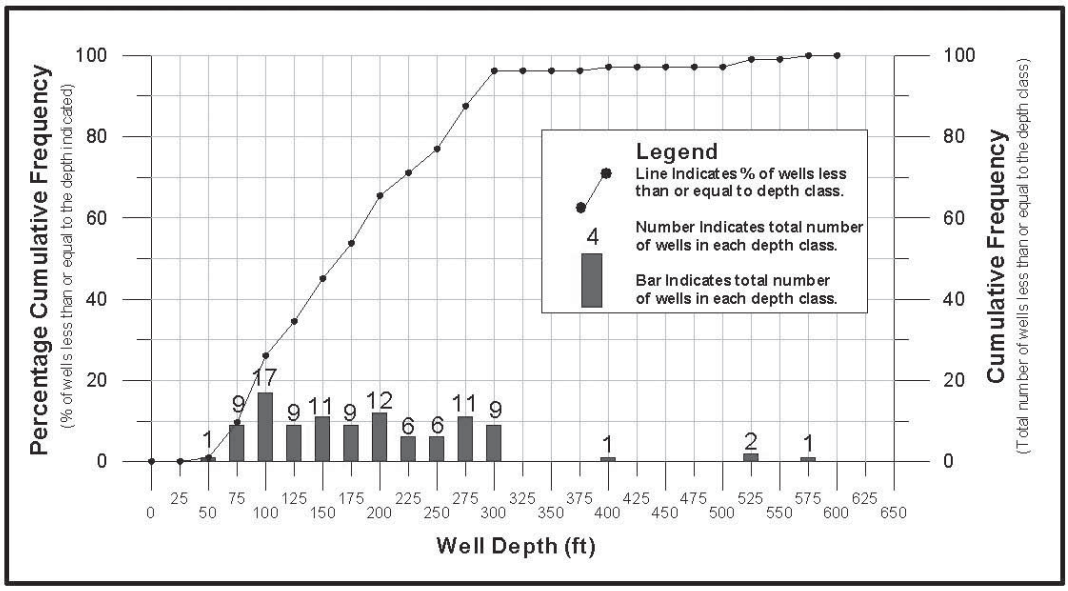


Figure 79 illustrates the cumulative frequency distribution of irrigation well depth data in the Cherokee Sub-inventory Unit. A total of 62 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 89 to 871 feet.

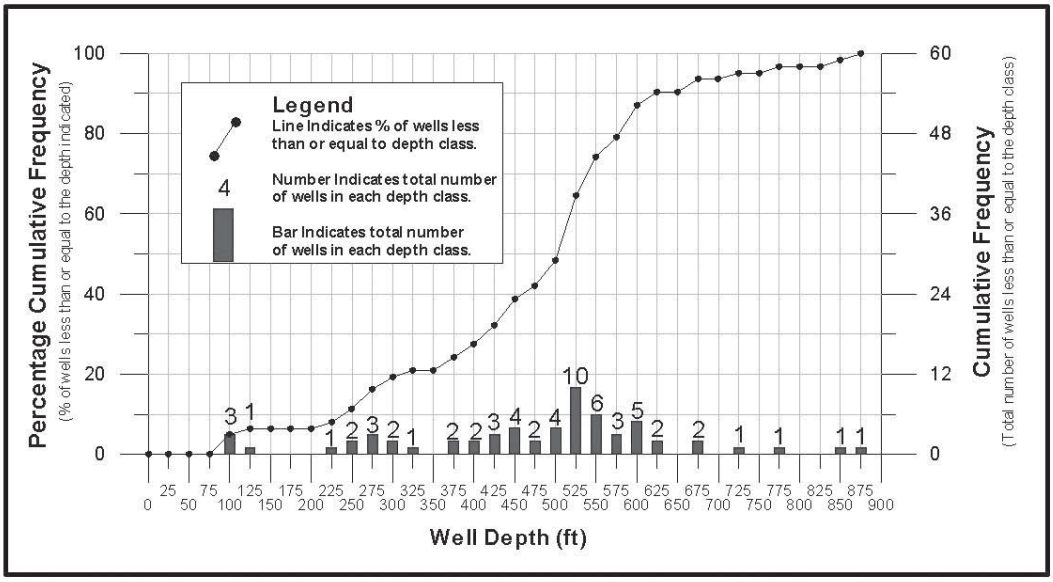
The histogram bars in Figure 79 show that the distribution of irrigation well depth data is also asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates

that there is a wide range of irrigation well depths within the Cherokee Sub-inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of irrigation well depth data for the Cherokee Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 505 feet or less,
- 20% of the wells are installed to a depth of 300 feet or less, and
- 10% of the wells are installed to a depth of 240 feet or less.

Figure 79.
Cumulative Frequency Distribution of Irrigation Wells, Cherokee Sub-inventory Unit



Western Canal Sub-inventory Unit

The Western Canal Sub-inventory Unit covers an area of about 44,750 acres. About one-third of the sub-inventory unit is in the West Butte Inventory Unit and the remainder is in the East Butte Inventory Unit (see Plate 1, Appendix A). The Western Canal Sub-inventory Unit corresponds roughly to the Butte County portion of the Western Canal Water District. A small portion of the southwestern corner of the water district is in Glenn County. Agricultural production in the Western Canal Sub-inventory Unit consists primarily of rice supported by surface water. In normal years, about 7% of the sub-inventory unit is in summer agricultural production supported by groundwater. During drought years, the area of summer agricultural production that is supported by groundwater increases to about 13%. The data presented in this section includes the entire Butte County portion of the Western Canal Sub-inventory Unit. For reference, the groundwater extraction and well data tables in Appendix B present the data for the entire sub-inventory unit in addition to the individual portions that fall within the East and West Butte inventory units.

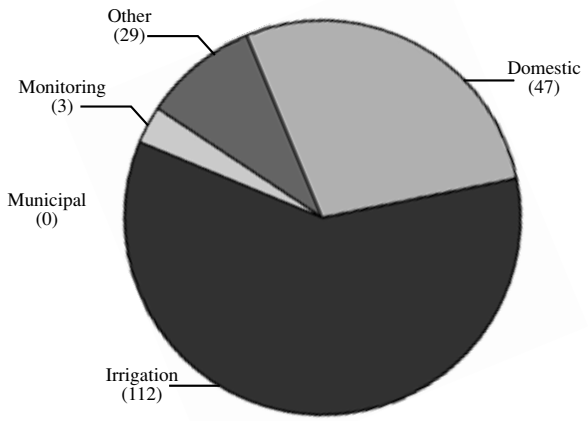
Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the Western Canal Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in

Section 1. A summary of well distribution data is provided in Table 1, Appendix B

There are about 191 wells in the Western Canal Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 47 wells are listed as domestic, 112 are listed as irrigation, 3 are listed as monitoring, and 29 are listed as other. Figure 80 illustrates the breakdown of wells by use for the Western Canal Sub-inventory Unit.

Figure 80.
Number of Wells by Use, Western Canal Sub-inventory Unit.



Total Number of Well = 191

Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 7 wells in the Western Canal Sub-inventory Unit. Three of the 7 wells are dedicated monitoring wells with continuous groundwater level recording equipment. Two of these wells, 20N/02E-15H01M and 20N/02E-15H02M were constructed to measure water levels in the intermediate and shallow portions of the aquifer system, respectively. The other dedicated observation well, 20N/01E-18L01M, was constructed to measure a very deep aquifer zone and it also serves as an extensometer. Well 20N/01E-18L01M continuously records both groundwater levels and aquifer subsidence. To date, no inelastic aquifer subsidence has been recorded. The 4 remaining monitoring wells consist of a combination of domestic and irrigation wells. Table 14 lists the current monitoring wells along with the annual fluctuations in groundwater levels during normal and drought years. Table 14 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. DWR and BCDWRC monitoring wells are shown on Plate 6, Appendix A.

Table 14 shows that the annual fluctuations in groundwater levels in the unconfined portion of the aquifer system average about 2 to 4 feet during years of normal precipitation and about 7 feet during years of drought. The annual fluctuations in groundwater levels associated with monitoring a composite section of the aquifer system average 5 feet during normal years and up to 40 feet during years of drought. Composite monitoring wells measure a combined groundwater level in multiple water-bearing zones within the aquifer system. Table 14 also shows that the annual fluctuations in groundwater levels in the confined portion of the aquifer system range from 5 to 10 feet during years of normal precipitation.

Table 14.
Current Groundwater Monitoring Wells and Estimated Annual Fluctuations in Groundwater Levels, Western Canal Sub-inventory Unit.

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
19N/01E-09Q01M	Irrigation	Confined	1990-2000	5	10
20N/01E-18L01M	Observation	Confined	1999-2000	3-5	*
20N/01E-35C01M	Domestic	Semi-Confined	1946-2000	2-3	4-8
20N/02E-15H01M	Observation	Confined	1995-2000	10-20	*
20N/02E-15H02M	Observation	Unconfined	1995-2000	2-4	*
20N/02E-16P01M	Irrigation	Composite	1990-2000	5	30-40
20N/02E-28N01M	Unused/Dom.	Unconfined	1946-2000	2-4	6-8

*Insufficient Data

Drought-year groundwater level data for the confined aquifer system in the Western Canal Sub-inventory Unit are limited and commonly affected by active pumping within the monitoring well. Recently installed dedicated monitoring wells will help provide more accurate data on seasonal fluctuations in groundwater levels during future drought years.

Groundwater hydrographs illustrate changes in groundwater levels over time. A hydrograph representing the seasonal and long-term groundwater level changes in the semi-confined portion of the aquifer system is presented in Figure 81.

Figure 81 is a hydrograph for an active domestic Well 20N/01E-35C01M located in the central portion of the Western Canal Sub-inventory Unit. The area surrounding this well is characterized as rural and agricultural. Agricultural cultivation in this area consists of rice production supported by surface water in normal years and a combination of surface and groundwater in drought years. The well is constructed in the upper portion of the aquifer for domestic use. The groundwater level measurement record dates back to the mid-1960s. Groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until 1991 and on a monthly basis from 1991 to about 1994. Since 1994, this well has been monitored four times a year during March, July, August, and October.

Figure 81 shows that the spring-to-summer fluctuations in groundwater levels average only 2 to 3 feet during years of normal precipitation and 4 to 8 feet during years of drought. Summer groundwater level monitoring of Well 20N/01E-35C01M indicates that the upper aquifer recharges during summer months due to flood irrigation for rice production. A long-term comparison of spring-to-spring groundwater levels in Well 20N/01E-35C01M shows almost no change in groundwater levels associated with the 1976-77 drought and only a small decline associated with the 1986-94 drought. A further long-term analysis of spring-to-spring groundwater levels indicates little change in groundwater levels since the late 1940s.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Plate 7 shows that the spring groundwater elevation in the Western Canal Sub-inventory Unit range from an elevation of about 80 feet in the southwestern portion of the sub-inventory unit to an elevation of about 120 feet in the area northeast of Nelson.

Figure 81.
Groundwater Hydrograph for Well 20N/01E-35C01M,
Western Canal Sub-inventory Unit.

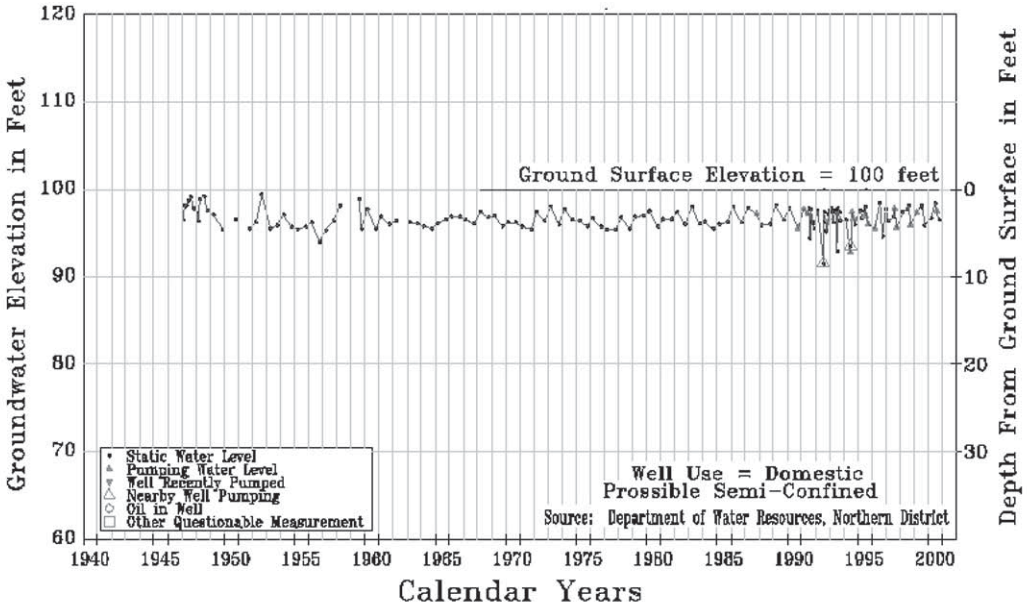


Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. The graphic shows that the seasonal groundwater elevation fluctuations in the Western Canal Sub-inventory Unit during a normal year range from 2 feet in areas of flood irrigation to 10 feet in areas adjacent to the sub-inventory unit.

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). Plate 7 shows that the regional pattern of spring groundwater movement in the Western Canal Sub-inventory Unit is in a southwesterly direction, at a gradient of about 5 feet per mile, toward the Sacramento River and adjacent to Butte Creek.

Groundwater Extraction

Estimates of groundwater extraction in the Western Canal Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that normal-year groundwater extraction for the Western Canal Sub-inventory Unit is estimated at 22 taf. Groundwater extraction of 22 taf represents about 5% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 22 taf of groundwater extracted during a normal year, about 16.3 taf are for summer agricultural use, 0.1 taf is for

municipal use, and 5.6 taf are for fall agricultural use. Table 3 shows that, in a normal year, summer agricultural groundwater serves an area of about 3,300 acres, for an applied water average of 4.9 af/acre. Table 1 also shows that about 4.4 taf of the extracted groundwater return to the aquifer via deep percolation in a normal year.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show that drought-year groundwater extraction in the Western Canal Sub-inventory Unit is estimated at 75.1 taf, or about 3-1/2 times the normal-year extraction estimate. Of the 75.1 taf of groundwater extracted during a drought year, about 53 taf are for summer agricultural use, 0.1 taf is for annual municipal use, and 22 taf are for fall agricultural use. Table 4 also shows that in a drought year about 8.9 taf of the extracted groundwater return to the aquifer via deep percolation.

Well Depth

Well depth and well use data for the Western Canal Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 166 well records in the Western Canal Sub-inventory Unit were evaluated and classified into two well types: domestic and irrigation. There are no municipal well reports for this sub-inventory unit on file with DWR. A statistical summary of the well depth data, listed by well type, is presented in Table 5, Appendix B. Cumulative frequency curves associated with the Western Canal Sub-inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the Western Canal Sub-inventory Unit are for irrigation use. The average irrigation well depth is about 470 feet. Table 5 also shows that the average domestic well is significantly shallower. The average domestic well depth is 145 feet.

The well depth data were further analyzed by an evaluation of the cumulative frequency distribution of well depths for domestic and irrigation wells. Figure 82 shows the cumulative frequency distribution of well depths for domestic wells in the Western Canal Sub-inventory Unit. A total of 47 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 50 to 540 feet.

The histogram bars in Figure 82 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the domestic well depth data is skewed to the right toward deeper well depths. Right-skewed distribution of domestic well data indicates that average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the Western Canal Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 125 feet or less,
- 20% of the wells are installed to a depth of 100 feet or less, and
- 10% of the wells are installed to a depth of 85 feet or less.

Figure 83 illustrates the cumulative frequency distribution of irrigation well depth data in the Western Canal Sub-inventory Unit. A total of 112 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 108 to 880 feet.

The histogram bars in Figure 83 show that the distribution of irrigation well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the Western Canal Sub-inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of irrigation well depth data for the Western Canal Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 500 feet or less,
- 20% of the wells are installed to a depth of 275 feet or less, and
- 10% of the wells are installed to a depth of 190 feet or less.

Figure 82.
Cumulative Frequency Distribution of Domestic Wells,
Western Canal Sub-inventory Unit.

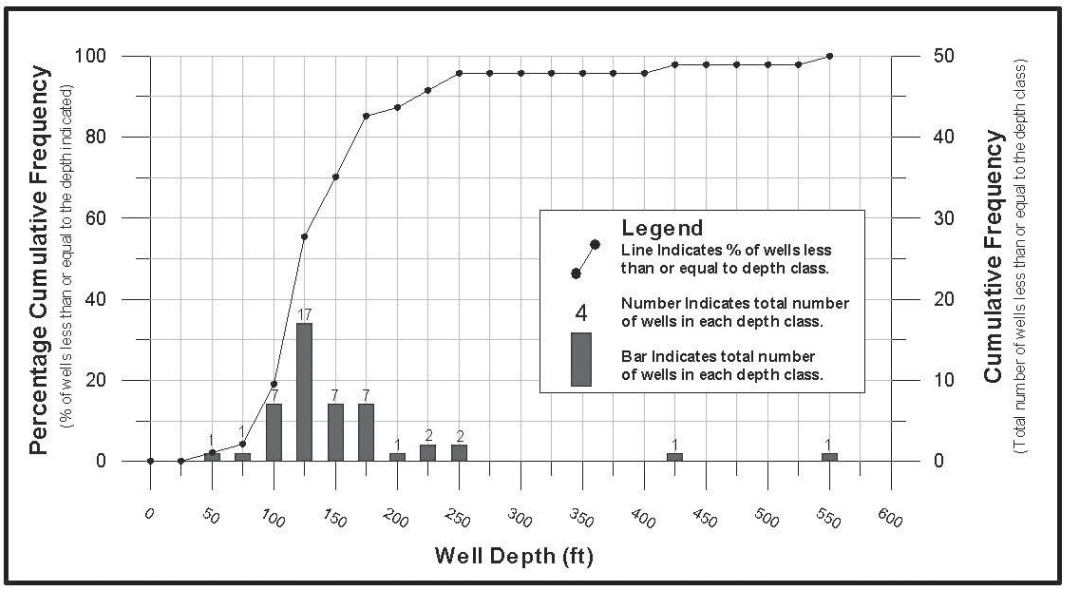
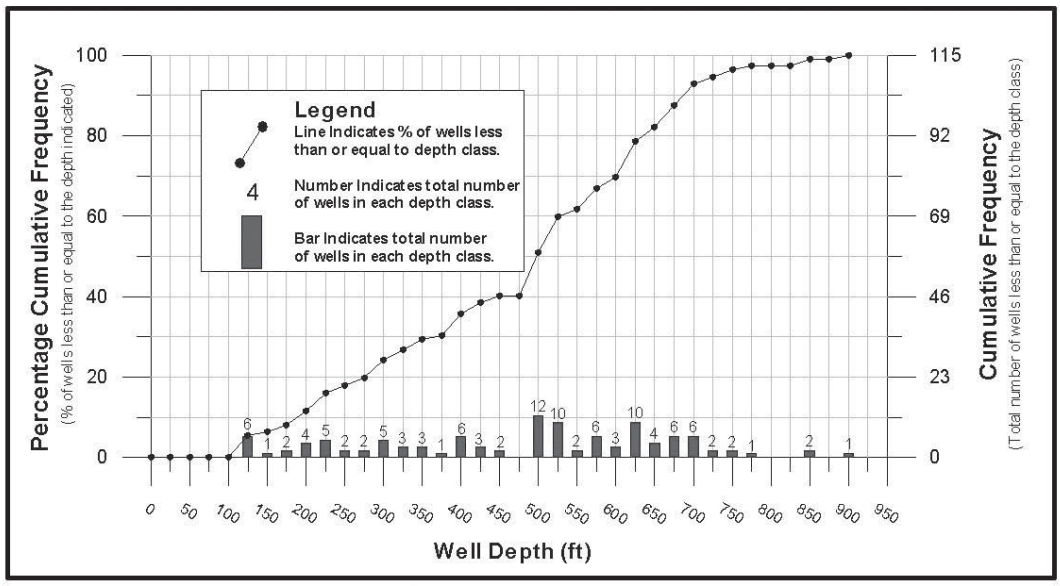


Figure 83.
Cumulative Frequency Distribution of Irrigation Wells,
Western Canal Sub-inventory Unit.



Richvale Sub-inventory Unit

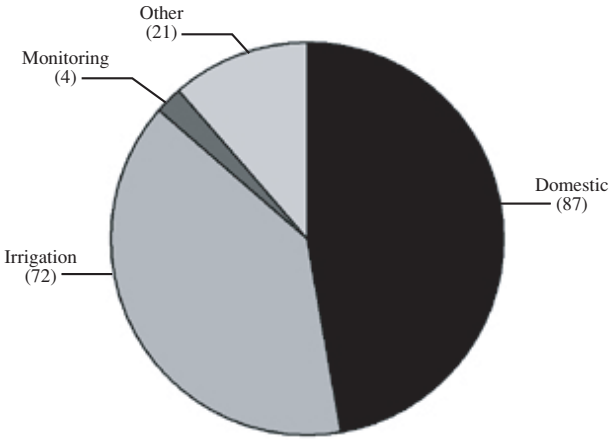
The Richvale Sub-inventory Unit covers an area of about 39,400 acres. It is bordered by the Western Canal Sub-inventory Unit to the north, Biggs-West Gridley Sub-inventory Unit to the south, Thermalito Sub-inventory Unit to the east and Butte Creek to the west (see Plate 1, Appendix A). The Richvale Sub-inventory Unit corresponds roughly to the service area of the Richvale Irrigation District. Normal-year agricultural cultivation in the sub-inventory unit consists primarily of rice production supported almost solely by surface water. In drought years, about 17% of the Richvale Sub-inventory Unit consists of summer agricultural production supported by groundwater.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the Richvale Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are about 184 wells in the Richvale Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 87 wells are listed as domestic, 72 are listed as irrigation, none are listed as municipal, 4 are listed as monitoring, and 21 are listed as other. Figure 84 illustrates the breakdown of wells by use for the Richvale Sub-inventory Unit.

Figure 84.
Number of Wells by Use, Richvale Sub-inventory Unit. Groundwater Level



Total Number of Well = 184

Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 6 wells in the Richvale Sub-inventory Unit. Five of the wells have over 25 years of groundwater level monitoring data. Of the 6 wells, one is a dedicated monitoring well, 1 is an unused irrigation well, and the remaining 4 are active domestic wells. The unused irrigation well, 19N/02E-15N02M, contains continuous groundwater level measuring equipment. Table 15 lists the current monitoring wells along with the annual fluctuations in groundwater levels during normal and drought years. Table 15 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. DWR and BCDWRC monitoring wells are shown on Plate 6, Appendix A.

Table 15 shows that the annual fluctuations in groundwater levels in the unconfined portion of the aquifer system are about 3 to 4 feet during years of normal precipitation and up to 7 feet during years of drought. The annual fluctuations in groundwater levels associated with monitoring a composite section of the aquifer system average 2 to 3 feet during normal years and up to 10 feet during years of drought. Composite monitoring wells measure a combined groundwater level in multiple water-bearing zones within the aquifer system. Table 15 also shows that the annual fluctuations in groundwater levels in the confined portion of the aquifer system range from 2 to 4 feet during years of normal precipitation and 10 to 25 feet during years of drought.

Table 15.
Current Groundwater Monitoring Wells and Estimated Annual Fluctuations in Groundwater Levels, Richvale Sub-inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
18N/01E-13M01M	Domestic	Composite	1947-2000	2-3	10
18N/01E-15D02M	Domestic	Composite	1975-2000	2-3	5
19N/01E-27Q01M	Observation	Confined	1976-2000	2-4	10-25
19N/01E-28R01M	Domestic	Unconfined	1957-2000	3-4	4-5
19N/02E-15N02M	Unused/Irr.	Confined	2000-2000	*	*
19N/02E-17A01M	Domestic	Unconfined	1959-2000	3-4	4-5

*Insufficient Data

Groundwater hydrographs illustrate changes in groundwater levels over time. Hydrographs representing the seasonal and long-term groundwater level changes in the unconfined and confined portions of the aquifer are presented in Figures 85 and 86.

Figure 85 is a hydrograph for Well 19N/01E-28R01M, located in the western portion of the Richvale Sub-inventory Unit. The area surrounding this well is characterized as rural and agricultural. Agricultural cultivation in this area consists of rice production supported by surface water in normal years and a combination of surface and groundwater in drought years. The well is an active domestic well constructed in the upper portion of the aquifer, for which groundwater level measurements date back to the late 1950s. Groundwater levels in this well were monitored on a monthly basis from 1959 to 1979, on a semi-annual basis (spring and fall) from 1979 to 1991, and on a monthly basis again from 1991 to about 1994. Since 1994, this well has been monitored four times a year during March, July, August, and October.

Figure 85 shows that the spring-to-summer fluctuations in groundwater levels in the unconfined portion of the aquifer system average only 3 to 4 feet during years of normal precipitation and 4 to 5 feet during years of drought. Close examination of the spring-to-summer fluctuations in Well 19N/01E-28R01M indicates that the upper aquifer recharges during summer months due to flood irrigation for rice production. A long-term comparison of spring-to-spring groundwater levels in Well 19N/01E-28R01M shows almost no change in levels associated with either the 1976-77 or 1986-94 droughts. Further long-term analysis of spring-to-spring groundwater levels indicates little change in groundwater levels since the late 1950s.

Figure 86 is a hydrograph for Well 19N/01E-27Q01M, located in the western portion of the Richvale Sub-inventory Unit. Although Well 19N/01E-27Q01M is only 1 mile from Well 19N/

01E-28R01M shown in Figure 85, the differences in well construction result in a difference in the fluctuation of groundwater levels in these wells. Well 19N/01E-27Q01M is a dedicated monitoring well constructed in the middle to lower portion of the aquifer, for which groundwater level measurements date back to the late 1970s. The area surrounding Well 19N/01E-27Q01M is also characterized as rural and agricultural. Agricultural cultivation in this area consists of rice supported by surface water in normal years and a combination of surface and groundwater in drought years. Groundwater levels in Well 19N/01E-27Q01M were monitored on a semi-annual basis (spring and fall) from 1978 to 1991 and on a monthly basis from 1991 to about 1995. Since 1996, this well has been monitored four times a year during March, July, August, and October.

Figure 85.
Groundwater Hydrograph for Well 19N/01E-28R01M, Richvale Sub-inventory Unit

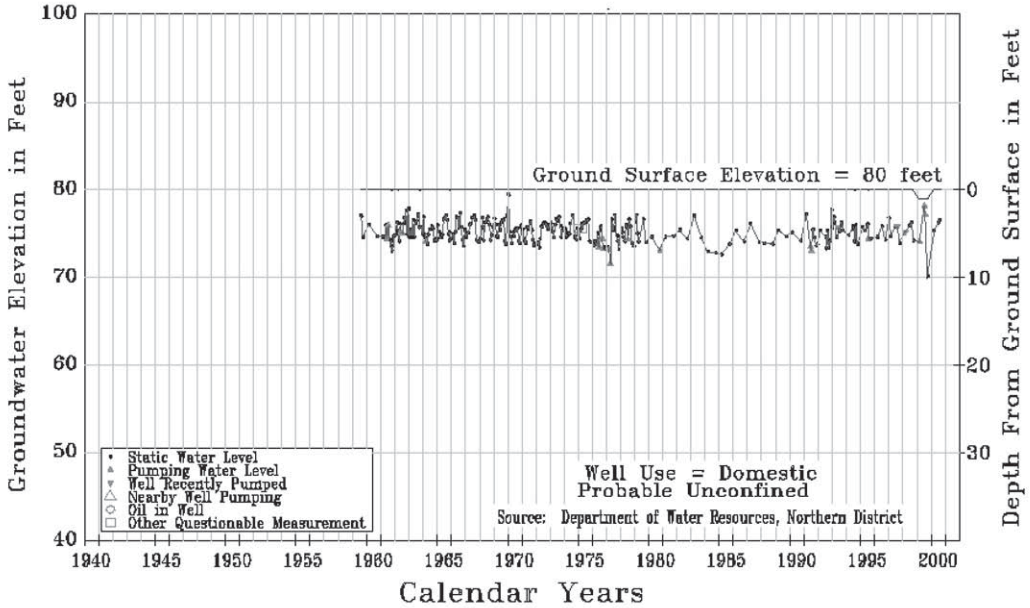


Figure 86 shows that the spring-to-summer fluctuations in groundwater levels in the confined portion of the aquifer system average 2 to 4 feet during years of normal precipitation and up to 25 feet during years of drought.

The increased decline in summer groundwater levels during drought years is the result of increased groundwater extraction from the middle and lower portion of the aquifer system. Figure 86 shows that summer flood irrigation with surface water has little short-term effect on the deeper portion of the aquifer system. Although summer groundwater levels in Figure 86 show a decline during drought years, a long-term comparison of spring-to-spring groundwater levels in Well 19N/01E-27Q01M shows little change in groundwater levels during the 1986-94 drought. Overall comparison of spring-to-spring groundwater levels indicates little change since the late 1970s.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Plate 7 shows that the spring groundwater elevations in the Richvale Sub-inventory Unit range from an about 60 feet in the southwestern portion of the sub-inventory unit to an elevation of about 100 feet just north of Richvale.

Figure 86.
Groundwater Hydrograph for Well 19N/01E-27Q01M, Richvale Sub-inventory Unit

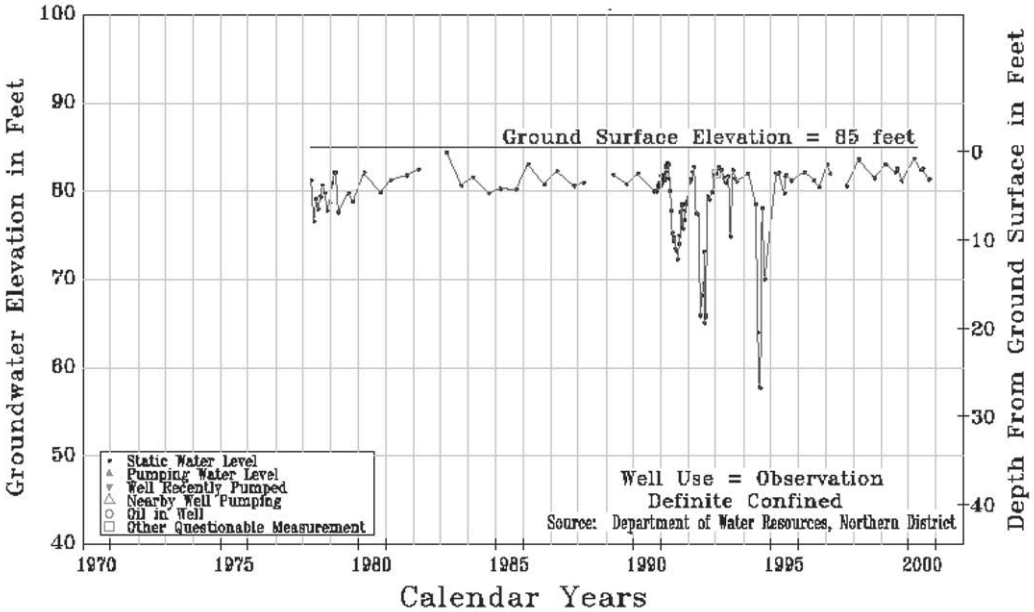


Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. Plate 8 shows that the spring-to-summer fluctuations in groundwater elevations in the Richvale Sub-inventory Unit during a normal year range from two feet of decline to two feet of increase due to summer recharge from flood irrigation with surface water.

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). Plate 7 shows that the regional pattern of spring groundwater movement in the Richvale Sub-inventory Unit is in a south-to-southwesterly direction, at a gradient of about 4 feet per mile, toward Butte Creek and the Sacramento River.

Groundwater Extraction

Estimates of groundwater extraction in the Richvale Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that normal-year groundwater extraction for the Richvale Sub-inventory Unit is estimated at 0.3 taf. Groundwater extraction of 0.3 taf represents about 0.07% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 0.3 taf of groundwater extracted during a normal year, about 0.2 taf is for summer agricultural use and 0.1 taf is for municipal,

primarily domestic, uses. Table 3 shows that about 0.2 taf of the extracted groundwater returns to the aquifer via deep percolation in a normal year.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show that drought-year groundwater extraction in the Richvale Sub-inventory Unit is estimated at 30.5 taf, or about 100 times the normal-year extraction estimate. Of the 30.5 taf of groundwater extracted during a drought year, about 30.3 taf are for summer agricultural use and 0.2 taf is for annual municipal use. Table 4 also shows that in a drought year about 5.3 taf of the extracted groundwater return to the aquifer via deep percolation.

Well Depth

Well depth and well use data for the Richvale Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 159 well records in the sub-inventory unit were evaluated and classified into two well types: domestic and irrigation. There are no municipal well completion reports for this sub-inventory unit on file with DWR. A statistical summary of the well depth data, listed by well type, is presented in Table 5, Appendix B. Cumulative frequency curves associated with the Richvale Sub-inventory Unit are presented in Figures 87 and 88.

Table 5, Appendix B, shows that the majority of wells in the Richvale Sub-inventory Unit are for domestic use. The average domestic well depth is 114 feet. The table also shows that wells drilled for irrigation purposes tend to be deeper than the domestic wells. The average irrigation well depth is 303 feet.

The well depth data were further analyzed by an evaluation of the cumulative frequency distribution of well depths for domestic and irrigation wells. Figure 87 shows the cumulative frequency distribution of well depths for domestic wells in the Richvale Sub-inventory Unit. A total of 87 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 40 to 500 feet.

The histogram bars in Figure 87 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the domestic well depth data is skewed to the right toward deeper well depths. Right-skewed distribution of domestic well depth data indicates that average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the Richval Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 100 feet or less,
- 20% of the wells are installed to a depth of 70 feet or less, and
- 10% of the wells are installed to a depth of 55 feet or less.

Figure 88 illustrates the cumulative frequency distribution of irrigation well depth data in the Richvale Sub-inventory Unit. A total of 72 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 80 to 855 feet.

The histogram bars in Figure 88 show that the distribution of irrigation well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the Richvale Sub-inventory Unit, and that no dominant well depth preference exists.

The cumulative frequency curve of irrigation well depth data for the Richvale Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 265 feet or less,
- 20% of the wells are installed to a depth of 170 feet or less, and
- 10% of the wells are installed to a depth of 120 feet or less.

Figure 87.
Cumulative Frequency Distribution of Domestic Wells, Richvale Sub-inventory Unit

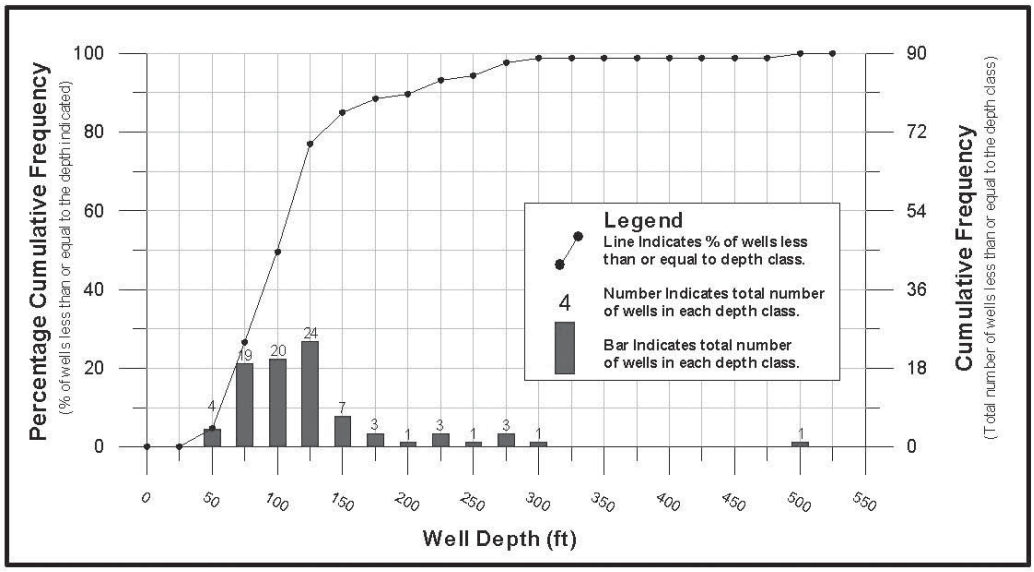
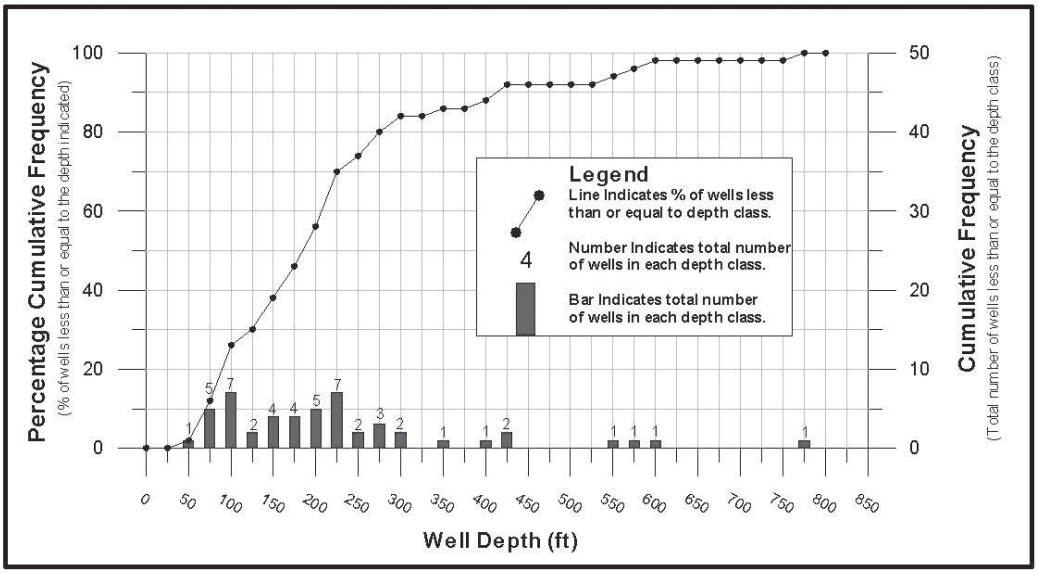


Figure 88.
Cumulative Frequency Distribution of Irrigation Wells, Richvale Sub-inventory Unit



Thermalito Sub-inventory Unit

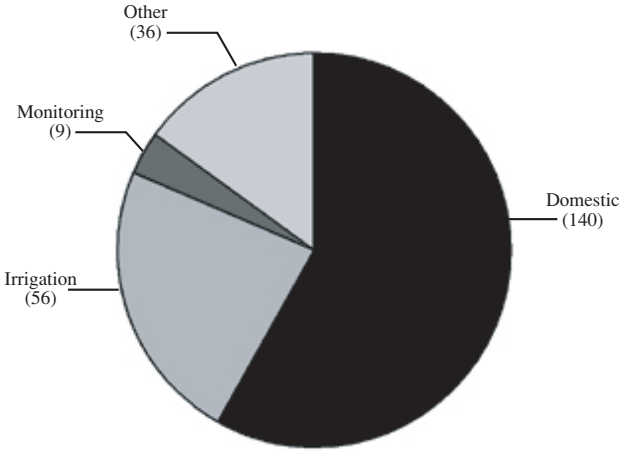
The Thermalito Sub-inventory Unit covers an area of about 25,500 acres. It is bordered by foothills to the north, the Feather River to the south and east, and the sub-inventory units of Western Canal, Richvale, and Biggs-West Gridley to the west (see Plate 1, Appendix A). The northwestern portion of the Thermalito Sub-inventory Unit consists primarily of the Thermalito Afterbay and the surrounding native vegetation. To the northeast, the sub-inventory unit encompasses portions of Oroville and the Thermalito Irrigation District and is characterized by urban, rural, and agricultural land uses. Land use within the southern portion of the sub-inventory unit is primarily agricultural, consisting of orchards and rice production supported predominantly by groundwater. In a normal year, about 17% of the Thermalito Sub-inventory Unit is in summer agricultural production supported by groundwater.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the Thermalito Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are about 241 wells in the Thermalito Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 140 wells are listed as domestic, 56 are listed as irrigation, none are listed as municipal, 9 are listed as monitoring, and 36 are listed as other. Figure 89 illustrates the breakdown of wells by use for the Thermalito Sub-inventory Unit.

Figure 89.
Number of Wells by Use, Thermalito Sub-inventory Unit



Total Number of Well = 241

Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 3 wells in the Thermalito Sub-inventory Unit. Two of the wells are active irrigation wells and the third is an active domestic well. Table 16 lists the current monitoring wells along with the annual fluctuations in groundwater levels during normal and drought years. Table 16 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. DWR and BCDWRC monitoring wells are shown on Plate 6, Appendix A.

Table 16 shows that all 3 of the sub-inventory unit monitoring wells have been qualified as "composite." Composite monitoring wells measure a combined groundwater level in multiple water-bearing zones within the aquifer system. The annual fluctuations in groundwater levels associated with monitoring a composite section of the aquifer system are 3 to 8 feet during normal years and up to 25 feet during years of drought.

Table 16.
Current Groundwater Monitoring Wells and Estimated Annual Fluctuations in Groundwater Levels, Thermalito Sub-inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
18N/03E-05K01M	Irrigation	Composite	1993-2000	3-7	5-10
18N/03E-21G01M	Irrigation	Composite	1951-2000	5-8	3-5
19N/03E-05N02M	Domestic	Composite	1976-2000	3-6	15-25

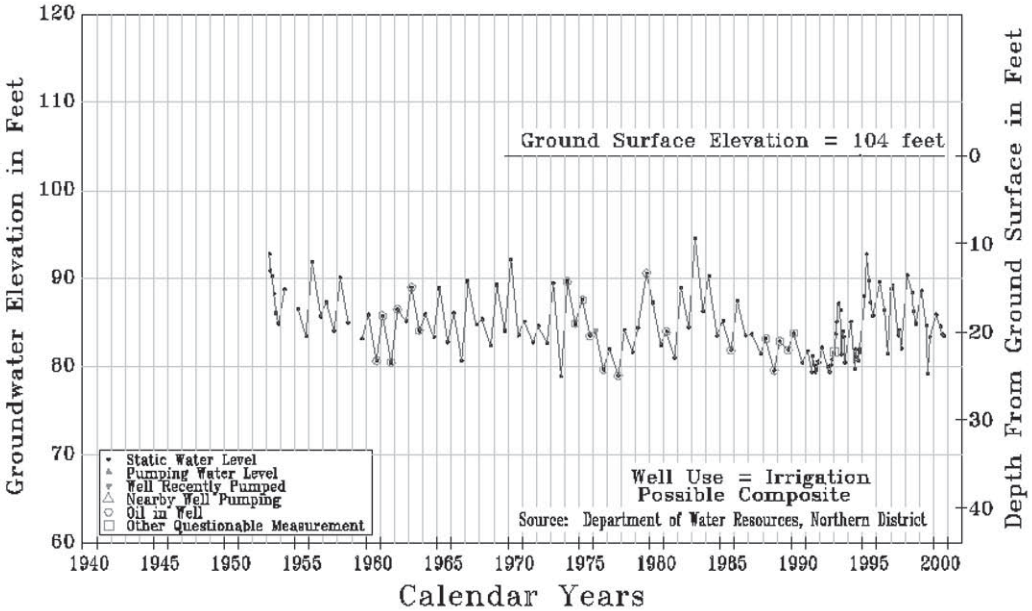
Groundwater hydrographs illustrate changes in groundwater levels over time. Hydrographs representing the seasonal and long-term groundwater level changes in the aquifer system are presented in Figure 90.

Figure 90 is a hydrograph for Well 18N/03E-21G01M, located in the southern portion of the Thermalito Sub-inventory Unit, about 1 mile west of the Feather River. The area surrounding this well is characterized as rural and agricultural. Agricultural cultivation in this area consists of orchard crops supported primarily by groundwater extraction. Well 18N/03E-21G01M is an active irrigation well producing groundwater from the shallow to intermediate portions of the aquifer system. The groundwater level measurement record dates back to the late 1940s. Groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until 1991 and on a monthly basis from 1991 to about 1994. Since 1994, this well has been monitored four times a year during March, July, August, and October.

Figure 90 shows interesting spring-to-summer fluctuations in groundwater levels between normal and drought years. Groundwater levels fluctuate about 5 to 8 feet during years of normal precipitation, but the fluctuation decreases during years of drought to about 2 to 5 feet. A closer look at the hydrograph shows that the decreases in spring-to-summer fluctuations are the result of a drop in spring groundwater levels, while the summer levels remain constant. The decline in spring groundwater levels indicates that the aquifer system in this area does not fully recharge during years of drought. The rapid drop to a relatively constant level during drought years, indicates that the aquifer system in this area is likely being recharged from a steady source of surface water; in this case, the Feather River. During drought years, groundwater levels drop relatively quickly until they reach the point where the aquifer is interconnected with the Feather River. The hydrograph indicates that, in this area, the surface water–groundwater interconnection takes place at about 23 feet below ground surface, or at an elevation of about 80 feet above mean sea level.

A long-term comparison of spring-to-spring groundwater levels in Figure 90 shows an overall decline of 5 to 8 feet during the 1976-77 and 1986-94 droughts, followed by recovery to predrought levels. A further long-term comparison of spring-to-spring groundwater levels during normal years in Well 18N/03E-21G01M indicates little change since the late 1950s.

Figure 90.
Groundwater Hydrograph for Well 18N/03E-21G01M, Thermalito Sub-inventory Unit



Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Plate 7 shows that the spring groundwater elevation in the Thermalito Sub-inventory Unit range from an elevation of about 85 feet in the southern portion of the sub-inventory unit to an elevation of about 150 feet north of Oroville.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. Plate 8 shows that the spring-to-summer fluctuations in groundwater elevations in the Thermalito Sub-inventory Unit during a normal year range from 0 to 5 feet. This is like the result of recharge from the Thermalito Afterbay and the Feather River.

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). The graphic shows that the regional pattern of spring groundwater movement in the Thermalito Sub-inventory Unit is toward the south. Locally, groundwater mounding due to recharge from the Thermalito Afterbay causes groundwater to move in a southeasterly direction toward the Feather River and in a southwesterly direction toward the Butte Sub-inventory Unit. The average groundwater gradient in the Thermalito Sub-inventory Unit is about 5 feet per mile.

Groundwater Extraction

Estimates of groundwater extraction in the Thermalito Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep

percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that normal-year groundwater extraction for the Thermalito Sub-inventory Unit is estimated at about 22 taf. Groundwater extraction of 22 taf represents 5% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 22 taf of groundwater extracted during a normal year, about 18.8 taf are for summer agricultural use, 1.5 taf are for municipal and domestic uses, and 1.7 taf are for fall agricultural use. Table 3 shows that, in a normal year, summer agricultural groundwater serves an area of about 4,500 acres, for an applied water average of 4.2 af/acre. Table 3 also shows that about 4.8 taf of the extracted groundwater return to the aquifer via deep percolation in a normal year.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. Table 4 shows that drought-year groundwater extraction in the Thermalito Sub-inventory Unit is estimated at 24.1 taf, an increase of about 10% over the normal-year extraction estimate. Of the 24.1 taf of groundwater extracted during a drought year, about 21.4 taf are for summer agricultural use, 0.5 taf is for annual municipal and domestic uses, and 2.2 taf are for fall agricultural use. Table 4 also shows that, in a drought year, about 5.3 taf of the extracted groundwater return to the aquifer via deep percolation.

Well Depth

Well depth and well use data for the Thermalito Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 196 well records in the Thermalito Sub-inventory Unit were evaluated and classified into two well types: domestic and irrigation. There are no municipal well reports for this sub-inventory unit on file with DWR. A statistical summary of the well depth data, listed by well type, is presented in Table 5, Appendix B. Cumulative frequency curves associated with the Thermalito Sub-inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the Thermalito Sub-inventory Unit are for domestic use. The average domestic well depth is 98 feet. The table also shows that wells drilled for irrigation purposes tend to be deeper than domestic wells. The average irrigation well depth is 158 feet.

The well depth data were further analyzed by an evaluation of the cumulative frequency distribution of well depths for domestic and irrigation wells. Figure 91 shows the cumulative frequency distribution of well depths for domestic wells in the Thermalito Sub-inventory Unit. A total of 140 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 37 to 480 feet.

The histogram bars in Figure 91 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the domestic well depth data is skewed to the right toward deeper well depths. Right-skewed distribution of domestic well depth data indicates that the average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the Thermalito Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 80 feet or less,
- 20% of the wells are installed to a depth of 60 feet or less, and
- 10% of the wells are installed to a depth of 50 feet or less.

Figure 91.
Cumulative Frequency Distribution of Domestic Wells, Thermalito Sub-inventory Unit

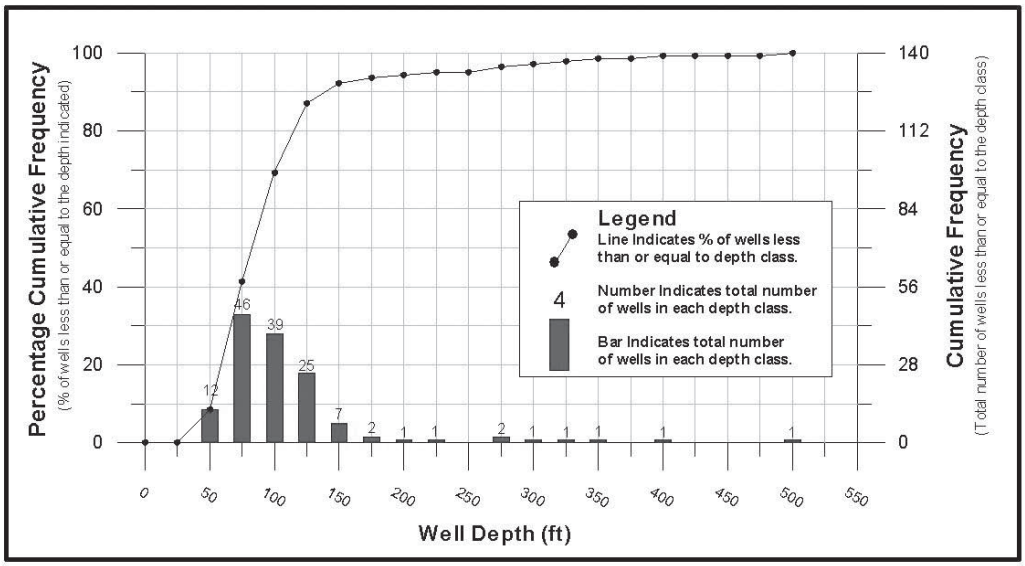


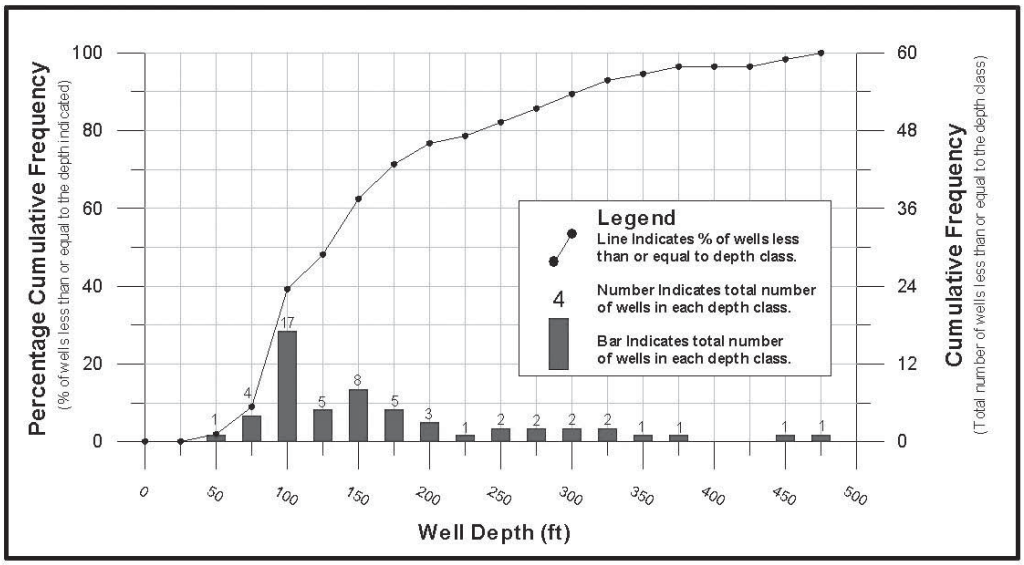
Figure 92 illustrates the cumulative frequency distribution of irrigation well depth data in the Thermalito Sub-inventory Unit. A total of 56 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 36 to 460 feet.

The histogram bars in Figure 92 show that the distribution of the irrigation well depth data is skewed to the right toward deeper well depths. Right-skewed distribution of irrigation well data indicates that average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of irrigation well depth data for the Thermalito Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 135 feet or less,
- 20% of the wells are installed to a depth of 80 feet or less, and
- 10% of the wells are installed to a depth of 75 feet or less.

Figure 92.
Cumulative Frequency Distribution of Irrigation Wells, Thermalito Sub-inventory Unit



Biggs-West Gridley Sub-inventory Unit

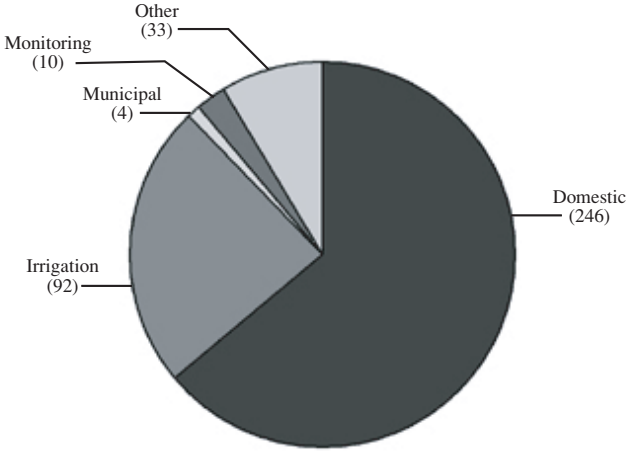
The Biggs-West Gridley Sub-inventory Unit covers an area of about 34,000 acres. It is bordered by the Richvale Sub-inventory Unit to the north, Sutter County to the south, the Thermalito and Butte Sub-inventory Units to the east, and the Butte Sink Sub-inventory Unit to the southwest (see Plate 1, Appendix A). The Biggs-West Gridley Sub-inventory Unit corresponds roughly to the service area of the Biggs-West Gridley Irrigation District. Land use within the sub-inventory unit is mainly agricultural, although portions of the cities of Biggs and Gridley fall within the eastern edge of the sub-inventory unit boundary. Agricultural crops consist mainly of rice production, with smaller areas of orchard, grain, and field crops. A mixture of surface water and groundwater supports agricultural production. In a normal year, about 7% of the Biggs-West Gridley Sub-inventory Unit is in summer agricultural production supported by groundwater. In a drought year, about 13% of the sub-inventory unit is in summer agricultural production supported by groundwater.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the Biggs-West Gridley Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are about 385 wells in the Biggs-West Gridley Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 246 wells are listed as domestic, 92 are listed as irrigation, 4 are listed as municipal, 10 are listed as monitoring, and 33 are listed as other. Figure 93 illustrates the breakdown of wells by use for the Biggs-West Gridley Sub-inventory Unit.

Figure 93.
Number of Wells by Use, Biggs-West Gridley Sub-inventory Unit



Total Number of Well = 385

Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 6 wells in the Biggs-West Gridley Sub-inventory Unit. The well-types consist of a combination of active domestic and irrigation wells with an average monitoring period of record of over 50 years. Table 17 lists the current monitoring wells, along with the annual fluctuations in groundwater levels during normal and drought years. Table 17 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. DWR and BCDWRC monitoring wells are shown on Plate 6, Appendix A.

Table 17 shows that the annual fluctuations in groundwater levels in the unconfined portion of the aquifer system are just 1 to 2 feet during years of normal precipitation and up to 5 feet during years of drought. The annual fluctuations in groundwater levels associated with monitoring a composite section of the aquifer system are 2 to 3 feet during normal years and up to 7 feet during years of drought. Composite monitoring wells measure a combined groundwater level in multiple water-bearing zones within the aquifer system. Table 17 also shows that the annual fluctuations in groundwater levels in the confined portion of the aquifer system range from 3 to 5 feet during years of normal precipitation and 5 to 8 feet during years of drought.

Table 17.
Current Groundwater Monitoring Wells and Estimated Annual Fluctuations in Groundwater Levels, Biggs-West Gridley Sub-inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
17N/01E-10A01M	Domestic	Composite	1952-2000	3-5	6-7
17N/02E-16C01M	Domestic	Unconfined	1946-2000	1-2	3-5
18N/02E-16F01M	Irrigation	Unconfined	1946-2000	1-2	2-4
18N/02E-25M01M	Irrigation	Composite	1959-2000	1-2	3-5
18N/02E-32Q02M	Domestic	Composite	1946-2000	2-3	3-4
18N/03E-18F01M	Irrigation	Confined	1946-2000	3-5	5-8

Groundwater hydrographs illustrate changes in groundwater levels over time. Hydrographs representing the seasonal and long-term groundwater level changes in the unconfined portion of the aquifer are presented in Figure 94.

Figure 94 is a hydrograph for Well 18N/02E-16F01M located in the north-central portion of the Biggs-West Gridley Sub-inventory Unit. The area surrounding this well is characterized as rural and agricultural. Agricultural cultivation in this area consists primarily of rice production supported by a mixed water source. The well is an active irrigation well constructed in the upper portion of the aquifer, for which groundwater level measurements date back to the late 1940s. Groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until 1991, on a monthly basis from 1991 to 1994, and on a semi-annual basis from 1994 to 1996. Since 1996 this well has been monitored four times a year during March, July, August, and October.

Figure 94 shows that the spring-to-summer fluctuations in groundwater levels in the unconfined portion of the aquifer system average only 1 to 2 feet during years of normal precipitation and 2 to 4 feet during years of drought. Close examination of the spring-to-summer fluctuations in Well 18N/02E-16F01M indicates that groundwater levels rise during the summer months as the upper aquifer recharges due to flood irrigation for rice production. Long-term comparison of spring-to-spring groundwater levels in the well shows almost no change in groundwater levels associated with either the 1976-77 or the 1986-94 droughts. Further long-term analysis of spring-to-spring groundwater levels indicates little change in groundwater levels since the late 1940s.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater elevation contour map for the Sacramento Valley Region of Butte County. Plate 7 shows that the spring groundwater elevations in the Biggs-West Gridley Sub-inventory Unit range from about 60 feet in the southwestern portion of the sub-inventory unit to about 100 feet in the northeast.

Figure 94.
Groundwater Hydrograph for Well 18N/02E-16F01M,
Biggs-West Gridley Sub-inventory Unit

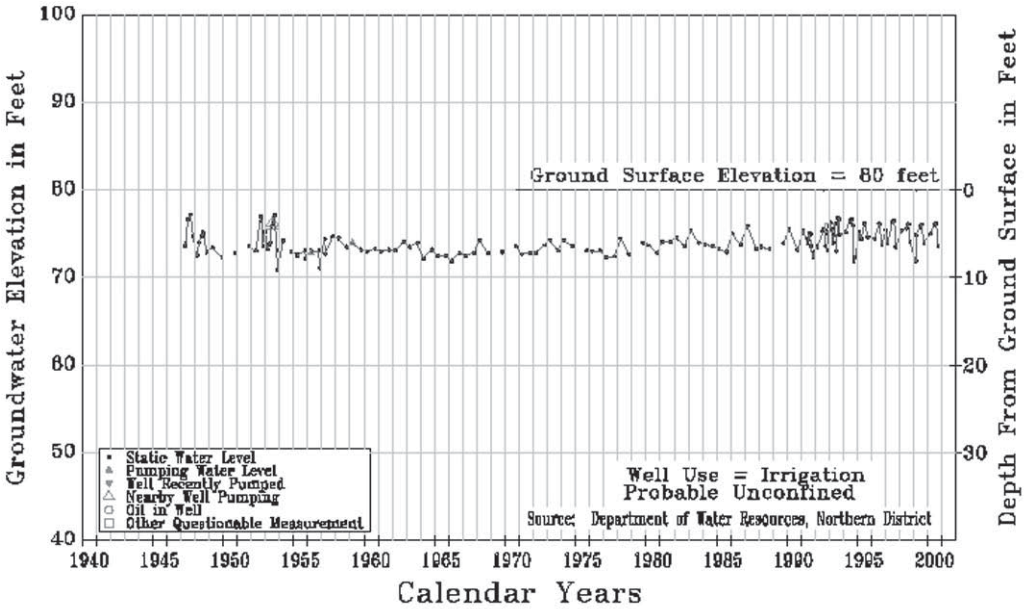


Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. Plate 8 shows that the spring-to-summer fluctuation in groundwater elevations in the Biggs-West Gridley Sub-inventory Unit during a normal year is about 2 feet. This minimal fluctuation is likely due to recharge from the agricultural application of surface water during the summer months.

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). Plate 7, Appendix A, shows that the regional pattern of spring groundwater movement in the Biggs-West Gridley Sub-inventory Unit is in a southwesterly direction, at a gradient of about 3 feet per mile, toward Butte Creek and the Butte Sink Sub-inventory Unit.

Groundwater Extraction

Estimates of groundwater extraction in the Biggs-West Gridley Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that the normal-year groundwater extraction for the Biggs-West Gridley Sub-inventory Unit is estimated at 13.1 taf. Groundwater extraction of 13.1 taf represents about 3% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 13.1 taf of groundwater extracted during a normal year, about 12.7 taf are for summer agricultural use and 0.4 taf is for municipal and domestic uses. Table 1 shows that, in a normal year, summer agricultural groundwater services an area of about 2,500 acres, for an applied water average of 5.1 af/acre. Table 3 also shows that about 3.8 taf of the extracted groundwater return to the aquifer via deep percolation in a normal year.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show that drought-year groundwater extraction in the Biggs-West Gridley Sub-inventory Unit is estimated at 28 taf, or about two times the normal-year extraction estimate. Of the 28 taf of groundwater extracted during a drought year, about 25 taf are for summer agricultural use, 0.5 taf is for annual municipal and domestic uses, and 2.5 taf are for wildlife refuge use. Table 4 also shows that in a drought year, about 7.4 taf of the extracted groundwater return to the aquifer via deep percolation.

Well Depth

Well depth and well use data for the Biggs-West Gridley Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 342 well records were evaluated and classified into three well types: domestic, irrigation, and municipal. A statistical summary of the well depth data, listed by well type, is presented in Table 5, Appendix B. Cumulative frequency curves associated with the Biggs-West Gridley Sub-inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the Biggs-West Gridley Sub-inventory Unit are for domestic use. The average domestic well depth is 92 feet. Table 5 also shows that wells drilled for irrigation and municipal uses tend to be deeper than the domestic wells. The average irrigation well depth for the Biggs-West Gridley Sub-inventory Unit is 221 feet. The average municipal well depth is 328 feet.

The cumulative frequency distribution of well depth data was also evaluated for domestic and irrigation wells. Figure 95 shows the cumulative frequency distribution of well depths for domestic wells in the Biggs-West Gridley Sub-inventory Unit. A total of 246 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 32 to 243 feet.

The histogram bars show that the distribution of the domestic well depth data is fairly symmetrical. Symmetrical distribution of domestic well data indicates that an equal number of wells exist on either side of the most frequently occurring well depth.

The cumulative frequency curve of domestic well depth data for the Biggs-West Gridley Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 90 feet or less,
- 20% of the wells are installed to a depth of 65 feet or less, and
- 10% of the wells are installed to a depth of 60 feet or less.

Figure 95.
Cumulative Frequency Distribution of Domestic Wells,
Biggs-West Gridley Sub-inventory Unit

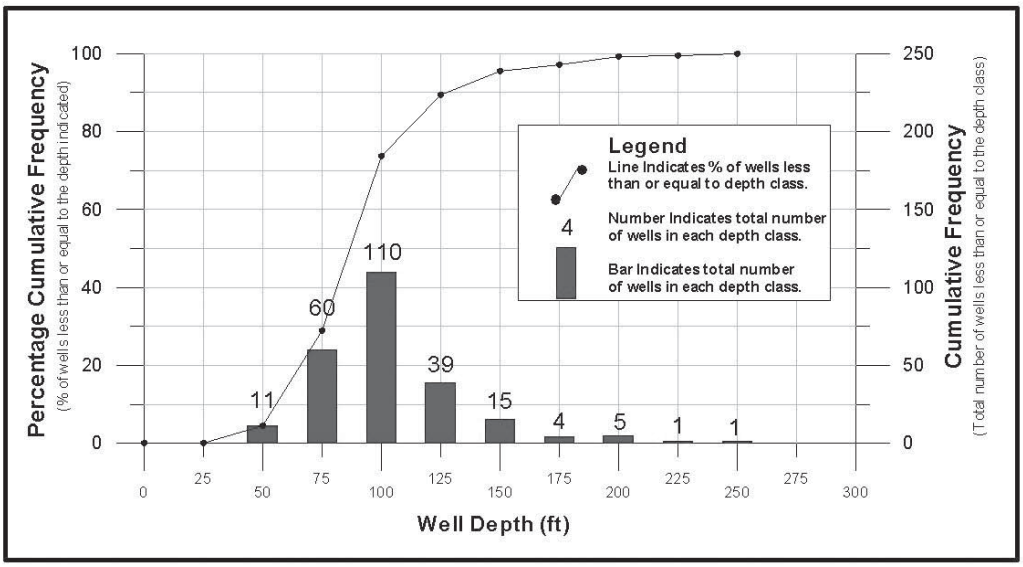


Figure 96 illustrates the cumulative frequency distribution of irrigation well depth data in the Biggs-West Gridley Sub-inventory Unit. A total of 92 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 40 to 707 feet.

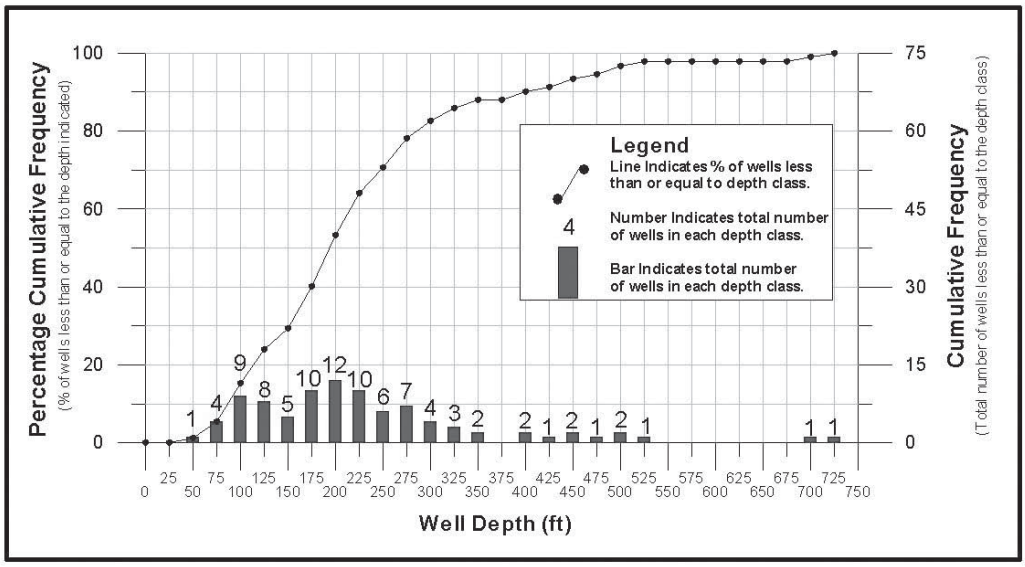
The histogram bars in Figure 96 show that the distribution of irrigation well depth data is skewed to the right toward deeper well depths. Right-skewed distribution of irrigation well data indicates that average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of irrigation well depth data for the Biggs-West Gridley Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 195 feet or less,
- 20% of the wells are installed to a depth of 115 feet or less, and
- 10% of the wells are installed to a depth of 85 feet or less.

There are 4 municipal wells in the Biggs-West Gridley Sub-inventory Unit. The well depths range from a minimum of 260 feet to a maximum of 362 feet. A cumulative frequency curve was not developed for municipal wells in the Biggs-West Gridley Sub-inventory Unit because the small number of wells tends to limit a statistically meaningful evaluation.

Figure 96.
Cumulative Frequency Distribution of Irrigation Wells, Biggs-West Gridley Sub-inventory Unit



Butte Sub-inventory Unit

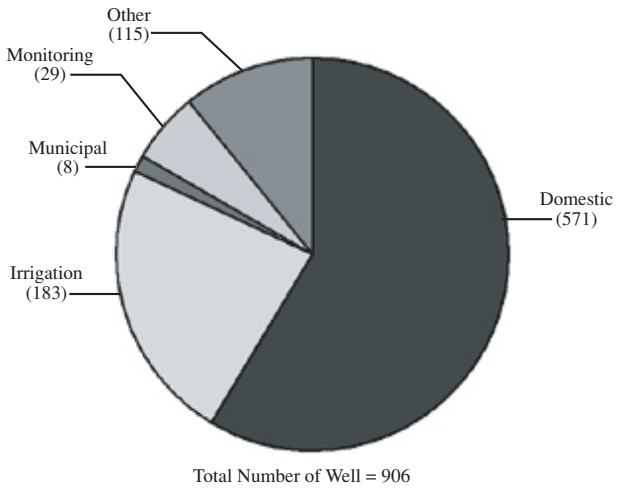
The Butte Sub-inventory Unit covers an area of about 21,400 acres. It is bordered by the Biggs-West Gridley and Thermalito Sub-inventory Units to the north and west, the North Yuba Inventory Unit to the East, and Sutter County to the south (see Plate 1, Appendix A). The Butte Sub-inventory Unit corresponds roughly to the service area for the Butte Irrigation District. Land use within the sub-inventory unit is mainly agricultural, but also includes most of the urban area for the cities of Biggs and Gridley. Agricultural production consists mainly of orchard crops with smaller areas of rice and field crops. A mixture of surface water and groundwater supports agricultural production. In a normal year, about 29% of the Butte Sub-inventory Unit is in summer agricultural production supported by groundwater. Groundwater is also used as the municipal water source for much of the urban area surrounding the cities of Biggs and Gridley.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the Butte Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are about 906 wells in the Butte Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 571 wells are listed as domestic, 183 are listed as irrigation, 8 are listed as municipal, 29 are listed as monitoring, and 115 are listed as other. Figure 97 illustrates the breakdown of wells by use for the Butte Sub-inventory Unit.

Figure 97.
Number of Wells by Use, Butte Sub-inventory Unit



Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 4 wells in the Butte Sub-inventory Unit. The monitoring grid consists of a combination of active domestic and irrigation wells, with an average monitoring period of record of over 50 years. Table 18 lists the current monitoring wells along with the annual fluctuations in groundwater levels during normal and drought years. Table 18 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. DWR and BCDWRC monitoring wells are shown on Plate 6, Appendix A.

Table 18 shows that all of the monitoring wells are qualified as "composite." Composite monitoring wells measure a combined groundwater level in multiple water-bearing zones within the aquifer system. The annual fluctuations in groundwater levels associated with monitoring a composite section of the aquifer system range from 2 to 6 feet during normal years and up to 10 feet during years of drought.

Table 18.
Current Groundwater Monitoring Wells and Estimated Annual Fluctuations in Groundwater Levels, Butte Sub-inventory Unit

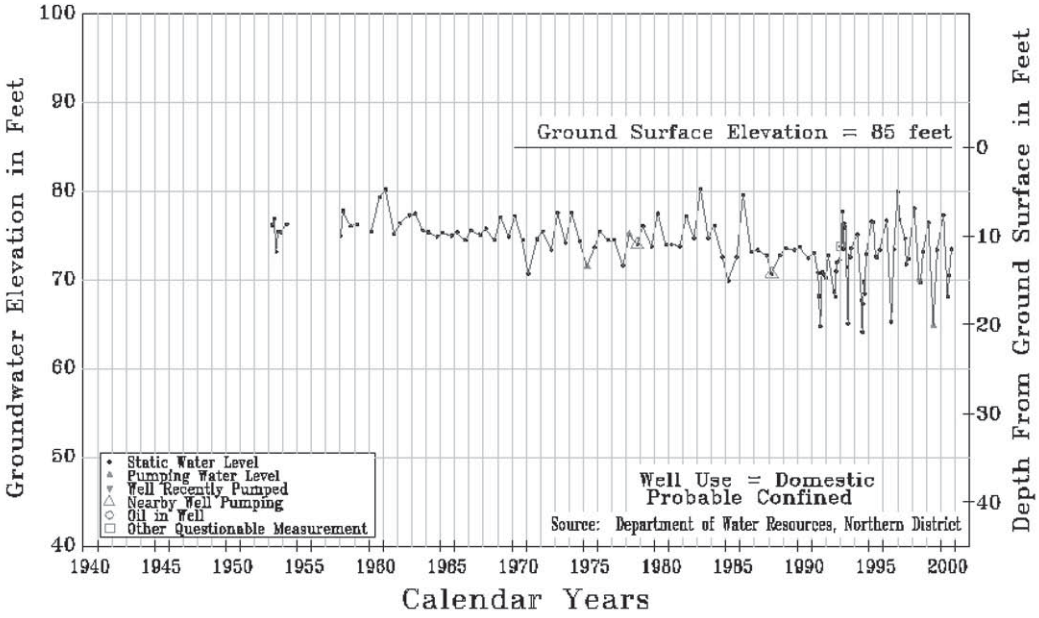
State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
17N/02E-14A01M	Irrigation	Composite	1946-2000	2-3	5-10
17N/03E-05C01M	Irrigation	Composite	1946-2000	3-5	8-10
17N/03E-08G01M	Domestic	Composite	1952-2000	3-5	5-10
17N/03E-16N01M	Domestic	Composite	1952-2000	3-6	5-10

Groundwater hydrographs illustrate changes in groundwater levels over time. Hydrographs showing the seasonal and long-term groundwater level changes in the unconfined and confined portions of the aquifer are presented in Figure 98.

Figure 98 is a hydrograph for Well 17N/03E-16N01M located in the southeastern portion of the Butte Sub-inventory Unit. The area surrounding this well is characterized as rural and agricultural. Agricultural cultivation in this area consists primarily of orchard crops supported by groundwater. Well 17N/03E-16N01M is an active domestic well constructed over the upper and middle portions of the aquifer, for which groundwater level measurements date back to the mid-1950s. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until about 1991, on a monthly basis from about 1991 to 1995, and are currently monitored four times a year during March, July, August, and October.

Figure 98 shows that the spring-to-summer fluctuations in composite groundwater levels average only 3 to 6 feet during years of normal precipitation and 5 to 10 feet during years of drought. A long-term comparison of spring-to-spring groundwater levels in Well 18N/02E-16F01M shows a small drop in spring groundwater levels associated with the 1976-77 and 1986-94 droughts followed by recovery to pre-drought levels. Further long-term analysis of spring-to-spring groundwater levels indicates little change in groundwater levels since the 1950s.

Figure 98.
Groundwater Hydrograph for Well 17N/03E-16N01M, Butte Sub-inventory Unit



Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. Plate 7 shows that the spring groundwater elevations in the Butte Sub-inventory Unit range from an elevation of about 75 feet in the southern sub-inventory unit to an elevation of about 95 feet in the north.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and

summer measurement periods. Plate 8 shows that the spring-to-summer fluctuations in groundwater elevations in the Butte Sub-inventory Unit during a normal year range from 0 feet in areas of surface water irrigation in the west to 10 feet of decline in areas of groundwater irrigation to the east.

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). The figure shows that the regional pattern of spring groundwater movement in the Butte Sub-inventory Unit is in a southerly direction. Locally, groundwater mounding, due to recharge from the Thermalito Afterbay, causes groundwater to move in a southeasterly direction toward the Feather River and in a southwesterly direction toward the Biggs-West Gridley Sub-inventory Unit. The average groundwater gradient in the Butte Sub-inventory Unit is about 4 feet per mile.

Groundwater Extraction

Estimates of groundwater extraction in the Butte Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that the normal-year groundwater extraction for the Butte Sub-inventory Unit is estimated at 26.5 taf. Groundwater extraction of 26.5 taf represents about 6% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 26.5 taf of groundwater extracted during a normal year, about 22.1 taf are for summer agricultural use and 4.4 taf are for municipal and domestic uses. Table 3, Appendix B shows that, in a normal year, summer agricultural groundwater serves an area of about 6,100 acres, for an applied water average of 3.6 af/acre. Table 3 also shows that about 6 taf of the extracted groundwater return to the aquifer via deep percolation in a normal year.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show that drought-year groundwater extraction in the Butte Sub-inventory Unit is estimated at 34.6 taf, an increase of about 30% over the normal-year extraction estimate. Of the 34.6 taf of groundwater extracted during a drought year, about 29.7 taf are for summer agricultural use and 4.9 taf are for annual municipal and domestic uses. Table 4 also shows that in a drought year, about 7.6 taf of the extracted groundwater return to the aquifer via deep percolation.

Well Depth

Well depth and well use data for the Butte Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 762 well records were evaluated and classified into three well types: domestic, irrigation, and municipal. A statistical summary of the well depth data, listed by well type, is presented in Table 5, Appendix B. Cumulative frequency curves associated with well depth in the Butte Sub-inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the Butte Sub-inventory Unit are for domestic use. The average domestic well depth is 83 feet. Table 5 also shows that wells drilled for irrigation and municipal uses tend to be deeper than the domestic wells. The average irrigation well depth for the Butte Sub-inventory Unit is 165 feet. The average municipal well depth is 228 feet.

The cumulative frequency distribution of well depth data was also evaluated for domestic and irrigation wells. Figure 99 shows the cumulative frequency distribution of well depths for domestic wells in the Butte Sub-inventory Unit. A total of 571 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 32 to 399 feet.

The histogram bars in Figure 99 show that the distribution of the domestic well depth data is skewed to the left toward more shallow well depths. Left-skewed distribution of domestic well data indicates that average well depth is less deep than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the Butte Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 80 feet or less,
- 20% of the wells are installed to a depth of 55 feet or less, and
- 10% of the wells are installed to a depth of 40 feet or less.

Figure 99.
Cumulative Frequency Distribution of Domestic Wells, Butte Sub-inventory Unit

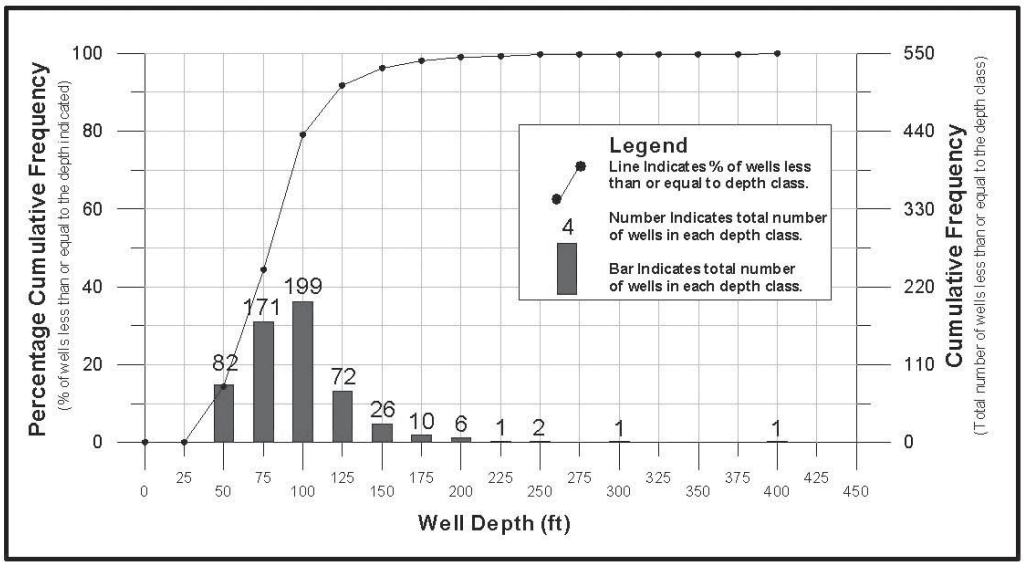


Figure 100 illustrates the cumulative frequency distribution of irrigation well depth data in the Butte Sub-inventory Unit. A total of 183 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 35 to 750 feet.

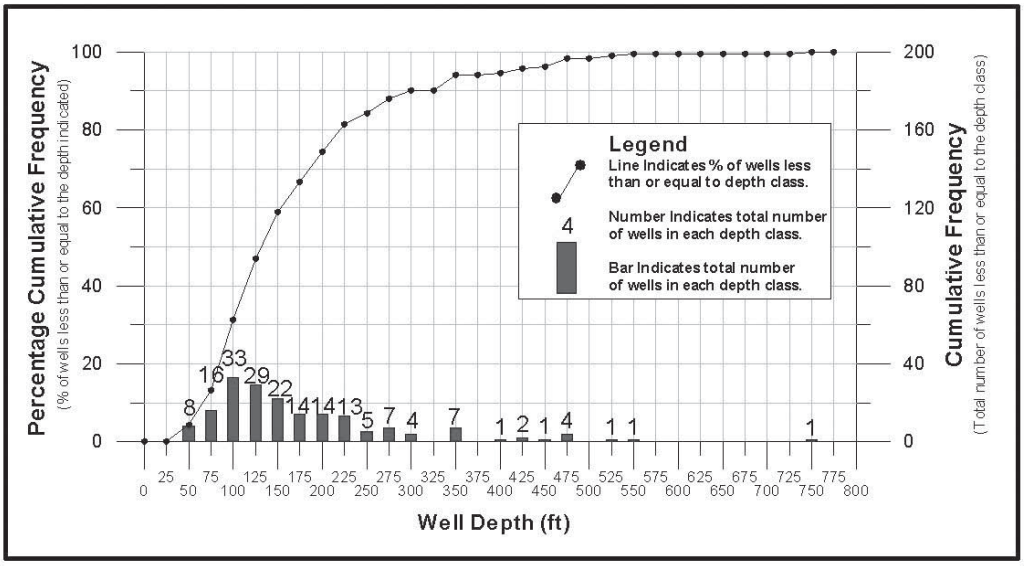
The histogram bars in Figure 100 show that the distribution of the irrigation well depth data are skewed to the right toward deeper well depths. Right-skewed distribution of irrigation well data indicates that average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of irrigation well depth data for the Butte Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 135 feet or less,
- 20% of the wells are installed to a depth of 85 feet or less, and
- 10% of the wells are installed to a depth of 65 feet or less.

There are 8 municipal wells in the Butte Sub-inventory Unit. The well depths range from a minimum of 70 feet to a maximum of 381 feet. A cumulative frequency curve was not developed for municipal wells in the Butte Sub-inventory Unit because the small number of wells tends to limit a statistically meaningful evaluation.

Figure 100.
Cumulative Frequency Distribution of Irrigation Wells, Butte Sub-inventory Unit



Butte Sink Sub-inventory Unit

The Butte Sink Sub-inventory Unit covers an area of about 10,300 acres. It is bordered by the Biggs-West Gridley Sub-inventory Unit to the north and east, Sutter County to the south, and Glenn County to the west (see Plate 1, Appendix A). Much of the Butte Sink area consists of waterfowl refuges surrounded by native riparian vegetation. A smaller portion of the sub-inventory unit supports agricultural production of rice and grain crops. Waterfowl refuges and agricultural land uses in this area are supported by the application of a combination of surface and groundwater. In a normal year, about 75% of the annually extracted groundwater is used during the fall and winter months for wildlife refuge use and 13% is used for summer agricultural production.

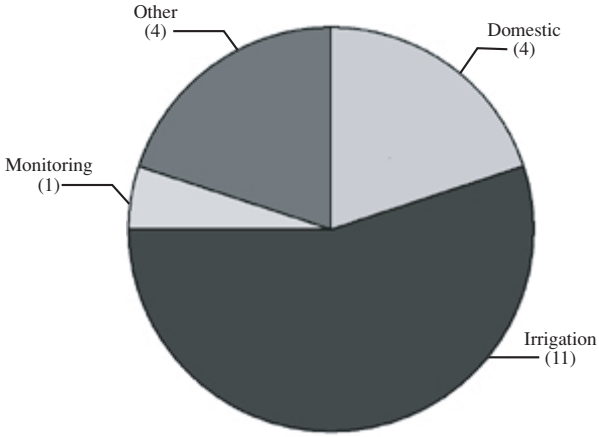
Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the Butte Sink Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are about 20 wells in the Butte Sink Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal,

monitoring, and other. Table 1 shows that 4 wells are listed as domestic, 11 are listed as irrigation, none are listed as municipal, 1 is listed as monitoring, and 4 are listed as other. Figure 101 illustrates the breakdown of wells by use for the Butte Sink Sub-inventory Unit.

Figure 101.
Number of Wells by Use, Butte Sink Sub-inventory Unit



Total Number of Well = 20

Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 3 wells in the Butte Sink Sub-inventory Unit. The wells consist of a nested set of dedicated observation wells, with the individual wells constructed in the upper, intermediate and lower portions of the aquifer system. Table 19 lists the wells along with the annual fluctuations in groundwater levels during normal and drought years. Table 19 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. DWR and BCDWRC monitoring wells are shown on Plate 6, Appendix A.

Table 19 shows that the annual fluctuations in groundwater levels in the confined and semi-confined portions of the aquifer system are 3 to 5 feet during normal years and up to 9 feet during years of drought. Table 19 also shows that none of the current monitoring wells have a long groundwater level measurement history.

Groundwater hydrographs illustrate changes in groundwater levels over time. A hydrograph representing the seasonal and long-term groundwater level changes in the semi-confined portion of the aquifer is presented in Figure 102.

Table 19.
Current Groundwater Monitoring Wells the Estimated Annual Fluctuations Groundwater Levels, Butte Sink Sub-inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
17N/01E-17F01M	Observation	Semi-Confined	1991-2000	3-5	5-8
17N/01E-17F02M	Observation	Confined	1991-2000	4-5	7-8
17N/01E-17F03M	Observation	Confined	1991-2000	4-5	6-9

Figure 102 is a hydrograph for Well 17N/01E-17F01M, located in the northwestern portion of the Butte Sink Sub-inventory Unit. The land uses surrounding this well are characterized as native riparian and agricultural. Agricultural cultivation in this area consists of rice production supported primarily by surface water. Surface water is also used as the primary source for flooding native riparian land for waterfowl habitat. The well is a dedicated monitoring well constructed in the upper to middle portions of the aquifer, for which groundwater level measurements date back to 1992. The groundwater levels in this well were monitored on a monthly basis from 1992 to 1995 and are currently monitored four times a year during March, July, August, and October.

Figure 102 shows that the spring-to-summer fluctuations in groundwater levels in the semi-confined portion of the aquifer system average only 3 to 5 feet during years of normal precipitation and 5 to 8 feet during years of drought. A long-term comparison of spring-to-spring groundwater levels in Well 17N/01E-17F01M shows little change in spring groundwater levels from 1986-94 drought levels. A further long-term analysis of spring-to-spring groundwater levels is not possible due to the short monitoring history.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater contour map for the Sacramento Valley Region of Butte County. The small number of data points within the Butte Sink Sub-inventory Unit limits the analysis that can be made for that region, but generally, Plate 7 shows that the spring groundwater elevations are uniform across the area at an elevation of 55 to 60 feet.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. The small number of data points within the Butte Sink Sub-inventory Unit limits the analysis that can be made for that region, but generally,

Figure 102.
Groundwater Hydrograph for Well 17N/01E-17F01M, Butte Sink Sub-inventory Unit

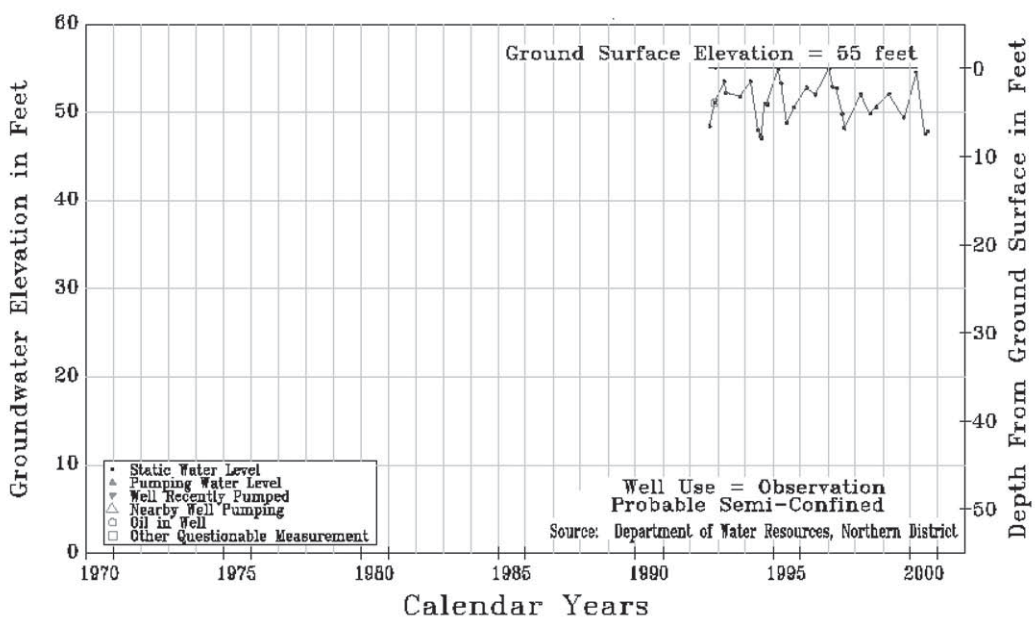


Plate 8 shows that the spring-to-summer fluctuations in groundwater elevations in the Butte Sink Sub-inventory Unit during a normal year range from 0 to 2 feet. The limited fluctuation is likely the result of limited groundwater extraction and summer irrigation of agricultural land with surface water.

Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). The small number of data points within the Butte Sink Sub-inventory Unit limits the analysis that can be made for that region, but generally, Plate 7 shows that the regional pattern of spring groundwater movement in the Butte Sink Sub-inventory Unit is in a southwesterly direction, at a gradient of about 3 feet per mile, toward Butte Creek.

Groundwater Extraction

Estimates of groundwater extraction in the Butte Sink Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that the normal-year groundwater extraction for the Butte Sink Sub-inventory Unit is estimated at 6.3 taf, which represents about 1.5% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 6.3 taf of groundwater extracted during a normal year, about 0.8 taf is for summer agricultural use, 0.4 is for fall agricultural use, and 5.1 are for wildlife refuge use. Table 3 shows that in a normal year, summer agricultural groundwater serves an area of about 100 acres, for an applied water average of 8.0 af/acre. About 8% (0.4 taf) of the groundwater extracted for application at wildlife refuges is used during the summer months. Table 3 also shows that about 0.3 taf of the extracted groundwater returns to the aquifer via deep percolation in a normal year.

Drought-year estimates of groundwater extraction and deep percolation of applied groundwater are provided in Table 4, Appendix B. The results in Table 4 show that drought-year groundwater extraction in the Butte Sink Sub-inventory Unit is estimated at 15.1 taf, or about 2.3 times the normal-year extraction estimate. Of the 15.1 taf of groundwater extracted during a drought year, about 1.6 taf are for summer agricultural use, 0.4 taf is for fall agricultural use, and 13.1 taf are for wildlife refuge use. About 3.2 taf (24%) of the groundwater extracted for application at wildlife refuges are used during the summer months. Table 4 also shows that in a drought year about 0.5 taf of the extracted groundwater returns to the aquifer via deep percolation.

Well Depth

Well depth and well use data for the Butte Sink Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 15 well records for the sub-inventory unit were evaluated and classified into two well types: domestic and irrigation. There are no municipal well reports for this sub-inventory unit on file with DWR. A statistical summary of the well depth data, listed by well type, is presented in Table 5, Appendix B.

Table 5, Appendix B, shows that 11 wells in the Butte Sink Sub-inventory Unit are for irrigation use and 4 are for domestic use. The average irrigation well depth is 446 feet. The depths of irrigation wells range from 130 to 616 feet. The average domestic well depth is 127 feet. The depths of domestic wells range from 90 to 200 feet.

Cumulative frequency curves were not developed for either the domestic or irrigation wells in the Butte Sink Sub-inventory Unit due to the low number of wells.

North Yuba Inventory Unit

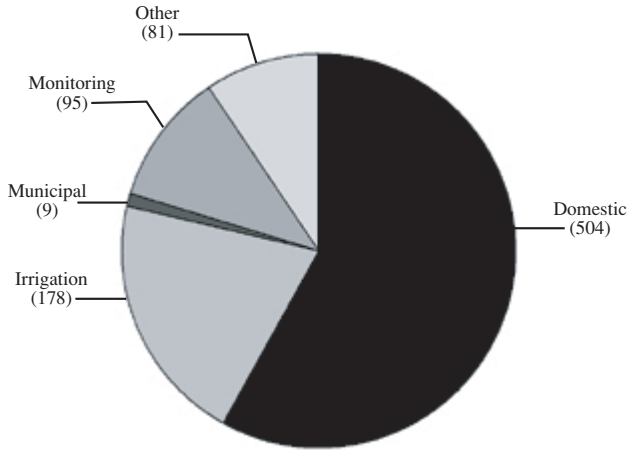
The North Yuba Inventory Unit covers about 47,500 acres in the southeastern portion of Butte County (Plate 1, Appendix A). It is bordered by the Feather River to the north and west, Yuba County to the south, and foothills to the east. In the northern portion of the inventory unit, in areas surrounding Oroville, the land use is primarily urban. In the central and southern portions of the inventory unit, the land uses are a mix of rural residential and agricultural. Agricultural land use is fairly diverse and consists of a combination of rice, orchards, grain, pasture, and field crops. The primary source of agricultural water in the North Yuba Inventory Unit is groundwater. In a normal water year, about 25% of the North Yuba Inventory Unit is in summer agricultural production supported by groundwater. Groundwater is also used as a municipal water source for portions of Oroville. The North Yuba Inventory Unit is not divided into sub-inventory units.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number, types, dates of installation and distribution of wells in the North Yuba Inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data, by area and by installation date, is provided in Tables 1 and 2, Appendix B.

There are an estimated 867 wells in the North Yuba Inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that, out of the 867 wells in the North Yuba Inventory Unit, 504 are listed as domestic, 178 are listed as irrigation, 9 are listed as municipal, 95 are listed as monitoring, and 81 are listed as other. Figure 103 illustrates the breakdown of wells by use for the North Yuba Inventory Unit.

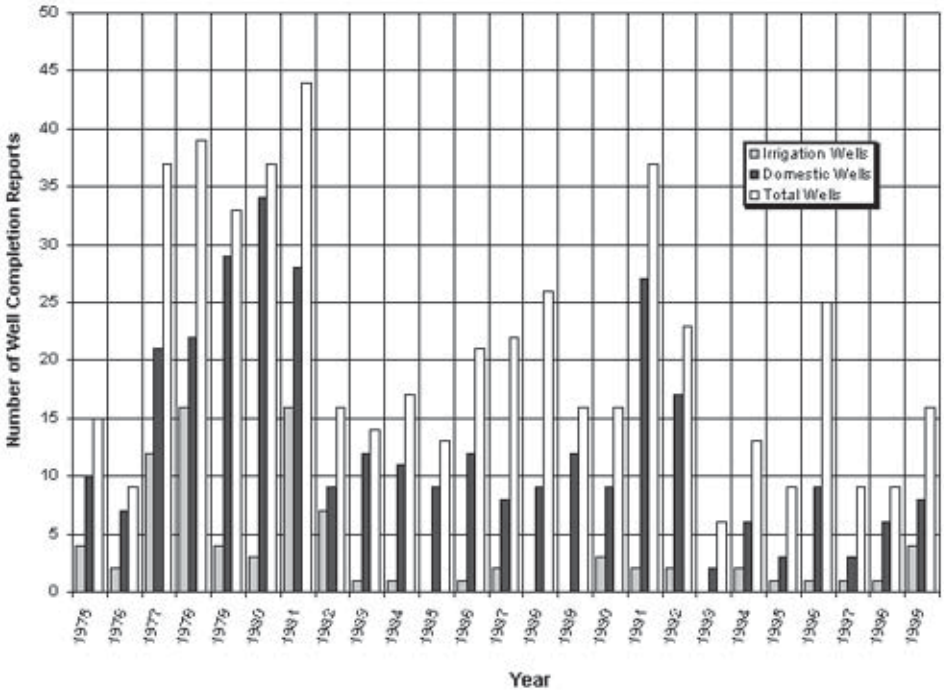
Figure 103.
Number of Wells by Use, North Yuba Inventory Unit



Total Number of Well = 867

Wells in the North Yuba Inventory Unit were also analyzed to determine the number and types of wells installed over time. Examination of the number and types of wells drilled over time can help offer perspective on the average age of the existing infrastructure and the approximate number of wells installed during normal and drought years. Table 2, Appendix B, lists the annual number and types of wells drilled in the North Yuba Inventory Unit between 1975 and 1999. The wells in Table 2 are divided into domestic, irrigation, miscellaneous, and total. Table 2, Appendix B, shows that 422 wells were drilled in the North Yuba Inventory Unit between 1975 and 1999. The number of wells drilled per year range from a low of 6 in 1993 to a high of 39 in 1978, with an average of about 17 wells per year. About 33% of the wells drilled during 1993 are listed as domestic, and none are listed as irrigation. About 56% of the wells drilled during 1978 are listed as domestic and 41% are listed as irrigation. Figure 104, shown below, illustrates the number of well completion reports filed per year for the North Yuba Inventory Unit.

Figure 104.
Number of Well Completion Reports Filed Per Year, North Yuba Inventory Unit



Groundwater Level

DWR and BCDWRC currently monitor groundwater levels in 8 wells within the North Yuba Inventory Unit. The monitoring well list consists of a combination of domestic and irrigation wells. Table 20 lists the current monitoring wells, along with the annual fluctuations in groundwater levels during normal and drought years. Table 20 also lists the well use, the aquifer system that is being monitored, and the monitoring period of record. The groundwater monitoring wells are shown on Plate 6, Appendix A.

Table 20 shows that the annual fluctuations in groundwater levels in the confined portion of the aquifer system are 5 to 20 feet during normal years and up to 40 feet during years of drought. The annual fluctuations in groundwater levels associated with monitoring a composite section of the aquifer system are 5 to 10 feet during normal years and up to 30 feet during years of drought. Composite monitoring wells measure a combined groundwater level in multiple water-bearing zones within the aquifer system.

Table 20.
Current Groundwater Monitoring Wells and Estimated Annual Fluctuations in Groundwater Levels, North Yuba Inventory Unit

State Well Number	Well Use	Aquifer System	Period of Record	Annual GW Fluctuation: Normal Years (feet)	Annual GW Fluctuation: Drought Years (feet)
17N/03E-03D01M	Irrigation	Composite	1947-2000	5-10	10-15
17N/04E-08A01M	Irrigation	Composite	1961-2000	5-10	20-30
17N/04E-22B01M	Domestic	Confined	1976-2000	5-15	15-20
18N/03E-25N01M	Irrigation	Confined	1976-2000	8-10	15-25
18N/04E-28L01M	Irrigation	Confined	1947-2000	15-20	20-40
18N/04E-08M01M	Irrigation	Confined	1961-2000	10-15	15-25
18N/04E-16C01M	Irrigation	Confined	1947-2000	5-15	15-25
19N/04E-32P01M	Domestic	Confined	1959-2000	5-10	10-13

Groundwater hydrographs illustrate changes in groundwater levels over time. Hydrographs representing the seasonal and long-term groundwater level changes in the aquifer are presented in Figures 105 and 106.

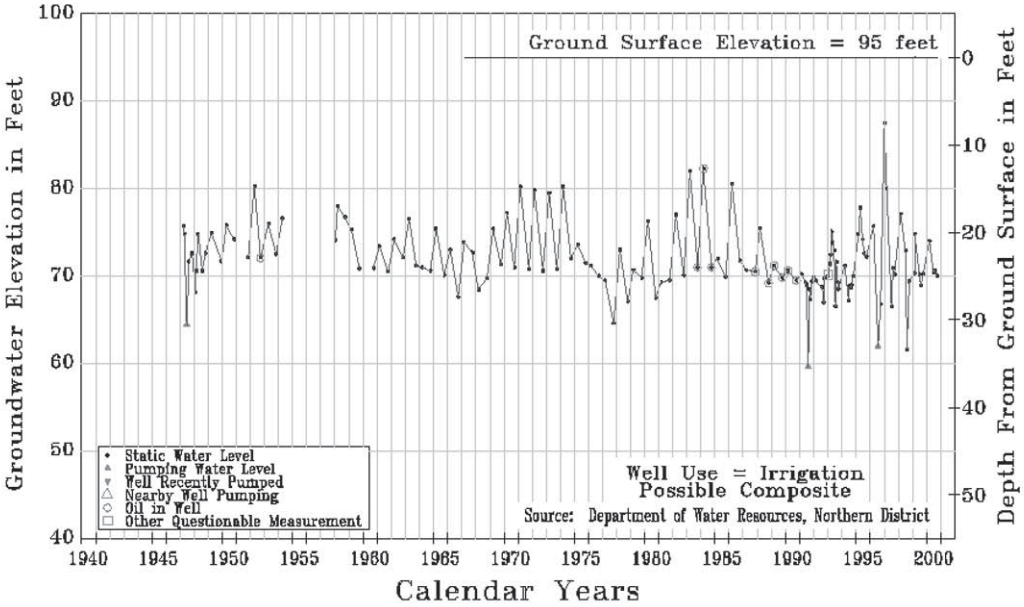
Figure 105 is a hydrograph for Well 17N/03E-03D01M located in the western portion of the North Yuba Inventory Unit. The area surrounding the well is characterized by rural and agricultural land uses supported by the application of both surface and groundwater. The well is an active irrigation well that draws water from the upper and middle portions of the aquifer system, for which groundwater level measurements date back to the late 1940s. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until 1991, on a monthly basis from 1991 to about 1995, and are currently being measured four times a year in March, July, August, and October.

Figure 105 shows that the seasonal fluctuations in groundwater levels are about 5 to 10 feet during years of normal precipitation and 10 to 15 feet during years of drought. A long-term comparison of spring-to-spring groundwater levels in Well 17N/03E-03D01M shows about a 10-foot decline in groundwater levels associated with the 1976-77 and 1986-94 droughts, followed by recovery to predrought levels. Overall comparison of spring-to-spring groundwater levels indicates that the upper to middle aquifer system in this area has changed little since the 1940s.

Figure 106 is a hydrograph for Well 18N/04E-08M01M located in the eastern portion of the North Yuba Inventory Unit. The land uses surrounding this well are characterized as rural residential and agricultural supported by groundwater. Agricultural production consists primarily of olive orchards and field crops. Well 18N/04E-08M01M is an active irrigation well that draws water from the middle portion of the aquifer system, for which groundwater level measurements date back to the 1960s. The groundwater levels in this well were monitored on a semi-annual basis (spring and fall) until about 1991, on a monthly basis from about 1991 to 1995, and are currently measured four times per year in March, July, August, and October.

Figure 106 shows that the seasonal fluctuations in groundwater levels are about 10 to 15 feet during years of normal precipitation and 15 to 25 feet during years of below-average precipitation. Figure 98 also shows that, prior to the start of summer monitoring in 1991, many of the seasonal fluctuations in groundwater levels were not

Figure 105.
Groundwater Hydrograph for Well 17N/03E-03D01M, North Yuba Inventory Unit



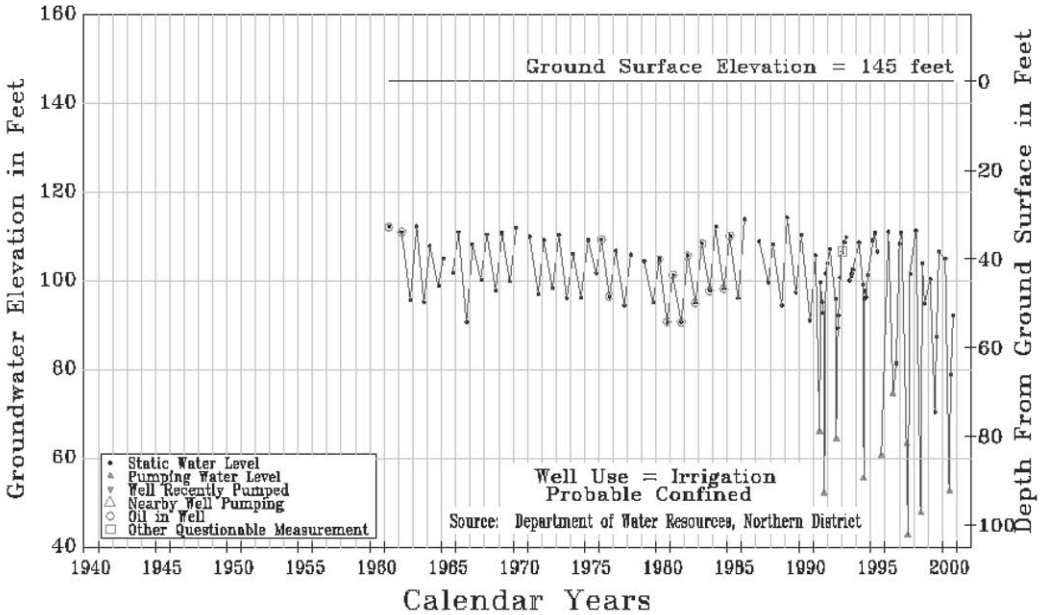
recorded. A long-term comparison of spring-to-spring groundwater levels in Well 18N/04E-08M01M shows almost no decline associated with the 1976-77 drought, but about a 10-foot drop associated with the 1986-94 drought. Overall comparison of spring-to-spring groundwater levels indicates little change in the confined portion of the aquifer system in this area since the 1960s.

Groundwater level data were also evaluated using groundwater elevation contour maps. Plate 7, Appendix A, is a spring 1997 groundwater elevation contour map for the Sacramento Valley Region of Butte County. Groundwater elevations for 1997 are considered representative of a normal water year. Spring groundwater elevations are commonly the highest of the year and, in areas unaffected by municipal use of groundwater, reflect the natural groundwater table distribution and direction of movement. Plate 7 shows that the spring groundwater elevations in the North Yuba Inventory Unit range from a low of about 70 feet in the southwest portion of the inventory unit to a high of about 160 feet along the eastern foothills.

Plate 8, Appendix A, is a contour map showing the seasonal changes in groundwater elevations between the spring and summer of a normal water year. The contours on Plate 8 represent equal changes in groundwater elevations between the spring and summer measurement periods. The seasonal fluctuations in groundwater elevations are often dependent on the sources of water used for agricultural and municipal land uses. A water source map, based on 1997 land and water use data, is provided on Plate 9, Appendix A.

Plate 8, Appendix A, shows that the seasonal groundwater level fluctuations for a normal year in the North Yuba Inventory Unit range from 5 to 20 feet, with the largest seasonal decline located between Honcut and Palermo along the eastern margin of the basin. The primary source of agricultural water in the Honcut and Palermo areas is groundwater (see Plate 9, Appendix A). Plate 8 also shows that during normal water years areas adjacent to the Feather River display little seasonal decline in groundwater levels. Recharge from the river in this area tends to reduce the seasonal decline in groundwater levels associated with pumping.

Figure 106.
Groundwater Hydrograph for Well 18N/04E-08M01M, North Yuba Inventory Unit



Groundwater Movement

The direction of groundwater movement is illustrated in the spring 1997 groundwater contour map by a series of small arrows, perpendicular to the groundwater elevation contours (see Plate 7, Appendix A). Plate 7 shows that the regional pattern of spring groundwater movement in the northern portion of the North Yuba Inventory Unit is to the west and south, away from the foothills and parallel to the Feather River. In the central and southern portions of the North Yuba Inventory Unit, the groundwater flow tends to converge toward the south-central area of the inventory unit, away from the Feather River and foothill areas. Groundwater movement away from the Feather River in this area indicates that the river is contributing surface water to the recharge of the aquifer system.

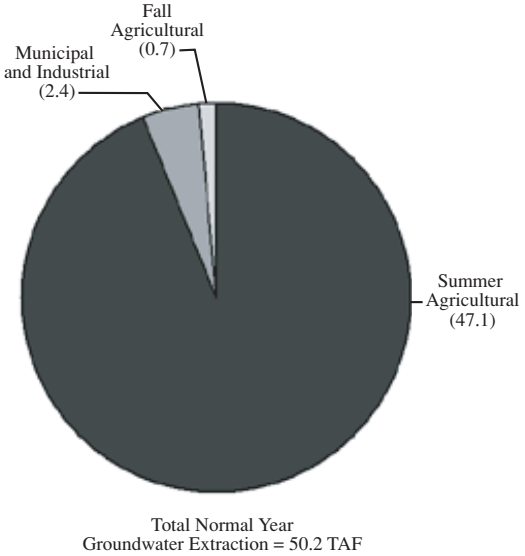
Groundwater Extraction

Estimates of groundwater extraction in the North Yuba Inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are summarized in Tables 3 and 4, Appendix B. Groundwater extraction estimates are divided into summer and winter agricultural use, annual municipal and industrial use, and annual wildlife refuge use. The annual deep percolation estimates are divided into agricultural, municipal, and industrial uses. A water source map, based on 1997 land and water use data, is provided on Plate 9, Appendix A.

The estimated amounts of normal-year groundwater extraction, by type of use, are presented in Table 3, Appendix B, and illustrated in Figure 107. The figure shows that the normal-year groundwater extraction for the North Yuba Inventory Unit is estimated at 50.2 taf. Groundwater extraction of 50.2 taf represents about 12% of the overall amount of groundwater extracted from the valley portion of Butte County during a normal year. Of the 50.2 taf of groundwater extracted during a normal year,

about 47.1 taf are for summer agricultural use, 2.4 taf are for annual municipal, industrial and domestic uses, and 0.7 taf is for fall agricultural use. Table 3, Appendix B, shows that summer agricultural groundwater in a normal year is applied to about 12,000 acres, for an applied water average of 3.9 af/acre. Table 3 also shows that during a normal year about 13.8 taf of the extracted groundwater return to the aquifer via deep percolation.

Figure 107.
Estimated Amount of Normal-Year Groundwater Extraction by Type of Use, North Yuba Inventory Unit



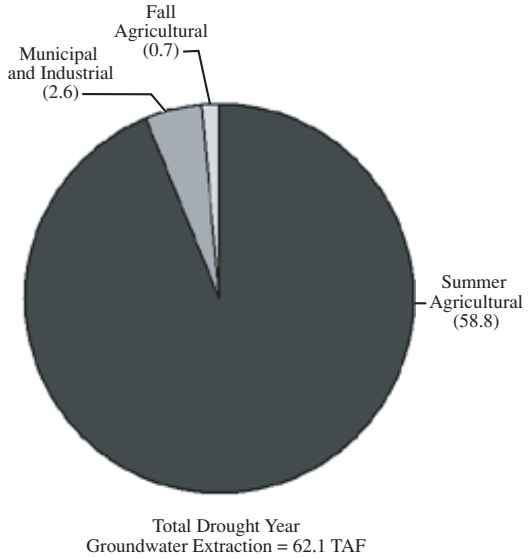
The estimated amounts of drought-year groundwater extraction, by type of use, are presented in Table 4, Appendix B, and illustrated in Figure 108. The figure shows that drought-year groundwater extraction in the North Yuba Inventory Unit is estimated at 62.1 taf, an increase of about 24% over the normal-year extraction estimate. Of the 62.1 taf of groundwater extracted during a drought year, about 58.8 taf are for summer agricultural use, 2.6 taf are for annual municipal use, and 0.7 taf is for fall agricultural use. Table 4, Appendix B, shows that the summer agricultural groundwater in a drought year is applied to about 12,400 acres, for an applied water average of 4.7 af/acre. Table 4 also shows that about 16.5 taf of the extracted groundwater return to the aquifer via deep percolation during a drought year.

Well Depth

Well depth and well use data for the North Yuba Inventory Unit were collected from well completion reports filed with DWR. A total of 691 well records for the inventory unit were evaluated and classified into three well types: domestic, irrigation, and municipal. A summary of the minimum, maximum, and average well depths, listed by well type, is presented in Table 5, Appendix B. A statistical distribution of the well depth data was also evaluated though a series of cumulative frequency distribution curves for domestic, irrigation, and municipal wells. Cumulative frequency curves associated with the North Yuba Inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the North Yuba Inventory Unit are for domestic use. The average domestic well depth is about 139 feet. Table 5 also shows that wells drilled for irrigation and municipal uses tend to be deeper than

Figure 108.
Estimated Amount of Drought-Year Groundwater Extraction by Type of Use, North Yuba Inventory Unit



those for domestic use. The average irrigation well depth for the inventory unit is 288 feet. The average municipal well depth is 171 feet.

The cumulative frequency distribution of well depth data was also evaluated for domestic, and irrigation wells in the North Yuba Inventory Unit. Figure 109 shows the cumulative frequency distribution of well depths for domestic wells in the North Yuba Inventory Unit. A total of 504 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 25 to 575 feet.

The histogram bars in Figure 109 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the domestic well depth data is skewed slightly to the right toward deeper well depths. Right-skewed distribution of domestic well depth data indicates that average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

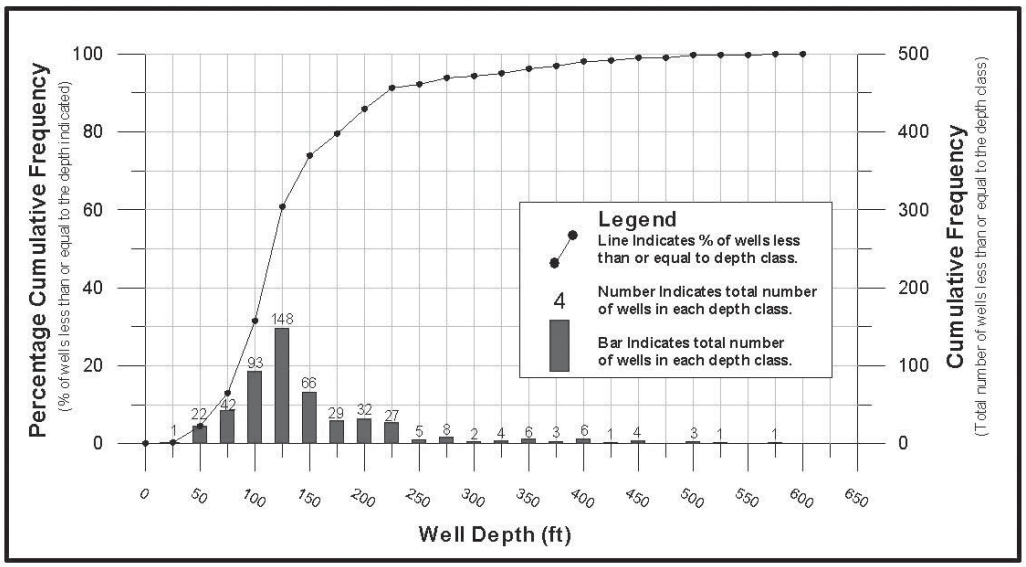
The cumulative frequency curve of domestic well depth data for the North Yuba Inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 120 feet or less,
- 20% of the wells are installed to a depth of 85 feet or less, and
- 10% of the wells are installed to a depth of 65 feet or less.

Figure 110 illustrates the cumulative frequency distribution of irrigation well depth data in the North Yuba Inventory Unit. A total of 178 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 28 to 983 feet.

The histogram bars in Figure 110 show that the distribution of irrigation well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the North Yuba Inventory Unit and that no dominant well depth preference exists.

Figure 109.
Cumulative Frequency Distribution of Domestic Wells, North Yuba Inventory Unit



The cumulative frequency curve of irrigation well depth data for the North Yuba Inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 150 feet or less,
- 20% of the wells are installed to a depth of 90 feet or less, and
- 10% of the wells are installed to a depth of 75 feet or less.

There are 9 municipal wells in the North Yuba Inventory Unit. The well depths range from a minimum of 98 feet to a maximum of 210 feet. A cumulative frequency curve was not developed for municipal wells in this inventory unit because the small number of wells tends to limit a statistically meaningful evaluation.

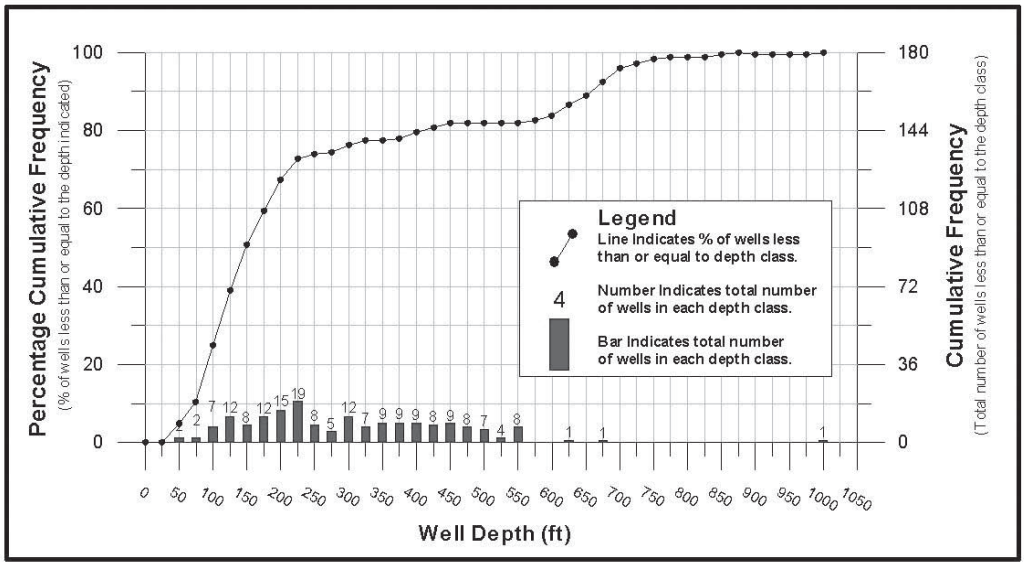
Well Yield

Well yield estimates for the North Yuba Inventory Unit were evaluated based on well completion reports filed with DWR, published investigations, and utility pump records. The utility records represent pumping test data from primarily municipal and agricultural wells. A further explanation of well yield data is provided in Section 1. A summary of well yield data is provided in Table 6, Appendix B.

Approximately 187 municipal and irrigation well completion reports are on file at DWR for the North Yuba Inventory Unit. Of the 187 reports, only 6 have well yield data. Table 6, Appendix B, shows that the average well yields, from well completion report data, in the North Yuba Inventory Unit range from a low of 80 gpm to a high of 400 gpm, with an average of about 225 gpm. Well yield data from well completion reports should serve only as a general guide to local well productivity.

In 1961, Olmsted and Davis of the USGS compiled utility pump test records for 21 areas within the Sacramento Valley. Three of these areas - Chico, Gridley, and Honcut - are located almost entirely in the Butte County portion of the Sacramento Valley. The Honcut area corresponds closely to the North Yuba Inventory Unit. Well yield data from the 1961 investigation are summarized in Table 6, Appendix B. The 1961 utility data for the Honcut area represents 23 pump tests taken prior to 1959. Table 6, Appendix B, shows that the average well yield in the Honcut area, as reported in the 1961 USGS report, is 840 gpm.

Figure 110.
Cumulative Frequency Distribution of Irrigation Wells, North Yuba Inventory Unit



Utility pump test records for this inventory unit were also evaluated for estimates of well yield. The utility pump data are summarized in Table 6, Appendix B. The well yield estimates for the North Yuba Inventory Unit shown in Table 6 represent data from 162 pump tests performed on 84 wells between 1989 and 1998. Table 6, Appendix B, shows that the well yields for the inventory unit range from a low of 84 gpm to a high of 4,178 gpm, with an average yield of 976 gpm. Utility pump tests are generally considered to provide an accurate estimate of well yields.

Specific Capacity

Specific capacity estimates for the North Yuba Inventory Unit were evaluated based on published investigations and utility pump test records from primarily municipal and agricultural wells. A further explanation of specific capacity data is provided in Section 1. A summary of specific capacity data is provided in Table 7, Appendix B.

In 1961, Olmsted and Davis of the USGS compiled utility pump test records for 21 areas within the Sacramento Valley. Three of these areas - Chico, Gridley and Honcut - are located almost entirely in the Butte County portion of the Sacramento Valley. The Honcut area corresponds closely to the North Yuba Inventory Unit. Specific capacity data from the 1961 USGS investigation are summarized in Table 7, Appendix B. The 1961 USGS utility data for the Honcut area represents 23 pump tests taken prior to 1959. Table 7 shows that the average specific capacity for the Honcut area, as reported in the 1961 USGS report, is 60 gpm/ft.

Table 7, Appendix B, shows that specific capacity figures from utility pump test records in the North Yuba Inventory Unit range from a low of 7 gpm/ft to a high of 170 gpm/ft. The average specific capacity in the North Yuba Inventory Unit, estimated from utility pump test data, is 48 gpm/ft. The specific capacity estimates shown in Table 7 represent 64 pump tests performed on 38 wells between 1989 and 1998. Utility pump tests are generally considered to provide a good estimate of specific capacity.

Groundwater Storage Capacity

For the purposes of this investigation, groundwater storage capacity is defined as the maximum volume of fresh groundwater capable of being stored beneath a given area

within an aquifer. Estimates of storage capacity were calculated by multiplying the area of the North Yuba Inventory Unit by the maximum saturated thickness and the average specific yield of the freshwater portion of the aquifer. Groundwater storage capacity estimates are summarized in Table 8, Appendix B. A further explanation of groundwater storage capacity is provided in Section 1.

Table 8, Appendix B, shows that the North Yuba Inventory Unit covers an area of about 47,500 acres. Groundwater storage capacity estimates for the North Yuba Inventory Unit listed in Table 8 assume uniform aquifer saturation from a depth of 10 feet, down to the average base of fresh water at a depth of about 600 feet, and an average specific yield of 8.8%. Based on the above assumptions, the estimated maximum groundwater storage capacity for the North Yuba Inventory Unit is about 2,470 taf.

Groundwater in Storage

Groundwater in storage is defined as the amount of water contained within the aquifer system at the time of measurement. Groundwater in storage in the North Yuba Inventory Unit was examined using three scenarios:

- the estimated volume of groundwater currently in storage over the entire freshwater portion of the aquifer system,
- the estimated seasonal decline in groundwater levels associated with the removal of groundwater in storage during a normal water year, and
- the estimated seasonal decline in groundwater levels associated with the removal of groundwater in storage during a drought water year.

The estimated amounts of groundwater in storage are summarized in Table 9, Appendix B. A further explanation of groundwater in storage is provided in Section 1.

- Estimated Volume of Groundwater in Storage. The North Yuba Inventory Unit covers an area of about 47,500 acres. Groundwater in storage estimates for the inventory unit assume uniform aquifer saturation from an average depth of 37 feet, down to the average base of fresh water at a depth of about 600 feet, and an average specific yield of 8.8%. The average depth of groundwater is based on monitoring data collected in spring 1997. Based on the above assumptions, the volume of groundwater in storage for the North Yuba Inventory Unit is estimated at 2,350 taf. A comparison of groundwater storage capacity and groundwater in storage estimates in Tables 8 and 9, Appendix B, indicates that the volume of groundwater in storage in the North Yuba Inventory Unit is slightly less than maximum capacity during normal water years.
- Estimated Seasonal Decline of Groundwater in Storage associated with Normal-Year Extraction. The normal-year groundwater demand for the North Yuba Inventory Unit was adjusted to reflect seasonal use during a normal water year. Seasonal groundwater extraction is estimated at 100% of the summer agricultural extraction, plus 70% of the annual municipal extraction, minus 30% of the annual deep percolation of applied surface water and groundwater. Based on the above assumptions, the seasonal groundwater demand for the North Yuba Inventory Unit during a normal year is estimated at about 44.1 taf. The average seasonal decline in groundwater levels associated with a normal-year extraction of 44.1 taf of groundwater in the North Yuba Inventory Unit is estimated at 11 feet. These results are shown in Table 11, Appendix B.
- Estimated Seasonal Decline of Groundwater in Storage associated with Drought-Year Extraction. The drought-year groundwater demand for the North Yuba

Inventory Unit was adjusted to reflect seasonal use during a drought water year. Seasonal groundwater extraction is estimated at 100% of the summer agricultural extraction, plus 70% of the annual municipal extraction, minus 30% of the annual deep percolation of applied surface water and groundwater. Based on the above assumptions, the seasonal groundwater demand in the inventory unit during a drought year is estimated at about 55 taf. The average seasonal decline in groundwater levels associated with a drought year extraction of 55 taf in the North Yuba Inventory Unit is about 13 feet. These results are shown in Table 11, Appendix B.

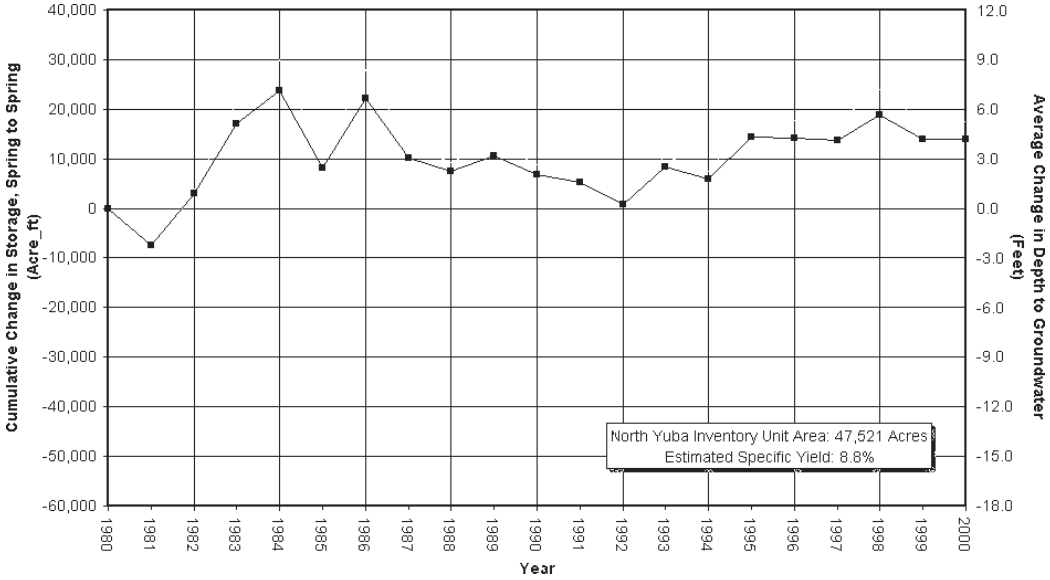
Changes in the Volume of Groundwater in Storage

The annual spring-to-spring changes in the volume of groundwater in storage for the North Yuba Inventory Unit were calculated over a 20-year period from 1980 to 2000. The changes in the volume of groundwater in storage are based on groundwater contour maps developed from spring groundwater level measurements in the upper portion of the aquifer. A summary of the spring-to-spring change in the volume of groundwater in storage data is provided in Table 11, Appendix B. The cumulative spring-to-spring changes in the volume of groundwater in storage for the North Yuba Inventory Unit are presented in Figure 111. A further explanation of the method for estimating changes in the volume of groundwater in storage is provided in Section 1.

Table 11, Appendix B, lists the annual changes in the volume of groundwater in storage, the cumulative changes in groundwater in storage, and the changes in groundwater elevations associated with the cumulative changes in storage for the North Yuba Inventory Unit. Table 11 shows that the largest single-year decline in spring-to-spring volume of groundwater in storage for the North Yuba Inventory Unit was about 19.5 taf in 1984-85. The largest single-year increase in groundwater in storage was about 17.6 taf in 1982-83.

The cumulative spring-to-spring changes in groundwater in storage for the North Yuba Inventory Unit are illustrated in Figure 111. The spring-to-spring changes in storage graph starts with a baseline of zero for spring 1980 and shows cumulative changes from 1980 to 2000. Figure 111 shows that the groundwater in storage increased during the wet years of 1983 and 1986, decreased slightly through 1992,

Figure 111.
Estimated Cumulative Changes in Spring-to-Spring Storage, North Yuba Inventory Unit



then increased slightly to stay above the 1980 base storage level over the last 8 years. The range of groundwater in storage between the low in 1981 and the peak in 1984 is estimated at about 39.0 taf. Overall, the amount of groundwater in storage in the North Yuba Inventory Unit during spring 2000 was about 17.4 taf more than during the spring of 1980.

FOOTHILL REGION

The Foothill Region lies just east of the Sacramento Valley Region of Butte County and covers an area of about 217,600 acres (340 mi^2). The region is bordered by Rock Creek to the north, Honcut to the south, the Sacramento Valley Region to the west, and the Mountain Region to the east (see Plate 1, Appendix A). The western and eastern margins of the Foothill Region increase in elevation from south to north. The western margin starts at an elevation of about 100 feet near the City of Honcut, increases to about 800 feet at the crossing of Doe Mill Ridge, and ends at an elevation of about 600 feet near Richardson Springs and Rock Creek. The eastern margin also starts at an elevation of about 100 feet near Honcut, increases to 770 feet at Oroville Dam, 3,500 feet at Sterling City, and ends at an elevation of 3,200 feet in the northeastern boundary of the region. The Foothill Region is comprised of one inventory unit, the Foothill Inventory Unit. The Foothill Inventory Unit is subdivided into the Cohasset, Ridge and Wyandotte sub-inventory units.

Foothill Inventory Unit

The principal sources of groundwater in the Foothill Inventory Unit are the reworked gravels and sands deposited between successive layers of lahar and mudflows of the Tuscan Formation (Slade 2000 – 3 reports). Limited amounts of groundwater are also available through secondary porosity associated with fracturing of the geologic formations in the region. Less than 140 acres (0.5 mi^2) of the Foothill Inventory Unit is in summer agricultural production supported by groundwater. The majority of groundwater extraction in the Foothill Inventory Unit is for domestic use.

The Foothill Inventory Unit is a recharge area for the Butte County portion of the Sacramento Valley groundwater basin aquifer. Groundwater recharge occurs from precipitation and deep percolation of runoff from the creeks, streams, and reservoirs.

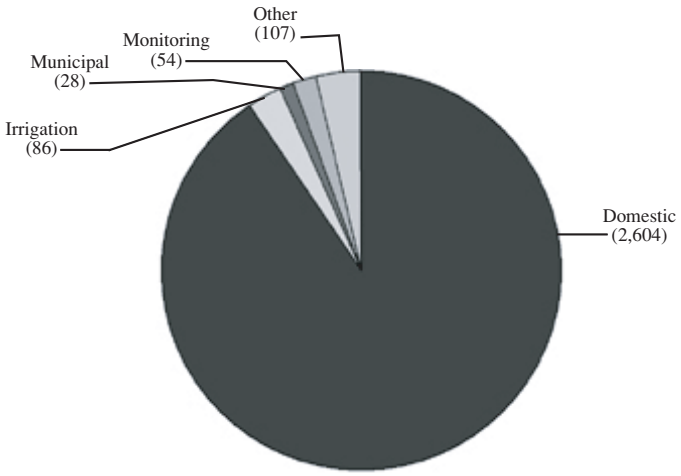
Information regarding well yields, groundwater levels, groundwater movement, groundwater storage capacity, and changes in groundwater in storage in the Foothill Inventory Unit is limited. The following discussion will focus on analysis of well infrastructure and estimates of groundwater extraction.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number, types, dates of installation, and distribution of wells in the Foothill Inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. Well distribution data at the inventory unit level are summarized in Tables 1 and 2, Appendix B.

There are an estimated 2,879 wells in the Foothill Inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that, of the 2,879 wells in this unit, 2,604 are listed as domestic, 86 are listed as irrigation, 28 are listed as municipal, 54 are listed as monitoring, and 107 are listed as other. Figure 112 illustrates the breakdown of wells by use for the Foothill Inventory Unit.

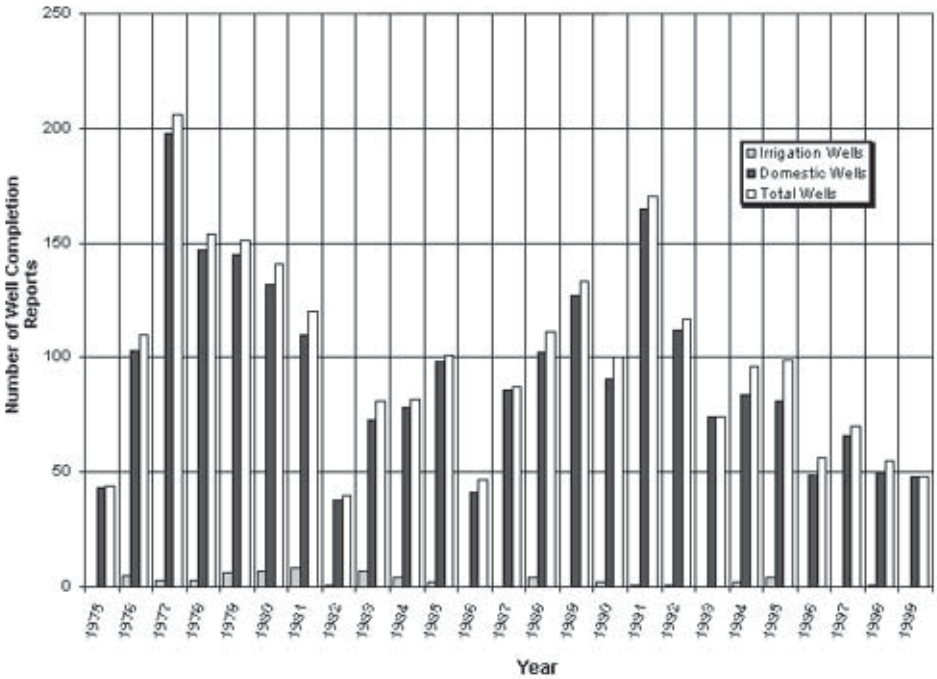
Figure 112.
Number of Wells by Use, Foothill Inventory Unit



Total Number of Well = 2,879

Wells in the Foothill Inventory Unit were also analyzed to determine the number and type of wells installed over time. Examination of the number and types of wells drilled over time can help offer a perspective on the average age of the existing infrastructure and the approximate number of wells installed during normal and drought years. Table 2, Appendix B, lists the annual number and types of wells drilled in this inventory unit between 1975 and 1999. The wells in Table 2 are divided into domestic, irrigation, miscellaneous, and total. Table 2, Appendix B, shows that 1,979 wells were drilled in the Foothill Inventory Unit between 1975 and 1999. The number of wells drilled per year range from a low of 40 in 1982 to a high of 206 in 1977, with an average of about 79 wells per year. About 95% of the wells drilled during 1982 are listed as domestic and 3% are listed as irrigation. About 96% of the wells drilled during 1978 are listed as domestic and 1% are listed as irrigation. Figure 113 illustrates the number of well completion reports filed per year for the Foothill Inventory Unit.

Figure 113.
Number of Well Completion Reports Filed Per Year, Foothill Inventory Unit



Groundwater Level

Groundwater level data for the Foothill Inventory Unit are limited. Neither DWR nor BCDWRC are currently monitoring wells in this area. However, local water purveyors currently monitor a few municipal wells in the Ridge Sub-inventory Unit, and DWR has limited groundwater level data from previous investigations in the foothill area. In addition, groundwater level data for the Ridge Sub-inventory Unit were recently compiled and published in a series of reports by Richard C. Slade & Associates. Groundwater level information from these sources will be presented under the Cohasset, Ridge, and Wyandotte sub-inventory unit sections of this report.

Groundwater Movement

There is insufficient data to accurately determine the direction and rate of groundwater movement in the Foothill Inventory Unit. In general, groundwater moves down-gradient following the contours of the topographic surface. In the foothills, groundwater can be interpreted to flow from areas of high elevation to areas of low elevation toward the natural valleys and regional discharge areas.

Groundwater Extraction

Estimates of groundwater extraction in the Foothill Inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are summarized in Tables 3 and 4, Appendix B. Groundwater extraction estimates are divided into summer and winter agricultural use, annual municipal and industrial use, and annual wildlife refuge use. The annual deep percolation estimates are divided into agricultural, municipal, and industrial uses. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

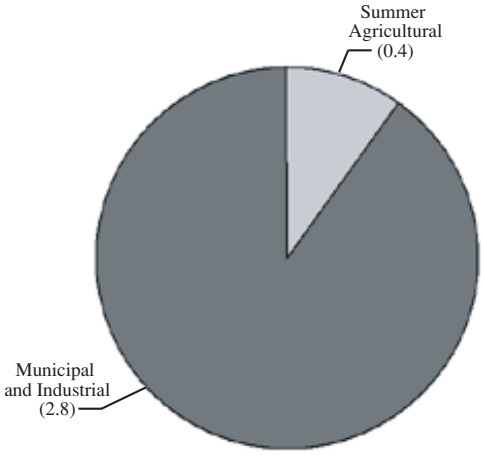
The estimated amounts of normal-year groundwater extraction, by type of use, are presented in Table 3, Appendix B, and illustrated in Figure 114. Figure 114 shows that normal-year groundwater extraction in the Foothill Inventory Unit is estimated at 3.2 taf. Of the 3.2 taf of groundwater extracted during a normal year, about 0.4 taf is for summer agricultural use and 2.8 taf are for annual municipal use. The annual groundwater extraction of 2.8 taf for municipal water demand represents about 19% of the total municipal water demand. The remaining 81% of municipal demand is provided by surface water. The 2.8 taf of groundwater used for municipal demand are based on an average per capita use of 0.24 acre-foot per year (af/yr). Table 3, Appendix B, shows that during a normal year about 1.8 taf, or 56% of the extracted groundwater, return to the aquifer via deep percolation.

The estimated amounts of drought-year groundwater extraction, by type of use, are presented in Table 4, Appendix B. Table 4 shows that drought-year groundwater extraction in the Foothill Inventory Unit is estimated to be 3.2 taf, the same as a normal year.

Well Depth

Well depth and well use data for the Foothill Inventory Unit were collected from well completion reports filed with DWR. A total of 2,718 well records for the inventory unit were evaluated and classified into three well types: domestic, irrigation, and municipal. A summary of the minimum, maximum, and average well depths, listed by

Figure 114.
Estimated Amount of Normal-Year Groundwater Extraction by Type of Use, Foothill Inventory Unit.



Total Normal Year
Groundwater Extraction = 3.2 TAF

well type, is presented in Table 5, Appendix B. A statistical distribution of the well depth data was also evaluated through a series of cumulative frequency distribution curves for domestic, irrigation, and municipal wells. Cumulative frequency curves associated with the Foothill Inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the Foothill Inventory Unit are for domestic use. The average domestic well depth is about 240 feet. Table 5 also shows that the average well depth for irrigation and municipal wells is 225 feet and 452 feet, respectively.

The cumulative frequency distribution of well depth data was also evaluated for domestic, irrigation, and municipal wells in the Foothill Inventory Unit. Figure 115 shows the cumulative frequency distribution of well depths for domestic wells in the inventory unit. A total of 2,604 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 18 to 1,060 feet.

The histogram bars in Figure 115 show the total number of wells associated with each 25-foot class interval. The histogram indicates that the distribution of the domestic well depth data is skewed slightly to the right toward deeper well depths. Right-skewed distribution of domestic well data indicates that average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the Foothill Inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 175 feet or less,
- 20% of the wells are installed to a depth of 90 feet or less, and
- 10% of the wells are installed to a depth of 75 feet or less.

Figure 115.
Cumulative Frequency Distribution of Domestic Wells, Foothill Inventory Unit

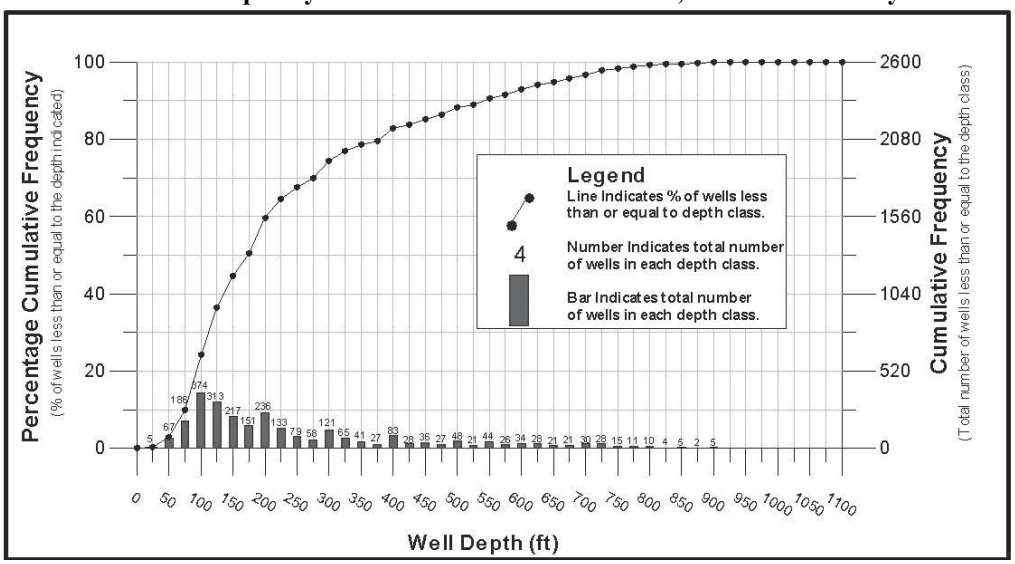


Figure 116 illustrates the cumulative frequency distribution of irrigation well depth data in the Foothill Inventory Unit. A total of 86 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 30 to 875 feet.

The histogram bars in Figure 116 show that the distribution of irrigation well depth data is skewed to the right toward deeper well depths. Right-skewed distribution of irrigation well depth data indicates that average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of irrigation well depth data for the Foothill Inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 185 feet or less,
- 20% of the wells are installed to a depth of 85 feet or less, and
- 10% of the wells are installed to a depth of 70 feet or less.

Figure 116.
Cumulative Frequency Distribution of Irrigation Wells, Foothill Inventory Unit

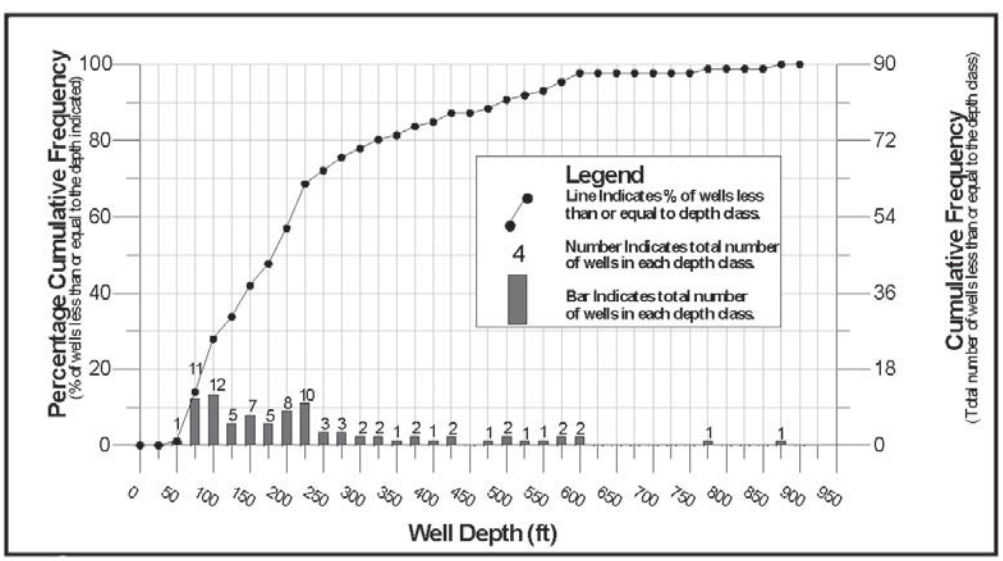


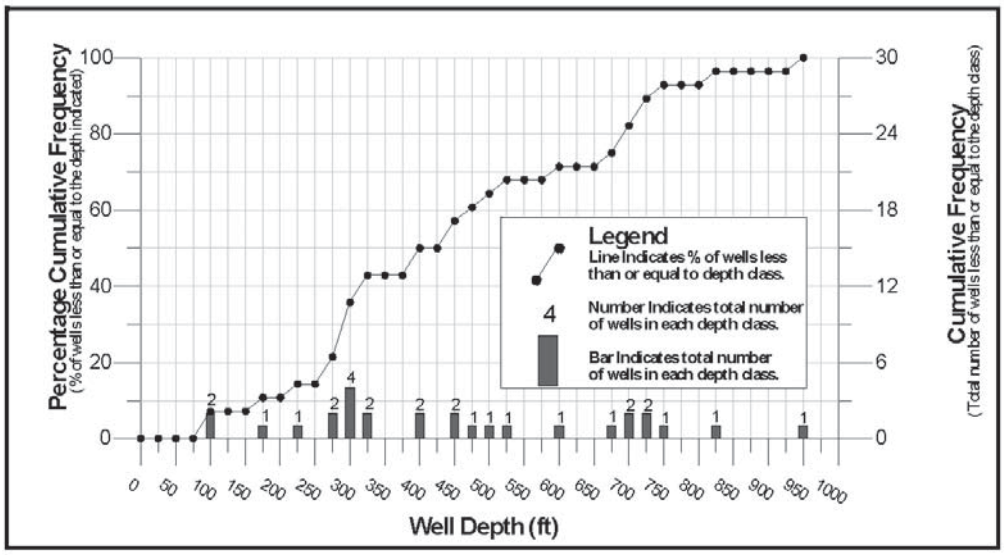
Figure 117 illustrates the cumulative frequency distribution of municipal well depth data in the Foothill Inventory Unit. A total of 28 municipal wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The municipal wells range in depths from 100 to 930 feet.

The histogram bars in Figure 117 show that the distribution of municipal well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the municipal well depth data indicates that there is a wide range of municipal well depths within the Foothill Inventory Unit and that no dominant well depth preference exists.

The cumulative frequency curve of municipal well depth data for the Foothill Inventory Unit shows that:

- 50% of the municipal wells are installed to a depth of 420 feet or less,
- 20% of the wells are installed to a depth of 275 feet or less, and
- 10% of the wells are installed to a depth of 175 feet or less.

Figure 117.
Cumulative Frequency Distribution of Municipal Wells,
Foothill Inventory Unit



Well Yield

Well yields vary considerably along the Foothill Inventory Unit. Although little well yield data has been collected in the Foothill Inventory Unit, some information has been collected from unpublished investigations. In general, domestic wells typically yield between 2 and 10 gpm and occasionally may yield up to 30 gpm. Municipal wells that are commonly deeper and of a larger diameter, typically yield in the range of 100 to 500 gpm.

Groundwater Storage

Groundwater in the Foothill Inventory Unit is largely stored in the secondary porosity of rock associated with fractures and jointing of the underlying consolidated rock. Due to the difficulties of predicting the location, density, and interconnection of subsurface fractures, little data are available on the amount of groundwater in storage in the area. However, recent studies (Slade 2000) and an unpublished investigation by

DWR shed some light on the groundwater in storage in portions of the inventory unit. Past investigations along the inventory unit indicate that more than half of the domestic wells rely on groundwater stored in the fractures and joints within the upper 250 feet of the aquifer. The groundwater storage in the upper portion of the aquifer is highly dependent on recharge from annual precipitation. During years of normal precipitation, the upper portion of the hard rock aquifer is recharged, providing an adequate supply to shallow wells. During drought conditions, the recharge to the upper portion of the aquifer is quickly reduced, causing dewatering in the shallowest wells. Although in some areas deeper wells provide a measure of protection against dewatering during years of drought, in other areas the available amount of groundwater in storage does not increase with depth. Recent studies in portions of the Ridge Sub-inventory Unit (Slade 2000) indicate that groundwater is being depleted from storage during years of below-normal precipitation, even in deep, large diameter wells.

Conclusions and Recommendations

Inventory analysis of the aquifer system beneath the Butte County Foothill Inventory Unit indicates that the overall groundwater supply is limited and that many wells, due to their shallow construction, are susceptible to dewatering during periods of drought. Over 50% of the domestic wells in the foothill area draw groundwater from the soil, weathered rock, and fractures located within the upper 175 feet of the aquifer. This upper aquifer zone is typically the first to recharge during wet periods but is also the first to dewater during periods of drought. In some areas, deeper wells tend to ensure a better supply; but they are still often prone to sharp declines in yield and groundwater levels during a drought.

Recommendations at this time are to do the following:

- initiate a groundwater level monitoring and data collection program for the Foothill Inventory Unit,
- closely evaluate the available dry-year water supply for future development in the Cohasset and Ridge sub-inventory units,
- promote the use of Butte County's entitlement of Lake Oroville water to provide surface water supply to water-short communities in the Magalia and Lime Saddle areas,
- promote conjunctive management of water resources in the Ridge Sub-inventory Unit to conserve groundwater resources during normal or wet years; and
- when possible, groundwater resources in the Ridge Sub-inventory Unit should be reserved for use during periods of drought when surface water supplies are limited.

Cohasset Sub-inventory Unit

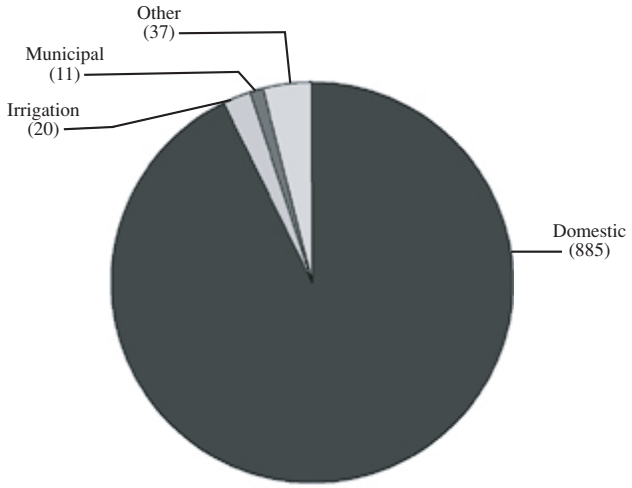
The Cohasset Sub-inventory Unit covers an area of about 73,000 acres in the northern-most portion of the Foothill Inventory Unit. The Cohasset Sub-inventory Unit is bordered by Rock Creek to the north, Butte Creek to the south, the Sacramento Valley Region to the west, and the Mountain Region to the east (see Plate 1, Appendix A). The elevation increases from west to east across the sub-inventory unit, with the western edge at an elevation of about 700 feet and the eastern edge at about 3,200 feet. The Cohasset Sub-inventory Unit is comprised of the cities of Cohasset and Forest Ranch. Land uses in this area are primarily native vegetation and rural residential. Domestic water use is supported completely by groundwater from

private and community wells. The availability of groundwater in this area is limited, and it occurs primarily through the secondary porosity found in the fractures and jointing of the Tuscan Formation and, in some portions of the Cohasset area, Cohasset Ridge Basalt.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the Cohasset Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

Figure 118.
Number of Wells by Use, Cohasset Sub-inventory Unit



Total Number of Well = 953

There are about 953 wells in the Cohasset Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 885 wells are listed as domestic, 20 are listed as irrigation, 11 are listed as municipal, none are listed as monitoring, and 37 are listed as other. Figure 118 illustrates the breakdown of wells by use for the Cohasset Sub-inventory Unit.

Groundwater Level

Groundwater level data for the Cohasset Sub-inventory Unit are limited. Neither DWR nor BCDWRC are currently monitoring wells in this area. However, some groundwater level data were collected during the late 1980s as part of a cooperative study conducted by DWR and the Butte County Planning Department. Between 1986 and 1988, groundwater levels were monitored within the Cohasset Ridge and Forest Ranch Ridge areas of the Cohasset Sub-inventory Unit. During the monitoring period, drought conditions existed in the foothills and surrounding areas.

In the Cohasset Ridge area, groundwater levels were measured in 17 wells. The groundwater monitoring wells range in depths from 60 to 265 feet. The majority of these wells are cased to a shallow depth with variable lengths of open holes below the casing. As a result, most of the groundwater level data reflect a mixture of confined and unconfined aquifer conditions. In the main portion of Cohasset Ridge, wells less than 80 feet deep produced water from the Cohasset Ridge Basalt. Deeper wells produce water from the basalt and underlying Tuscan Formation. Wells located below the main ridge produce water from the Tuscan Formation only.

The study of groundwater levels in the Cohasset Ridge area concluded:

- the depth to groundwater in wells constructed in the shallow portion of the aquifer system, within the weathered upper portions of the Cohasset Ridge Basalt, typically range from 40 to 60 feet,
- the depth to groundwater in wells constructed in the deeper portion of the aquifer system, within the fractures of the Tuscan Formation, typically range from 200 to 250 feet,
- drought conditions during monitoring illustrated that wells located in the shallow portion of the aquifer, within the weathered upper portions of the Cohasset Ridge Basalt, can quickly become dewatered when recharge from annual precipitation is reduced; and
- many dry holes were located along the edge and southern end of the Cohasset Ridge. These dry wells are an indication that the availability of groundwater in those locations is probably affected by seepage to the canyon wall via fractures and blockage of groundwater flow by crosscutting faults.

In the Forest Ranch area, groundwater levels were measured in 15 private wells between 1986 and 1988. The groundwater level monitoring wells range in depths from 74 to 759 feet. Similar to the Cohasset Ridge area, most wells along the Forest Ranch Ridge are cased to a shallow depth with variable lengths of open holes below the casings. As a result, most of the groundwater level data reflect a mixture of confined and unconfined aquifer conditions. The majority of wells in the Forest Ranch Ridge area produce water from the Tuscan Formation. A basalt flow, correlative to the Cohasset Ridge Basalt, caps portions of the southern spur of Doe Mill Ridge, thereby providing some shallow groundwater to wells.

The study of groundwater levels in the Forest Ranch Ridge area concludes:

- There are upper and lower groundwater-bearing zones on Forest Ranch Ridge. The upper zone occurs between depths of 50 to 150 feet and draws groundwater from a deep soil profile associated with the weathered upper surface of the Tuscan Formation and the network of fractures within the formation. The lower zone occurs between about 470 and 700 feet and draws groundwater from the weathered contacts between the layers of the Tuscan Formation and from gravels deposited by streams that cut into the formation between volcanic flow events.
- The depth to groundwater in wells constructed in the shallow portion of the aquifer system, within the soil and weathered upper portions of the Tuscan Formation, typically range from 30 to 50 feet during the spring.
- The depths to groundwater in wells constructed in the deeper portion of the aquifer system, within the fractures and gravels of the Tuscan Formation, typically range from 150 to 250 feet during the spring and up to 425 feet during the fall of a drought year.

Groundwater Extraction

Estimates of groundwater extraction in the Cohasset Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that the normal-year groundwater extraction for the Cohasset Sub-inventory Unit is estimated at only 0.5 taf. All of the groundwater extracted during a normal year is for municipal and domestic uses. The estimated municipal and domestic groundwater use is based on an average per capita use of 0.14 af/yr. Table 3, Appendix B, shows that during a normal year about 0.3 taf, or 60% of the extracted groundwater returns to the aquifer via deep percolation.

The estimated amounts of drought-year groundwater extraction, by type of use, are presented in Table 4, Appendix B. Table 4 shows that drought-year groundwater extraction in the Cohasset Sub-inventory Unit is estimated to be slightly less than a normal year at 0.4 taf.

Well Depth

Well depth and well use data for the Cohasset Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 916 well records were evaluated and classified into three well types: domestic, irrigation, and municipal. A statistical summary of the well depth data, listed by well type, is presented in Table 5, Appendix B. Cumulative frequency curves associated with the Cohasset Sub-inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the Cohasset Sub-inventory Unit are for domestic use. The average domestic well depth is about 227 feet. Table 5 also shows that the average well depth for irrigation and municipal wells is 228 feet and 562 feet, respectively.

The cumulative frequency distribution of well depth data was evaluated for domestic and irrigation wells. Figure 119 shows the cumulative frequency distribution of well depths for domestic wells in the Cohasset Sub-inventory Unit. A total of 885 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 25 to 1,060 feet.

The histogram bars in Figure 119 show that the distribution of the domestic well depth data is skewed to the right toward deeper well depths. Right-skewed distribution of domestic well depth data indicates that the average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

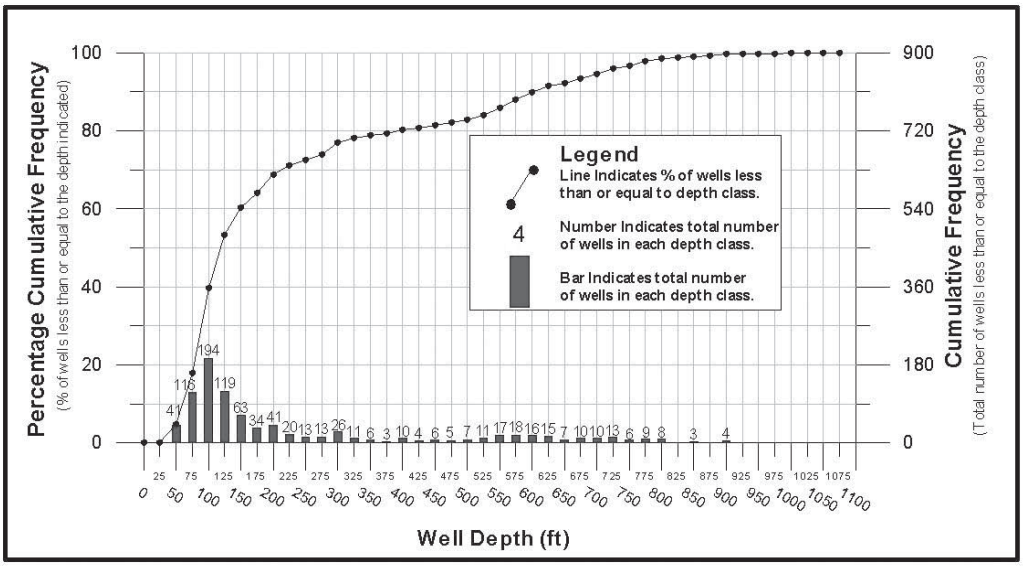
The cumulative frequency curve of domestic well depth data for the Cohasset Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 120 feet or less,
- 20% of the wells are installed to a depth of 75 feet or less, and
- 10% of the wells are installed to a depth of 60 feet or less.

Figure 120 illustrates the cumulative frequency distribution of irrigation well depth data in the Cohasset Sub-inventory Unit. A total of 20 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 55 to 875 feet.

The histogram bars in Figure 120 show that the distribution of the irrigation well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the Cohasset Sub-inventory Unit and that no dominant well depth preference exists. The asymmetrical nature could also be a function of the small number of irrigation wells in the data set.

Figure 119.
Cumulative Frequency Distribution of Domestic Wells, Cohasset Sub-inventory Unit

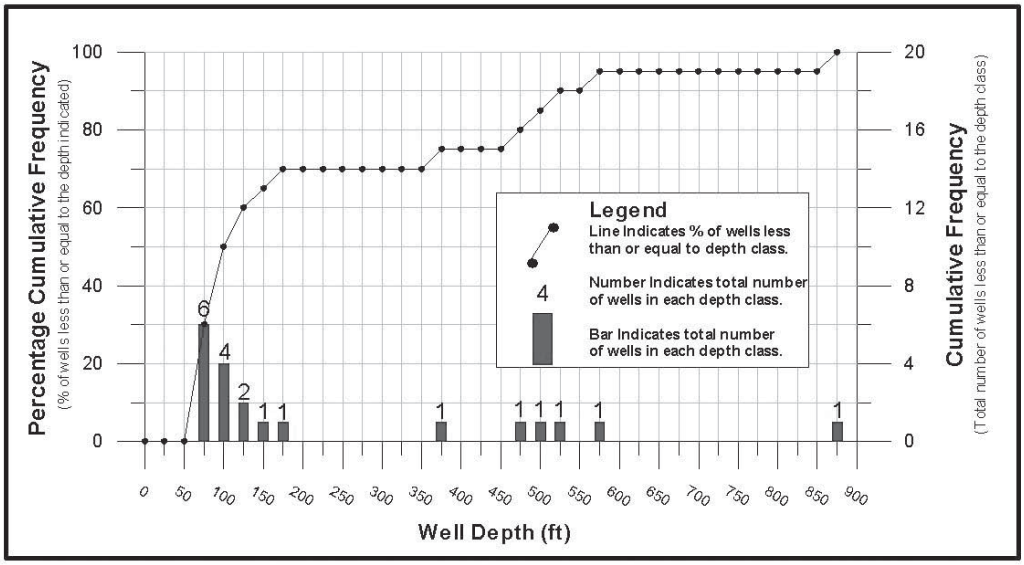


The cumulative frequency curve of irrigation well depth data for the Cohasset Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 100 feet or less,
- 20% of the wells are installed to a depth of 75 feet or less, and
- 10% of the wells are installed to a depth of 60 feet or less.

There are 11 municipal wells in the Cohasset Sub-inventory Unit. The well depths range from a minimum of 100 feet to a maximum of 930 feet. A cumulative frequency curve was not developed for municipal wells in the Cohasset Sub-inventory Unit because the small number of wells tends to limit a statistically meaningful evaluation.

Figure 120.
Cumulative Frequency Distribution of Irrigation Wells, Cohasset Sub-inventory Unit.



Ridge Sub-inventory Unit

The Ridge Sub-inventory Unit covers an area of about 108,000 acres in the central portion of the Foothill Inventory Unit. The sub-inventory unit is bordered by Butte Creek to the north, Oroville Dam and the Feather River to the south, the East Butte Inventory Unit to the west, and the west branch of the Feather River to the east (see Plate 1, Appendix A). The elevation increases from west to east and from south to north across the sub-inventory unit. The elevations along the western edge range from 200 feet at the City of Oroville to about 800 feet as it crosses the southern ridge of Butte Creek Canyon. The elevations along the eastern edge range from 770 feet at Oroville Dam to about 3,500 feet at Sterling City. The Ridge Sub-inventory Unit is comprised of the Cities and Towns of Paradise, Magalia, Sterling City, Lime Saddle, and Pentz.

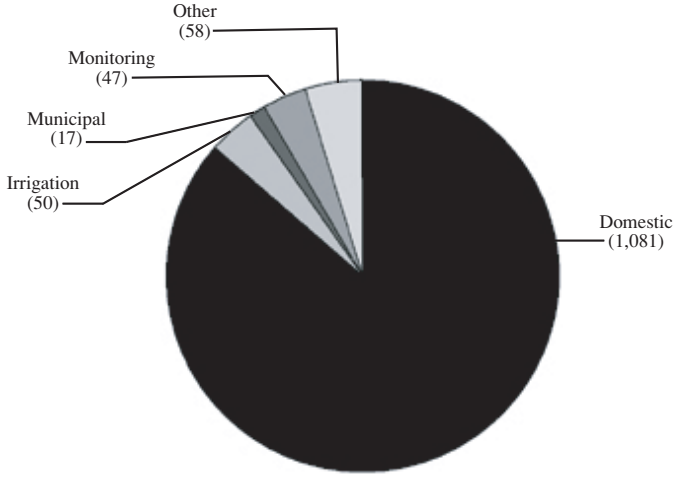
The major water purveyors in the Ridge Sub-inventory Unit include the Paradise Irrigation District and the Del Oro Water Company. Although small parcels of land within this sub-inventory unit are put to agricultural use, native vegetation and rural residential are the major land uses in this area. About 17% of the domestic water demand in the Ridge Sub-inventory Unit is supplied by groundwater and 87% is supplied by surface water. Domestic groundwater is provided by municipal water purveyor wells and private wells. Groundwater occurs primarily through the secondary porosity found in the fractures and jointing of the Tuscan Formation and is limited in supply.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the Ridge Sub-inventory Unit. Detailed descriptions of the source and accuracy of the well distribution data are provided in Section 1. A summary of well distribution data is provided in Table 1, Appendix B.

There are about 1,253 wells in the Ridge Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 1,081 wells are listed as domestic, 50 are listed as irrigation, 17 are listed as municipal, 47 are listed as monitoring, and 58 are listed as other. Figure 121 illustrates the breakdown of wells by use for the Ridge Sub-inventory Unit.

Figure 121.
Number of Wells by Use, Ridge Sub-inventory Unit



Total Number of Well = 1,253

Groundwater Level

Long-term groundwater level data for the Ridge Sub-inventory Unit are limited. Neither DWR nor BCDWRC are currently monitoring wells in this area. However, some groundwater level data were collected during the late 1980s as part of a cooperative study conducted by DWR and the Butte County Planning Department.

Between 1986 and 1988, groundwater levels were monitored within the Paradise area of the Ridge Sub-inventory Unit. During the monitoring period, drought conditions existed in the foothills and surrounding areas.

In the upper Paradise Ridge area, groundwater levels were measured in 17 private wells. Three of the wells were located in the northeastern study area and constructed in metamorphic basement rocks at depths ranging from 94 to 160 feet. The remaining 14 wells were located adjacent to the Skyway and constructed in the Tuscan Formation at depths ranging from 74 to 600 feet.

The study of groundwater levels in the Paradise portion of the Ridge Sub-inventory Unit concluded:

- groundwater in the metamorphic rocks is primarily unconfined and occurs within the overlying soil, weathered upper rock surfaces, and in the underlying joints and fractures,
- the depths to groundwater in the shallow wells constructed in the metamorphic rocks range from 40 to 60 feet during the spring months and 60 to 70 feet during the fall,
- groundwater within the Tuscan Formation occurs primarily from two zones, one shallow and one deep. The shallow zones range in depths from 60 to 200 feet and draws groundwater from deep within the soil profile (the weathered upper surface of the Tuscan Formation) and from the network of fractures within the Tuscan Formation. The deeper zone averages 370 to 520 feet deep and draws groundwater from the weathered contacts between the layers of the Tuscan Formation and from gravels deposited by streams that cut into the formation between volcanic flow events,
- the depths to groundwater in wells constructed in the shallow portion of the Tuscan Formation range from 20 to 30 feet during the spring months and 30 to 40 feet during the fall, and
- the depths to groundwater in wells constructed in the deeper portion of the Tuscan Formation range from 50 to 60 feet during the spring months and up to 115 feet during the fall of a drought year.

In the lower Butte Creek Canyon area, between the confluence of Butte and Little Butte Creeks and Quail Run Road, groundwater levels were measured in 9 private wells. To protect against the possibility of contamination from septic systems, all of the wells were drilled through the upper terrace deposits and into the underlying sandstone and claystone of the Chico Formation. The wells range in depths from 80 to 260 feet. Three of the wells were artesian at different times during the study with an artesian head between 10 and 30 feet.

In the southeastern portion of the Ridge Sub-inventory Unit, near the town of Cherokee and along the shallow valley known as Campbell Flat, groundwater levels were measured in 3 private wells. The wells range in depths from 105 to 200 feet and were completely within the Jurassic age metavolcanic rocks in the area. Groundwater in these rocks typically occurs within the upper weathered surfaces and the underlying fractures and joints. North-to-south faulting occurs along the axis of the

valley and likely plays a role in the movement of groundwater and the perching of groundwater nearby. Two shallow lakes are located in the lowest portions of the valley. The depth to groundwater in these areas varies with topography and seemingly with proximity to the lakes. The depths to groundwater range from 1 to 4 feet in wells located adjacent to the lakes and from 20 to 50 feet in wells located along the edge of the valley.

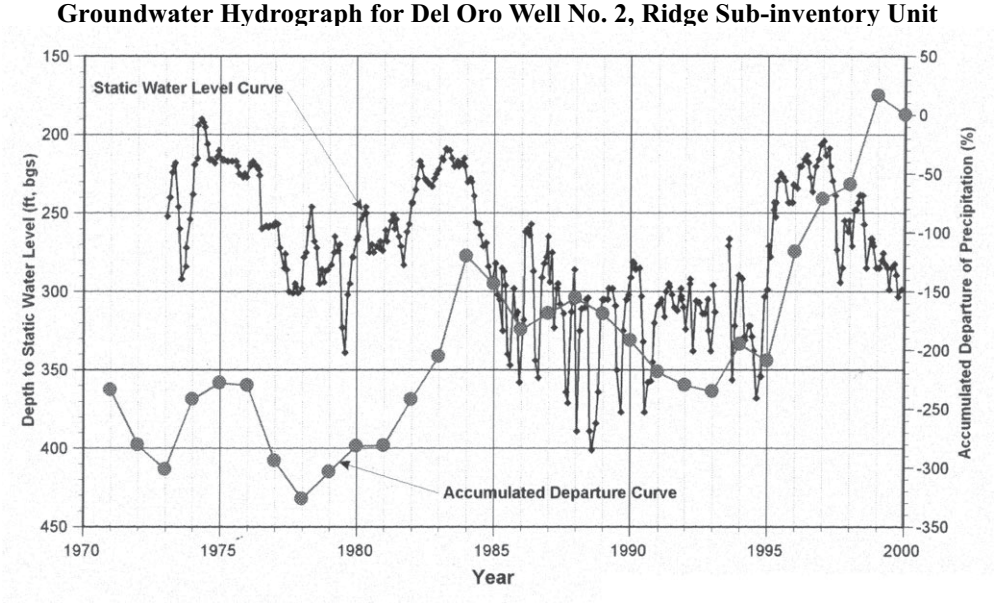
In addition to DWR groundwater level data, long-term groundwater level data were recently developed for 5 municipal wells in the Del Oro Water Company service area by Richard Slade & Associates LLC (Slade, Oct., 2000). Three static groundwater level hydrographs from these wells are presented below.

Figure 122 is a hydrograph for Del Oro Well No. 2 located in the north-central portion of the Ridge Sub-inventory Unit. Well No. 2 is an active municipal well constructed within the main shaft of the old Magalia Drift Mine, for which groundwater level measurements date back to 1973. The Magalia Drift Mine consists of a hand-dug shaft with numerous adits and tunnels. The adits and tunnels allow the well to recharge and draw groundwater from a much larger network of cracks, fissures and buried gravel channels than would be possible with a conventionally constructed well.

Figure 122 shows that the seasonal fluctuations in groundwater levels are highly variable, averaging about 20 to 40 feet during years of normal precipitation and 50 to 100 feet during years of drought. Long-term comparisons of spring-to-spring groundwater levels in Well No. 2 show a decline and recovery of groundwater levels associated with the 1976-77 and 1986-94 droughts. Although groundwater levels in the well show a recovery from the drought of the early 1990s, levels have continued to decline by about 100 feet during the relatively wet period of 1997 to 2000. The adits and tunnels associated with Well No. 2 allow for a much larger area to recharge the well but also create a larger radius of influence associated with the drawdown of groundwater levels due to the operation of this well. The total range of groundwater level fluctuation between normal and drought years is as much as 200 feet.

Figure 123 is a hydrograph for Del Oro Well No. 3 located in the north-central portion of the Ridge Sub-inventory Unit. The well is an active municipal well

Figure 122.
Groundwater Hydrograph for Del Oro Well No. 2, Ridge Sub-inventory Unit



constructed, using conventional drilling methods, within the lower Tuscan Formation. Groundwater level measurements for this well date back to 1974.

Figure 123 shows that the seasonal fluctuations in groundwater levels average 10 to 20 feet during years of normal precipitation and about 20 to 30 feet during years of drought. Long-term comparisons of spring-to-spring groundwater levels in Well No. 3 show that groundwater levels remained fairly stable during the wet periods of 1975 to 1980 and 1995 to 2000. However, during normal or below-normal years of precipitation from 1980 to 1995, groundwater levels steadily declined by over 100 feet. Overall, the hydrograph indicates that, during years of normal or below-normal precipitation, groundwater is being depleted from storage at a much greater rate than it is being recharged. The total range of groundwater level fluctuations between normal and drought years are as much as 140 feet.

Figure 123.
Groundwater Hydrograph for Del Oro Well No. 3, Ridge Sub-inventory Unit

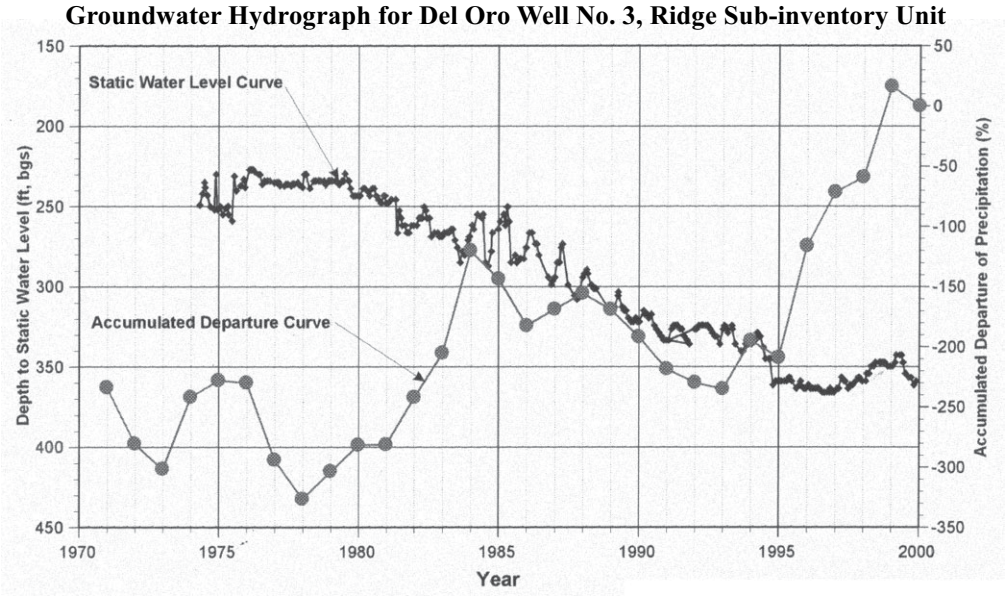


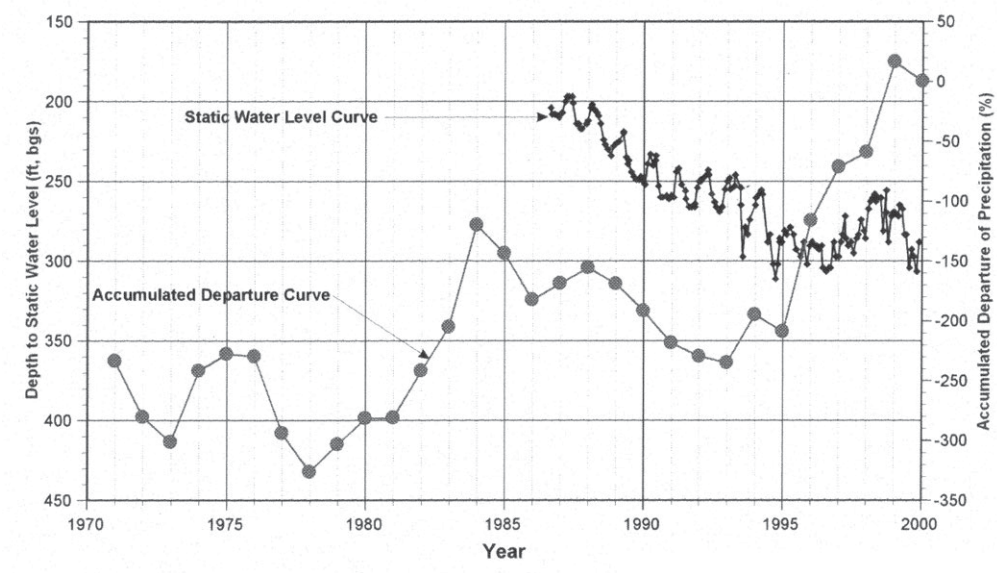
Figure 124 is a hydrograph for Del Oro Well No. 4, located in the north-central portion of the Ridge Sub-inventory Unit. The well is an active municipal well constructed, using conventional drilling methods, within the lower Tuscan Formation. Groundwater level measurements for this well date back to 1986.

Figure 124 shows that the seasonal fluctuations in groundwater levels average 20 to 30 feet during years of normal precipitation and 30 to 50 feet during years of drought. Similar to Del Oro Well No. 3, long-term comparisons of spring-to-spring groundwater levels in Well No. 4 show about a 100-foot drop in groundwater levels between 1986 and 1995. During the wet years following 1995, groundwater levels increased through 1997 and then began a decline to present levels. Overall, the hydrograph for Well No. 4 indicates that, during years of normal or below-normal precipitation, groundwater is being depleted from storage at a much greater rate than it is being recharged. The total range of groundwater level fluctuations between normal and drought years is as much as 110 feet.

Groundwater Extraction

Estimates of groundwater extraction in the Ridge Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought

Figure 124.
Groundwater Hydrograph for Del Oro No. 4, Ridge Sub-inventory Unit



years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that normal-year groundwater extraction for the Ridge Sub-inventory Unit is estimated at 2 taf. Of the 2 taf groundwater extracted during a normal year, 0.3 taf is for agricultural use and 1.7 taf are for municipal and domestic uses. Groundwater extraction is estimated to provide 17% of the total municipal water demand. The estimated municipal groundwater use is based on an average per capita use of 0.25 af/yr. Table 3, Appendix B, shows that, during a normal year, about 1.1 taf, or 55% of the extracted groundwater return to the aquifer via deep percolation.

The estimated amounts of drought-year groundwater extraction, by type of use, are presented in Table 4, Appendix B. Table 4 shows that drought-year groundwater extraction in the Ridge Sub-inventory Unit is about the same as that of a normal year.

Well Depth

Well depth and well use data for the Ridge Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 1,148 well records were evaluated and classified into three well types: domestic, irrigation, and municipal. A statistical summary of the well depth data, listed by well type, is presented in Table 5, Appendix B. Cumulative frequency curves associated with the Ridge Sub-inventory Unit are presented below.

Table 5, Appendix B, shows that the majority of wells in the Ridge Sub-inventory Unit are for domestic use. The average domestic well depth is 258 feet. Table 5 also shows that the average well depth for irrigation and municipal wells is 215 feet and 381 feet, respectively.

The cumulative frequency distribution of well depth data was also evaluated for domestic and irrigation wells. Figure 125 shows the cumulative frequency distribution of well depths for domestic wells in the Ridge Sub-inventory Unit. A

total of 1,081 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 18 to 1,030 feet.

The histogram bars in Figure 125 show that the distribution of the domestic well depth data is skewed to the right toward deeper well depths. Right-skewed distribution of domestic well depth data indicates that average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the Ridge Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 185 feet or less,
- 20% of the wells are installed to a depth of 100 feet or less, and
- 10% of the wells are installed to a depth of 80 feet or less.

Figure 125.
Cumulative Frequency Distribution of Domestic Wells, Ridge Sub-inventory Unit

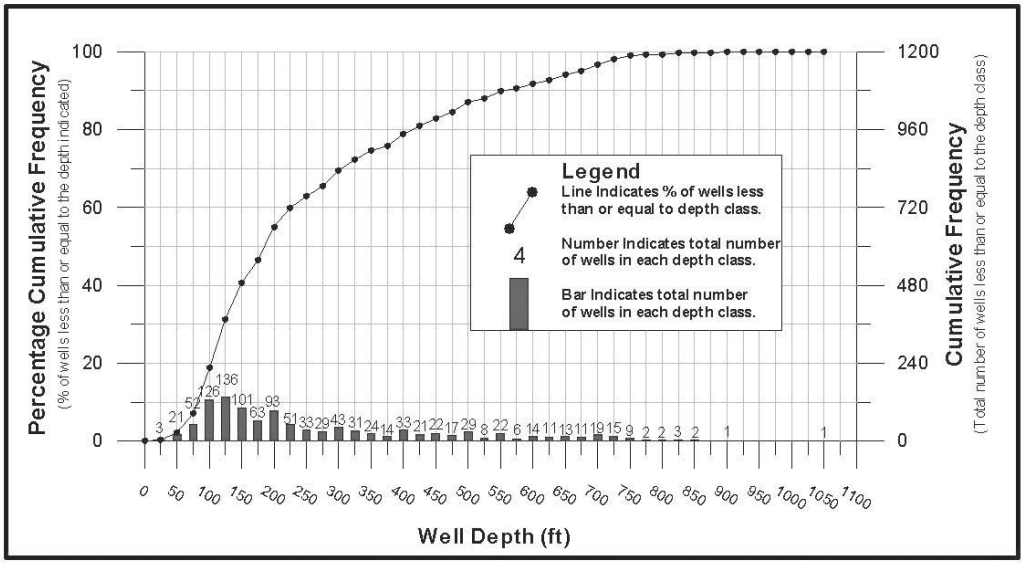


Figure 126 illustrates the cumulative frequency distribution of irrigation well depth data in the Ridge Sub-inventory Unit. A total of 50 irrigation wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The irrigation wells range in depths from 30 to 770 feet.

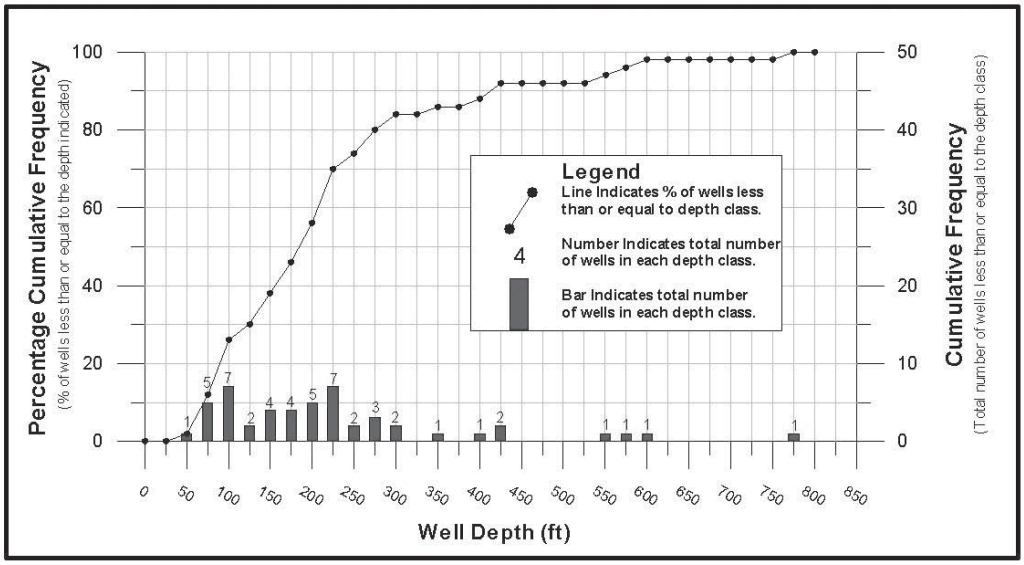
The histogram bars in Figure 126 show that the distribution of the irrigation well depth data is asymmetrical, showing no noticeable resemblance to a normal distribution. The asymmetrical distribution of the irrigation well depth data indicates that there is a wide range of irrigation well depths within the Ridge Sub-inventory Unit and that no dominant well depth preference exists. The asymmetrical nature could also be a function of the small number of irrigation wells in the data set.

The cumulative frequency curve of irrigation well depth data for the Ridge Sub-inventory Unit shows that:

- 50% of the irrigation wells are installed to a depth of 185 feet or less,
- 20% of the wells are installed to a depth of 85 feet or less, and
- 10% of the wells are installed to a depth of 75 feet or less.

There are 17 municipal wells in the Ridge Sub-inventory Unit. The well depths range from a minimum of 100 feet to a maximum of 740 feet. A cumulative frequency curve was not developed for municipal wells in the Ridge Sub-inventory Unit because the small number of wells tends to limit a statistically meaningful evaluation.

Figure 126.
Cumulative Frequency Distribution of Irrigation Wells, Ridge Sub-inventory Unit.



Wyandotte Sub-inventory Unit

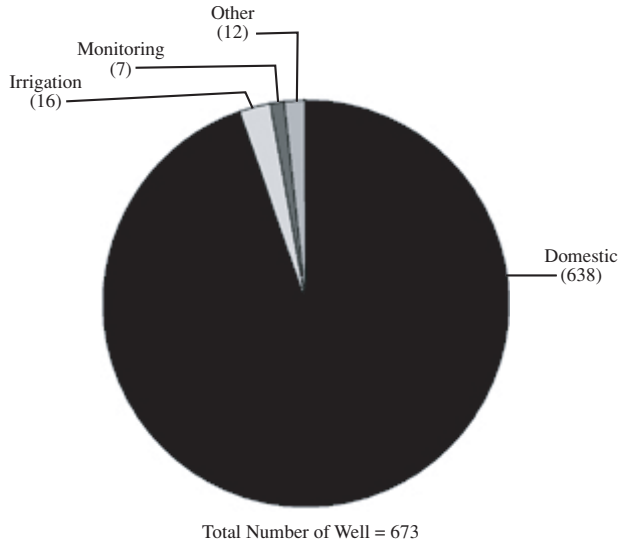
The Wyandotte Sub-inventory Unit covers an area of about 36,000 acres in the southern portion of the Foothill Inventory Unit. This sub-inventory unit is bordered by Oroville Dam and the Feather River to the north, the North Yuba Inventory Unit to the west, and the Mountain Inventory Unit to the east (see Plate 1, Appendix A). The elevation increases from west to east and from south to north across the sub-inventory unit. The elevations along the northern edge range from 200 to 770 feet between the City of Oroville and Oroville Dam. Although small parcels of land within this sub-inventory unit are put to agricultural use, native vegetation and rural residential are the major land uses in this area. Municipal and domestic water demand is supplied by both surface water and groundwater. Groundwater in this area is in limited supply, occurring primarily through the secondary porosity found in the fractures and jointing of the volcanic and metavolcanic rocks.

Well Distribution

The well completion report database files at DWR were analyzed to determine the number and types of wells in the Wyandotte Sub-inventory Unit. Detailed descriptions of the source and accuracy of well distribution data are provided in Section 1. Tables and figures associated with well distribution data at the sub-inventory unit level are summarized in Appendix B.

There are about 673 wells in the Wyandotte Sub-inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that 638 wells are listed as domestic, 16 are listed as irrigation, none are listed as municipal, 7 are listed as monitoring, and 12 are listed as other. Figure 127 illustrates the breakdown of wells by use for the Wyandotte Sub-inventory Unit.

Figure 127.
Number of Wells by Use, Wyandotte Sub-inventory Unit.



Groundwater Level

Long-term groundwater level data for the Wyandotte Sub-inventory Unit are limited. Neither DWR nor BCDWRC are currently monitoring wells in this area. However, some groundwater level data were collected during the late 1980s as part of a cooperative study conducted by DWR and the Butte County Planning Department.

Between 1986 and 1988, groundwater levels were monitored in 19 wells located within the Wyandotte Sub-inventory Unit. During the monitoring period, drought conditions existed in the foothills and surrounding areas. Three of the wells were located in the northern area of the Wyandotte Sub-inventory Unit. The wells range in depths from 110 to 220 feet and were all completely within the metavolcanic rock of this area. Depths to groundwater range from 7 to 10 feet. Eight of the wells were located in the mid-portion of the Wyandotte Sub-inventory Unit along the Bangor Highway. These wells range in depths from 118 to 320 feet. Depth to groundwater measurements range from 7 to 20 feet during spring months and up to 46 feet during the fall of a drought year.

The other eight wells were located in the southern portion of the Wyandotte Sub-inventory Unit near the town of Bangor. These wells range in depths from 100 to 300 feet. Depth to groundwater measurements range from 4 to 20 feet during spring months and up to 25 feet during the fall of a drought year.

Groundwater Extraction.

Estimates of groundwater extraction in the Wyandotte Sub-inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are provided in Tables 3 and 4, Appendix B. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

Table 3, Appendix B, shows that normal-year groundwater extraction for the Wyandotte Sub-inventory Unit is estimated at 0.7 taf. Of the 0.7 taf of groundwater extracted during a normal year, 0.1 taf is for agricultural use and 0.6 taf is for municipal and domestic uses. Groundwater extraction is estimated to provide 13% of the total municipal water demand. The estimated municipal groundwater use is based on an average per capita use of 0.35 af/yr. Table 3, Appendix B, shows that during a normal year about 0.4 taf, or 55% of the extracted groundwater returns to the aquifer via deep percolation.

The estimated amounts of drought-year groundwater extraction, by type of use, are presented in Table 4, Appendix B. Table 4 shows that drought-year groundwater extraction in the Wyandotte Sub-inventory Unit is about the same as that of a normal year.

Well Depth

Well depth and well use data for the Wyandotte Sub-inventory Unit were collected from well completion reports filed with DWR. A total of 654 well records were evaluated and classified into two well types: domestic and irrigation. No municipal well completion reports are on file for this sub-inventory unit. A statistical summary of the well depth data, listed by well type, is presented in Table 5, Appendix B. Table 5 shows that the majority of wells in the Wyandotte Sub-inventory Unit are for domestic use. The average domestic well depth is about 226 feet. Table 1 also shows that the average well depth for irrigation and municipal wells is 252 feet.

A cumulative frequency distribution curve for domestic wells in the Wyandotte Sub-inventory Unit is presented in Figure 128. A total of 638 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 25 to 860 feet.

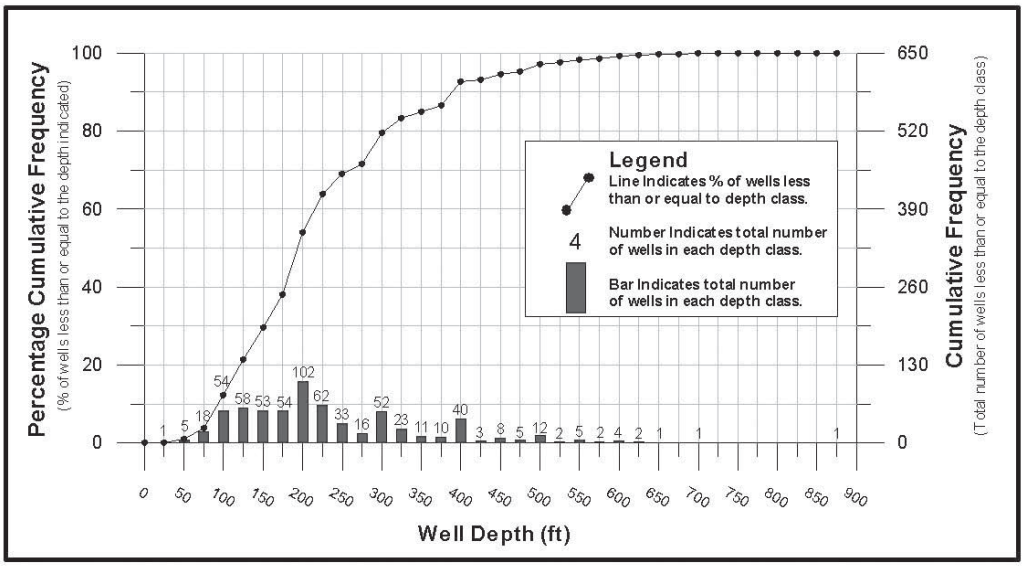
The histogram bars in Figure 128 show that the distribution of the domestic well depth data is skewed to the right toward deeper well depths. Right-skewed distribution of domestic well data indicates that average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the Wyandotte Sub-inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 190 feet or less,
- 20% of the wells are installed to a depth of 125 feet or less, and
- 10% of the wells are installed to a depth of 90 feet or less.

There are 16 irrigation wells in the Wyandotte Sub-inventory Unit. The well depths range from a minimum of 88 feet to a maximum of 580 feet. A cumulative frequency curve was not developed for irrigation wells in this sub-inventory unit because the small number of wells tends to limit a statistically meaningful evaluation.

Figure 128.
Cumulative Frequency Distribution of Domestic Wells, Wyandotte Sub-inventory Unit



MOUNTAIN REGION

The Mountain Region encompasses an area of about 410,000 acres (640 mi^2) along the eastern portion of Butte County. The region is bordered by Tehama County to the north, Yuba County to the south, the Foothill Inventory Unit to the west, and Plumas County to the east (see Plate 1, Appendix A). The western and eastern margins of the Mountain Region increase in elevation from south to north. The western margin starts at an elevation of about 100 feet near the City of Honcut, increases to about 700 feet near Oroville Dam, and ends at an elevation of about 3,200 feet near Highway 32. The eastern margin starts near Strawberry Valley at an elevation of about 3,700 feet and ends at an elevation of 5,100 feet near Jonesville in the far northeastern corner of the county. The Mountain Region is synonymous with the Mountain Inventory Unit. The Mountain Inventory Unit contains no sub-inventory units.

Mountain Inventory Unit

Groundwater resources in most areas of the Mountain Inventory Unit are limited. Although the Tuscan Formation is the main groundwater-bearing unit for the Foothill and Sacramento Valley regions in the Mountain Region, the Tuscan Formation is tightly cemented and consolidated and supplies only limited amounts of water. The majority of available groundwater in the Mountain Inventory Unit is contained in the secondary porosity associated with fracturing of the pre-Tertiary and Tertiary rocks. There are no significant quantities of groundwater contained in alluvial deposits in this region. Groundwater extraction in the Mountain Inventory Unit is primarily for domestic use.

Information regarding well yields, groundwater levels, groundwater movement, groundwater storage capacity and changes in groundwater in storage in the Mountain Inventory Unit is limited. The following discussions will focus on analysis of well infrastructure and estimates of groundwater extraction.

Well Distribution

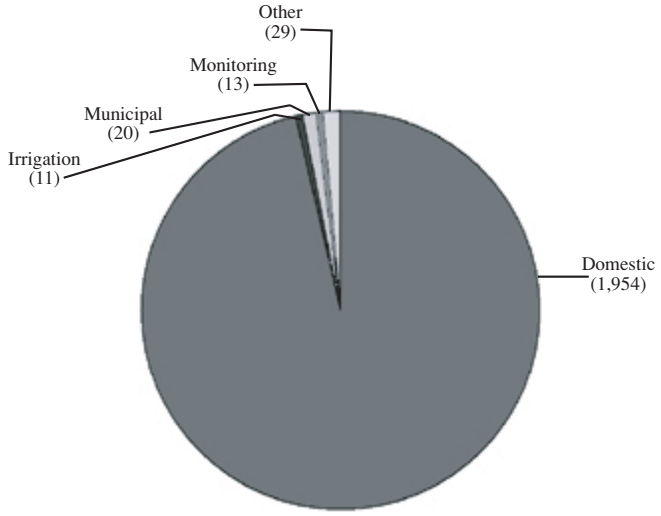
The well completion report database files at DWR were analyzed to determine the number, types, dates of installation, and distribution of wells in the Mountain Inventory Unit. Detailed descriptions of the source and accuracy of well distribution

data are provided in Section 1. A summary of well distribution data by area and by installation date is provided in Tables 1 and 2, Appendix B.

There are an estimated 2,027 wells in the Mountain Inventory Unit. Table 1, Appendix B, lists the number of wells according to five well types: domestic, irrigation, municipal, monitoring, and other. Table 1 shows that of the 2,027 wells in the Mountain Inventory Unit, 1,954 are listed as domestic, 11 are listed as irrigation, 20 are listed as municipal, 13 are listed as monitoring, and 29 are listed as other. Figure 129 illustrates the breakdown of wells by use for the Mountain Inventory Unit.

Wells in the Mountain Inventory Unit were also analyzed to determine the number and types of wells installed over time. Examination of the number and types of wells drilled over time can help offer a perspective on the average age of the existing infrastructure and the approximate number of wells installed during normal and drought years.

Figure 129.
Number of Wells by Use, Mountain Inventory Unit



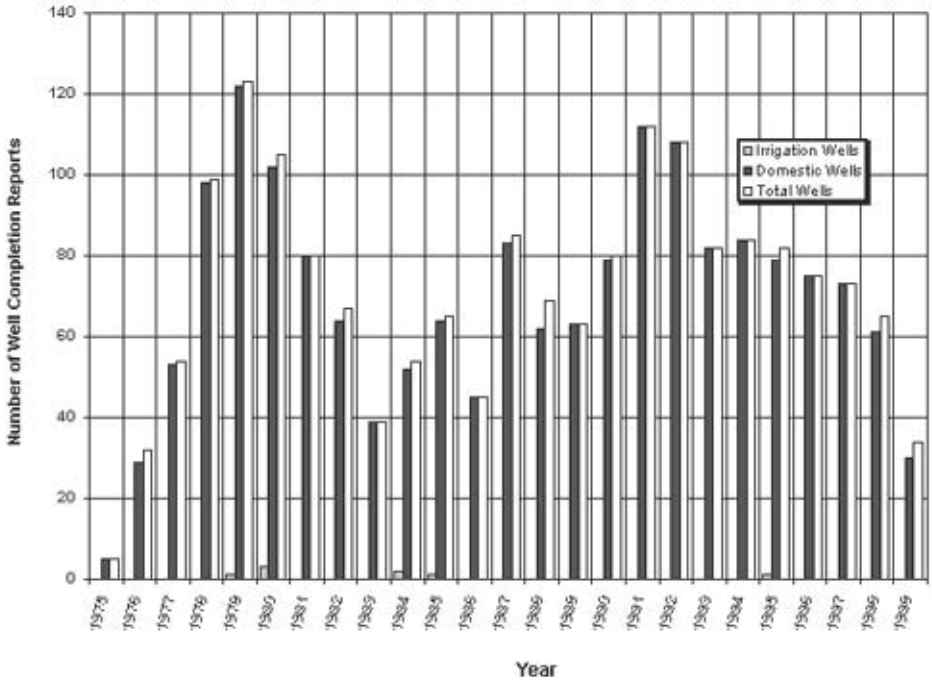
Total Number of Well = 2,027

Table 2, Appendix B, lists the annual number and types of wells drilled and shows that 1,590 wells were drilled in the Mountain Inventory Unit between 1975 and 1999. The wells in Table 2 are divided into domestic, irrigation, miscellaneous, and total. The number of wells drilled per year range from a low of 5 in 1975 to a high of 123 in 1979, with an average of about 64 wells per year. Of the 1,590 wells drilled in the unit between 1975 and 1999, 98% were drilled for domestic use. Figure 130 illustrates the number of well completion reports filed per year for the Mountain Inventory Unit.

Groundwater Extraction

Estimates of groundwater extraction in the Mountain Inventory Unit were developed for normal- and drought-year scenarios. Detailed descriptions of the methods for estimating annual groundwater extraction and the criteria for normal versus drought years are provided in Section 1. Groundwater extraction and deep percolation estimates during normal and drought years are summarized in Tables 3 and 4, Appendix B. Groundwater extraction estimates are divided into summer and winter agricultural use, annual municipal use, and annual wildlife refuge use. The annual deep percolation estimates are divided into agricultural and municipal uses. A water source map based on 1997 land and water use data is provided on Plate 9, Appendix A.

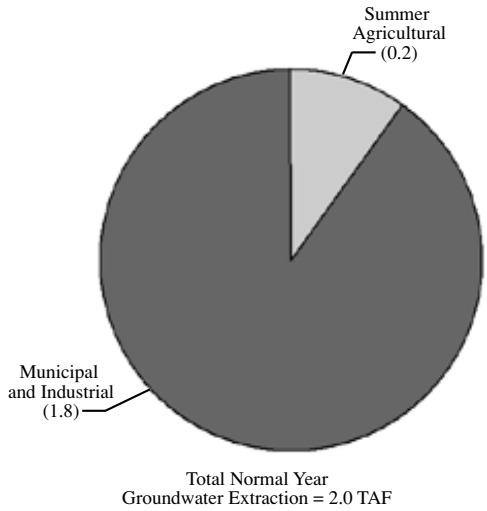
Figure 130.
Number of Well Completion Reports Filed Per Year, Mountain Inventory Unit



The estimated amounts of normal-year groundwater extraction, by type of use, are presented in Table 3, Appendix B, and illustrated in Figure 131. Figure 131 shows that normal-year groundwater extraction for the Mountain Inventory Unit is estimated at 2 taf. Of the 2 taf of groundwater extracted during a normal year, about 0.2 taf is for summer agricultural use and 1.8 taf are for annual municipal and domestic uses. All of the municipal and domestic water in the inventory unit is supplied by groundwater. Municipal and domestic water demand is based on an average per capita use of 0.32 af/yr. Table 3, Appendix B, shows that, during a normal year, about 1.1 taf, or 55% of the extracted groundwater return to the aquifer via deep percolation.

The estimated amounts of drought-year groundwater extraction, by type of use, are presented in Table 4, Appendix B. Table 4 shows that drought-year groundwater extraction in the Mountain Inventory Unit is about the same as during a normal year.

Figure 131.
Estimated Amount of Normal-Year Groundwater Extraction by Type of Use, Mountain Inventory Unit



Well Depth

Well depth and well use data for the Mountain Inventory Unit were collected from well completion reports filed with DWR. A total of 1,985 well records for the inventory unit were evaluated and classified into three well types: domestic, irrigation, and municipal. A summary of the minimum, maximum, and average well depths listed by well type is presented in Table 5, Appendix B. A statistical distribution of the well depth data was also evaluated through a cumulative frequency distribution curve for domestic well depths.

Table 5, Appendix B, shows that the majority of wells in the Mountain Inventory Unit are for domestic use. The average domestic well depth is about 205 feet. Table 5 also shows that the average well depth for irrigation and municipal wells is 204 feet and 240 feet, respectively.

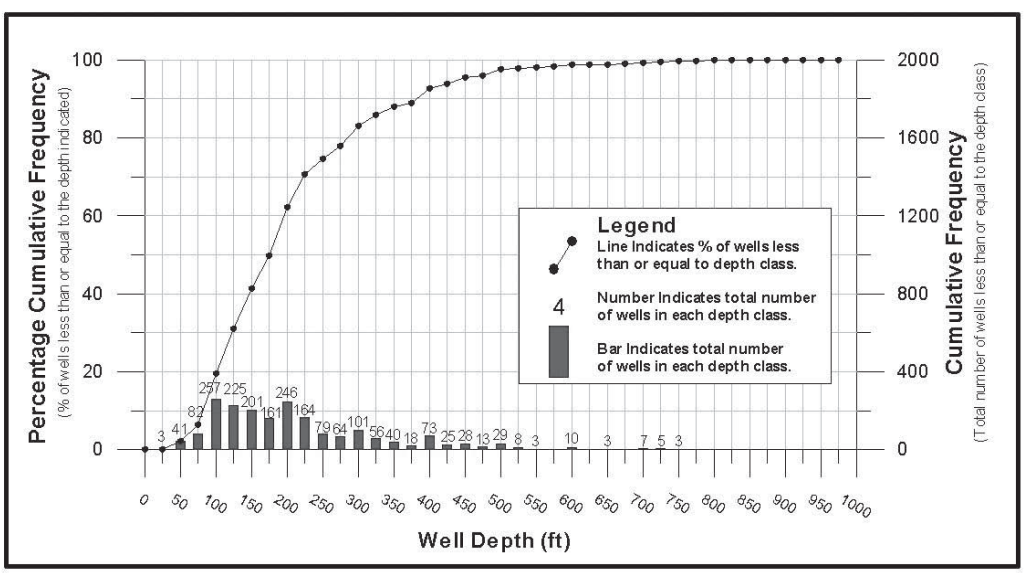
The cumulative frequency distribution of well depth data was evaluated for domestic wells in the Mountain Inventory Unit. Figure 132 shows the cumulative frequency distribution of well depths for domestic wells in the inventory unit. A total of 1,954 domestic wells were evaluated in terms of cumulative frequency distribution with respect to well depths. The depths of domestic wells range from 11 to 970 feet.

The histogram bars in Figure 132 show the total number of wells associated with each 25-foot class interval. The histogram bars indicate that the distribution of the domestic well depth data is skewed slightly to the right toward deeper well depths. Right-skewed distribution of domestic well depth data indicates that average well depth is deeper than the most frequently occurring well depth or the depth class interval with the greatest number of wells.

The cumulative frequency curve of domestic well depth data for the Mountain Inventory Unit shows that:

- 50% of the domestic wells are installed to a depth of 175 feet or less,
- 20% of the wells are installed to a depth of 100 feet or less, and
- 10% of the wells are installed to a depth of 80 feet or less.

Figure 132.
Cumulative Frequency Distribution of Domestic Wells, Mountain Inventory Unit



There are 11 irrigation wells and 20 municipal wells in the Mountain Inventory Unit. Irrigation well depths range from a minimum of 45 feet to a maximum of 450 feet. Municipal well depths range from a minimum of 100 feet to a maximum of 970 feet. A cumulative frequency curve was not developed for irrigation or municipal wells because the small number of wells tends to limit a statistically meaningful evaluation.

Conclusions and Recommendations

Groundwater resource information for the Mountain Inventory Unit is extremely limited. The majority of available groundwater in the inventory unit is contained in the secondary porosity associated with fracturing of pre-Tertiary and Tertiary rocks. There are no significant quantities of groundwater contained in alluvial deposits in this region. Groundwater extraction in the unit is primarily for domestic use. As such, the overall groundwater supply for this area is limited. Similar to the Foothill Inventory Unit, many of the domestic wells are shallow and susceptible to dewatering during periods of drought.

Recommendations at this time are to:

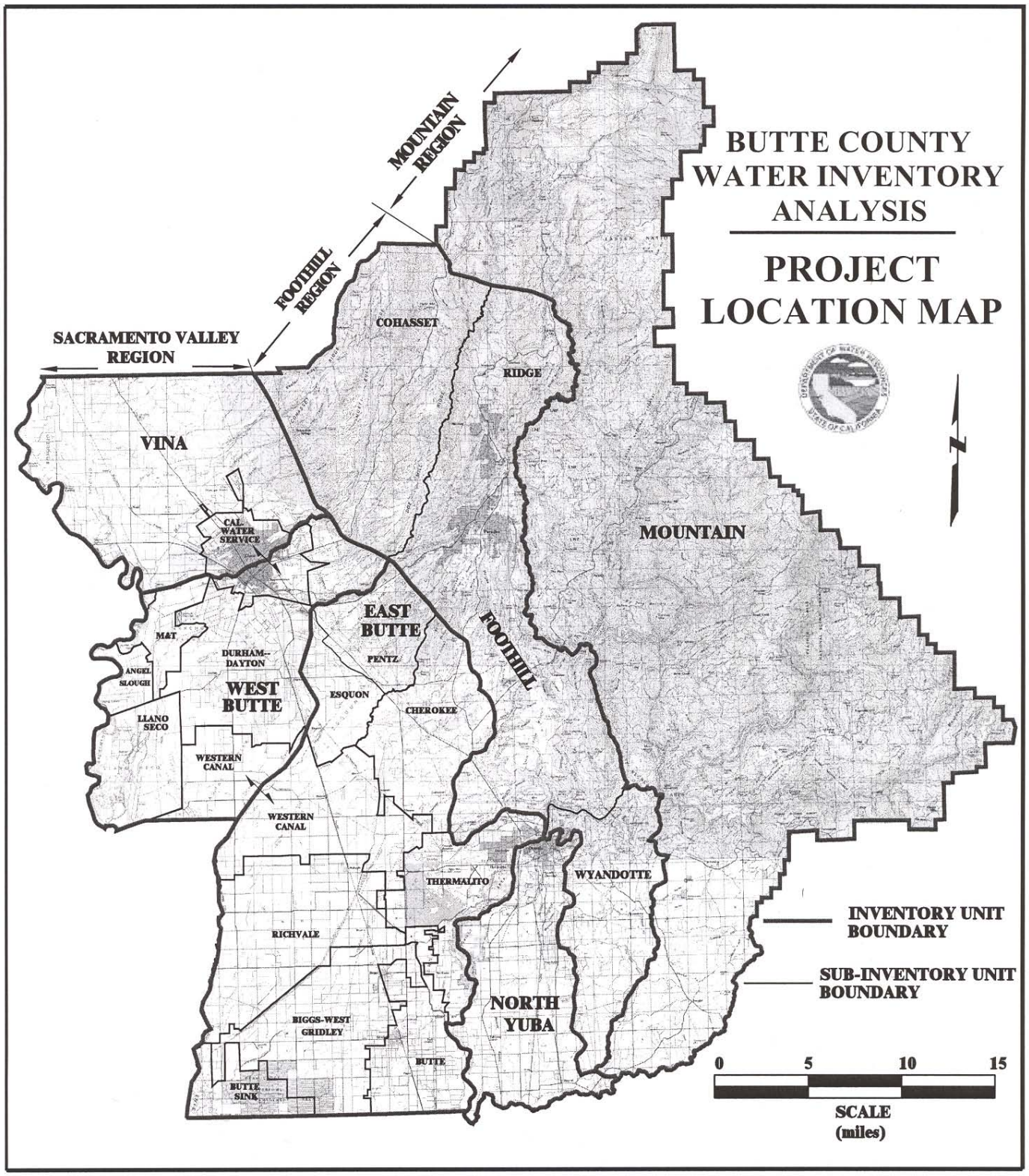
- work cooperatively with local communities in the Mountain Inventory Unit to collect groundwater, surface water, and land use data;
- analyze water resource and land use data to develop a better understanding of the interaction between land management practices, groundwater storage, and surface water runoff; and
- where data permits, evaluate the available dry-year water supply for future development of communities in the Mountain Inventory Unit.

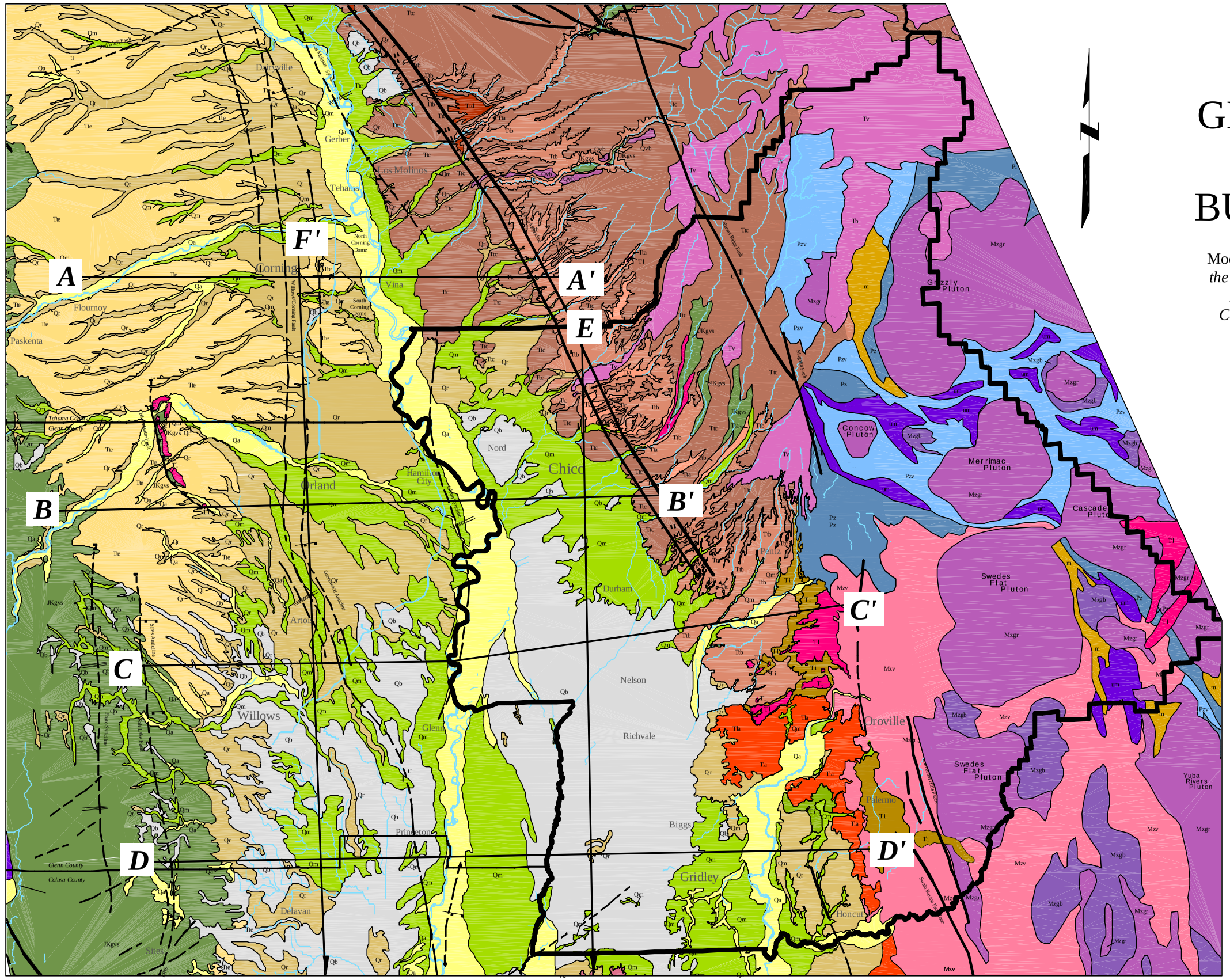
BUTTE COUNTY GROUNDWATER INVENTORY

APPENDIX A

PLATES 1 through 9

PLATE 1


BUTTE COUNTY
WATER INVENTORY
ANALYSIS
PROJECT
LOCATION MAP
MOUNTAIN REGION
FOOTHILL REGION
SACRAMENTO VALLEY REGION
COHASSET
RIDGE
VINA
CAL WATER SERVICE
MOUNTAIN
EAST BUTTE
FOOTHILL
M&T
DURHAM--DAYTON
PENTZ
ANGEL SLOUGH
WEST BUTTE
ESQUON
CHEROKEE
LLANO SECO
WESTERN CANAL
WESTERN CANAL
THERMALITO
WYANDOTTE
RICHVALE
INVENTORY UNIT BOUNDARY
SUB-INVENTORY UNIT BOUNDARY
NORTH YUBA
BIGGS-WEST GRIDLEY
BUTTE
BUTTE SINK
0
5
10
15
SCALE (miles)



GEOLOGIC MAP OF BUTTE COUNTY

Modified from - *Geology and Hydrogeology of the Freshwater Bearing Aquifer Systems of the Northern Sacramento Valley, California, California Department of Water Resources, Bulletin 118-7, 2001.*

Map Legend

U / D — **Fault** - dashed where location is approximate; U indicates upthrown side and D indicates downthrown side.

Anticline - Arrows indicate direction of dip.

Syncline - Arrows indicate direction of dip.

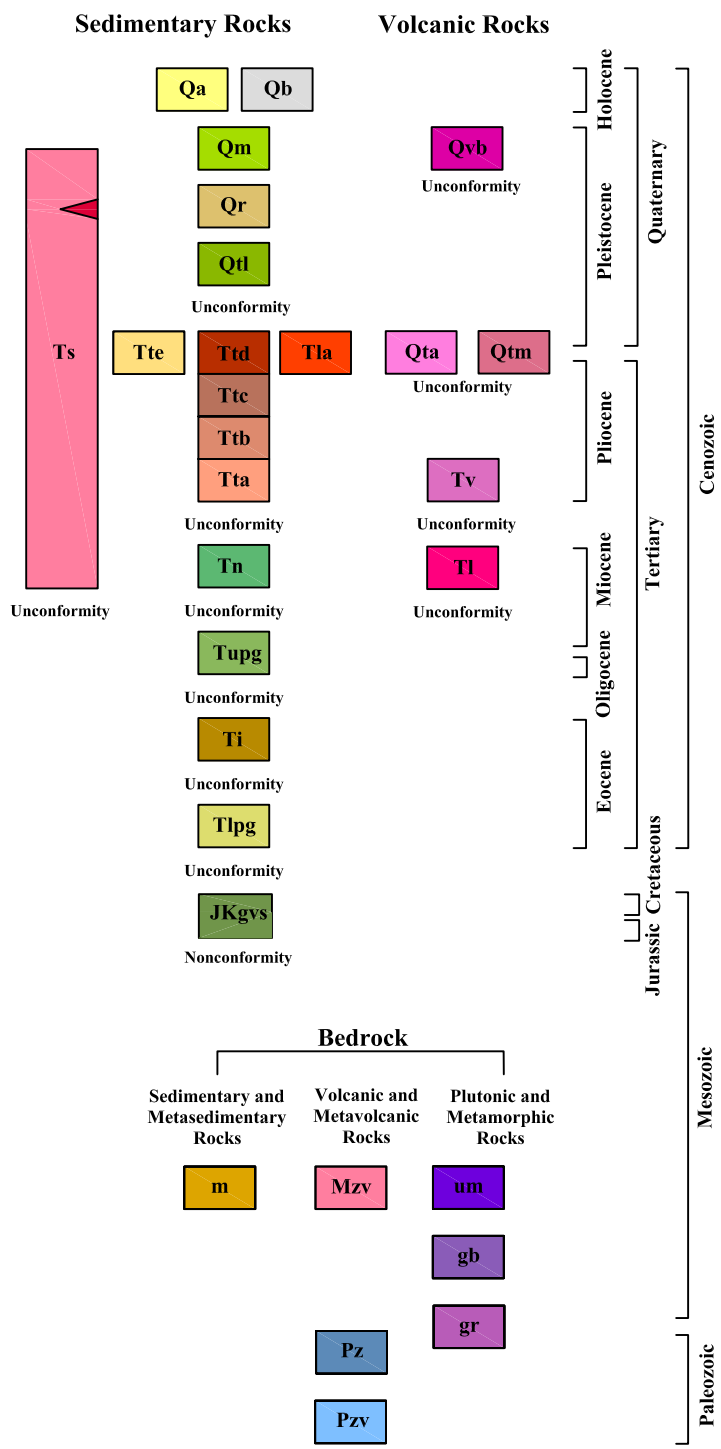
25 — **Monocline** - Arrows indicate direction of dip, number indicates steepness of dip in degrees.

D D' — **Location of Geologic Cross-Sections** - Letters correspond to geologic sections shown in Plates 4 and 5.

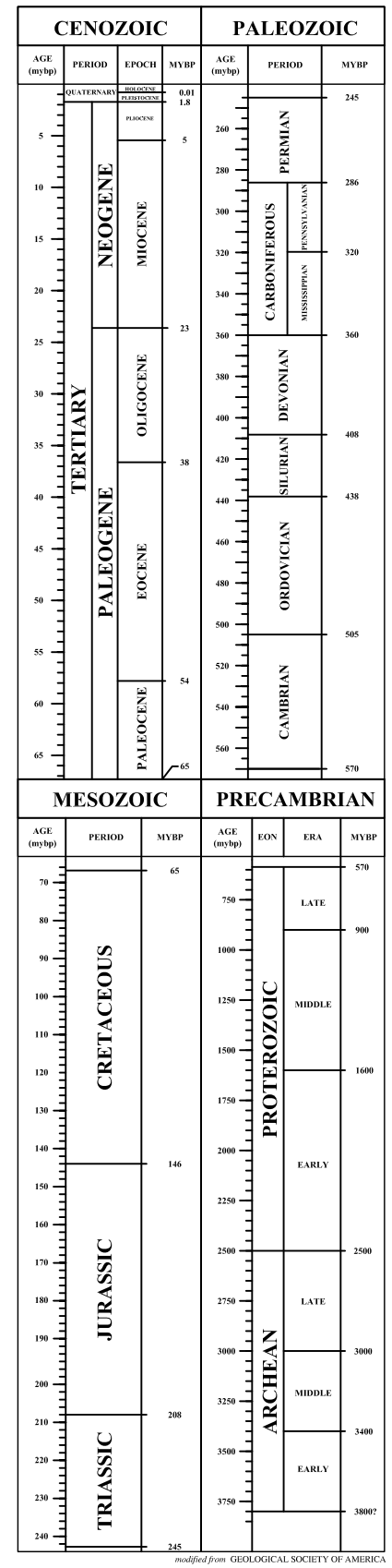
5 0 5 10

MILES

CORRELATION OF MAP UNITS



NORTH AMERICAN GEOLOGIC TIME SCALE



DESCRIPTION OF MAP UNITS

Qa — **Alluvium** (Holocene)-Includes surficial alluvium and stream channel deposits of unweathered gravel, sand and silt, maximum thickness 80 ft. *(adapted from Helley & Harwood, 1985)*.

Qb — **Basin Deposits** (Holocene)-Fine-grained silt and clay derived from adjacent mountain ranges, maximum thickness up to 200 ft. *(adapted from Helley & Harwood, 1985)*.

Qm — **Modesto Formation**, undifferentiated (Pleistocene)-Alluvial fan and terrace deposits consisting of unconsolidated weathered and unweathered gravel, sand, silt and clay; maximum thickness approximately 200 ft. *(adapted from Helley & Harwood , 1985).*

Qr — **Riverbank Formation**, undifferentiated (Pleistocene)-Alluvial fan and terrace deposits consisting of unconsolidated to semi-consolidated gravel, sand and silt; maximum thickness approximately 200 ft. *(adapted from Helley & Harwood, 1985).*

Qtl — **Turlock Lake** (Pleistocene)-Weathered and dissected arkosic gravels with minor amounts of resistant metamorphic rock fragments and quartz pebbles, sand and silt; maximum thickness approximately 100 ft. *(adapted from Helley & Harwood, 1985).*

Qvb — **Volcanic Basalts**, undifferentiated (Pleistocene)-Younger basalt flows found primarily on the east side of the Sacramento Valley, includes minor exposures of andesite; maximum thickness 100 ft. *(adapted from Helley & Harwood, 1985).*

Qtm — **Tuff Breccia** (Plio-Pleistocene)-Tuff breccia forming outer ring surrounding the Sutter Buttes *(adapted from Helley & Harwood, 1985)*.

Qta — **Volcanic Andesites**, undifferentiated (Plio-Pleistocene)-Younger andesites forming the center of the Sutter Buttes *(adapted from Helley & Harwood, 1985).*

Tte — **Tehama Formation** (Plio-Pleistocene)-Includes Red Bluff Formation on west side. Pale green, gray and tan sandstone and siltstone with lenses of pebble and cobble conglomerate; maximum thickness 2,000 ft. *(adapted from Helley & Harwood, 1985).*

Ttd — **Tuscan Unit D** (Plio-Pleistocene)-Fragmental flow deposits characterized by monolithic masses containing gray hornblende and basaltic andesites and black pumice, maximum thickness 160 ft. *(adapted from Helley & Harwood, 1985).*

Ttc — **Tuscan Unit C** (Plio-Pleistocene)-Includes Red Bluff Formation on east side. Volcanic lahars with some interbedded volcanic conglomerate and sandstone, and reworked sediments; maximum thickness 600 ft. *(adapted from Helley & Harwood, 1985, DWR Bulletin 118-7, 2001, draft report).*

Ttb — **Tuscan Unit B** (Pliocene)-Layered, interbedded lahars, volcanic conglomerate, volcanic sandstone and siltstone; maximum thickness 600 ft. *(adapted from Helley and Harwood, 1985; DWR Bulletin 118-7, 2001, draft report).*

Tta — **Tuscan Unit A** (Pliocene)-Interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone containing metamorphic rock fragments; maximum thickness 400 ft. *(adapted from Helley & Harwood, 1985; DWR Bulletin 118-7 (in progress), 2001).*

Tla — **Laguna Formation** (Pliocene)-Interbedded alluvial gravel, sand and silt; maximum thickness 450 feet. *(adapted from Helley & Harwood, 1985; Olmsted and Davis, 1961; DWR Bulletin 118-6, 1978).*

Tv — **Basalts and Andesites**, undifferentiated (Pliocene)-Older basalts and andesites found on the northeastern portion of the Sacramento Valley and southwest of Winters; maximum thickness up to 230 ft. *(adapted from Helley & Harwood, 1985).*

Ts — **Sutter Formation** (Late Miocene to Early Pleistocene)-Volcanic fluvatile sediments with lacustrine deposits; maximum thickness approximately 1,800 ft. *(adapted from Garrison, 1962).*

Tn — **Neroly Formation** (Miocene)-Marine to non-marine sediments, tuffaceous andesitic sandstone with interbeds of tuff and tuffaceous shales and occasional conglomerate lenses; max. thickness 500 ft. *(adapted from Redwine, 1972; Wagner and Saucedo, 1990).*

Tl — **Lovejoy Basalt** (Miocene)-Black, dense, hard microcrystalline basalt; maximum thickness 65 ft. *(adapted from Helley & Harwood, 1985).*

Tupg — **Upper Princeton Valley Fill** (Late Oligocene to Early Miocene)-Non-marine sediments composed of sandstone with interbeds of mudstone and occasional conglomerate and conglomerate sandstone; maximum thickness 1,400 ft. *(adapted from Redwine, 1972)*.

Ti — **Ione Formation** (Eocene)-Marine to non-marine deltaic sediments, light colored, commonly white conglomerate, sandstone and siltstone, which is soft and easily eroded; max. thickness 650 ft. *(adapted from DWR Bulletin 118-6, 1978; Creely, 1965).*

Tlpg — **Lower Princeton Submarine Valley Fill** (Eocene)-includes Capay Formation. Marine sandstone, conglomerate and interbedded silty shale, maximum thickness 2,400 ft. (*adapted from Redwine, 1972*)

JKgvs — **Great Valley Sequence** (Late Jurassic to Upper Cretaceous)-Marine clastic sedimentary rock consisting of siltstone, shale, sandstone and conglomerate; maximum thickness 15,000 ft.

m — **Mixed Rocks** (pre-Cenozoic)-Undivided metasedimentary and metavolcanic rocks of greatly varying types *(adapted from Jennings, 1977).*

Mzv — **Volcanic and Metavolcanic Rocks** (Mesozoic)-Undivided volcanic and metavolcanic rocks, andesite rhyolite flow rocks, greenstone and volcanic breccia *(adapted from Jennings, 1977).*

um — **Ultramafic Rocks** (Mesozoic)-Primarily composed of serpentine, with peridotite, gabbro and diabase *(adapted from Jennings, 1977).*

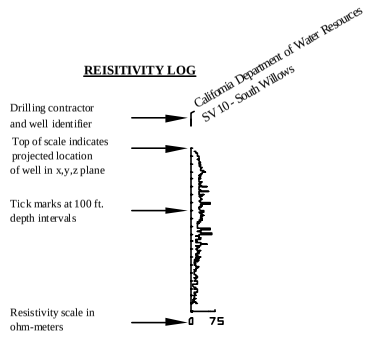
gb — **Gabbro** (Mesozoic)-Gabbro and dark diotric rocks *(adapted from Jennings, 1977).*

gr — **Undifferentiated Granitic Plutons** (Mesozoic-Paleozoic)-Undivided granitic plutons and related rocks *(adapted from Jennings, 1977).*

Pz — **Paleozoic Metasedimentary Rocks** (Paleozoic)-Undivided metasedimentary rocks including slate, shale, sandstone, chert, conglomerate, limestone, dolomite, marble, phyllite,schist, hornfels and quartzite *(adapted from Jennings, 1977).*

Pzv — **Paleozoic Metavolcanic Rocks** (Paleozoic)-Undivided metavolcanic rocks, primarily flows, breccia, and tuff, including greenstone, diabase and pillow lavas *(adapted from Jennings, 1977).*

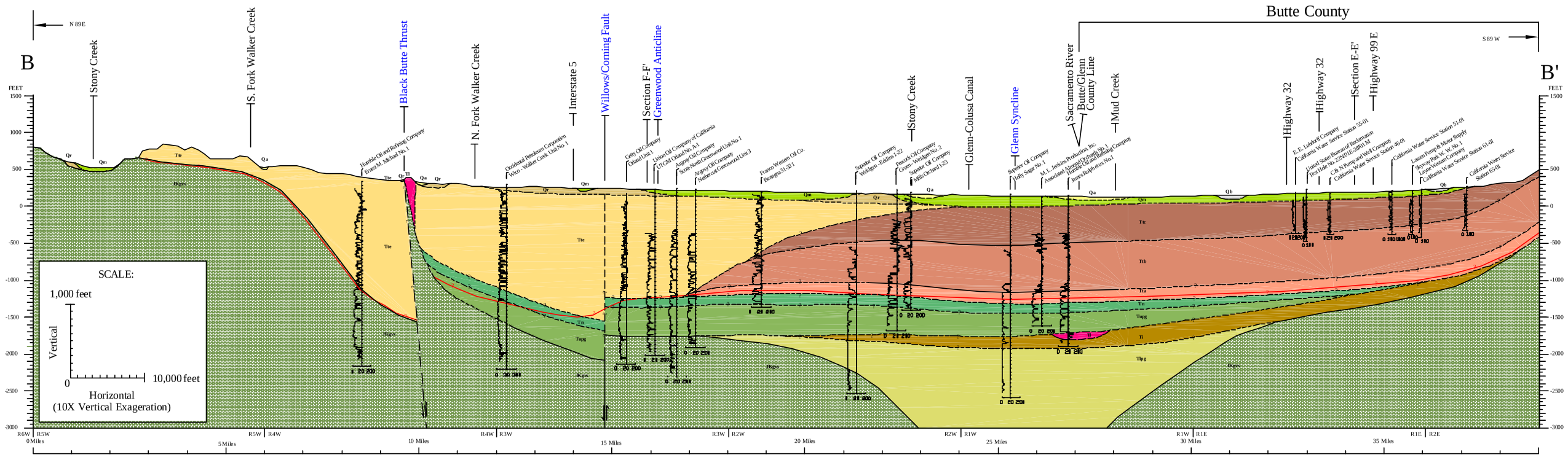
Cross Section B-B'



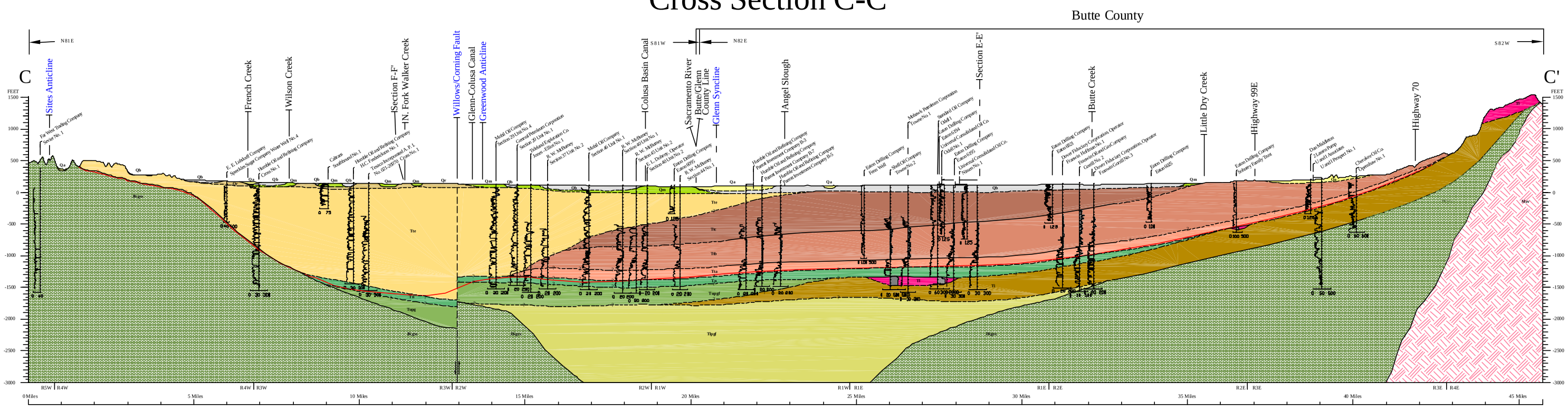
MAP LEGEND

- Geologic Contact-dashed where inferred, queried where uncertain.
- Fault-dashed where inferred, queried where uncertain. Arrows show relative direction of movement.
- Base of Freshwater-water with a specific conductance of less than 3,000 micromhos per centimeter; water with a specific conductance that exceeds 3,000 micromhos per centimeter is considered to be saline. Specific conductance was determined from resistivity logs portrayed along the section lines. Dashed where inferred, queried where uncertain.
- B — N 89 E / S 89 W — B' : Alignment of cross-section along B-B'.
- T17N | T16N : Boundary between Township 17 North and Township 16 North.
- R1W | R1E : Boundary between Range 1 West and Range 1 East.

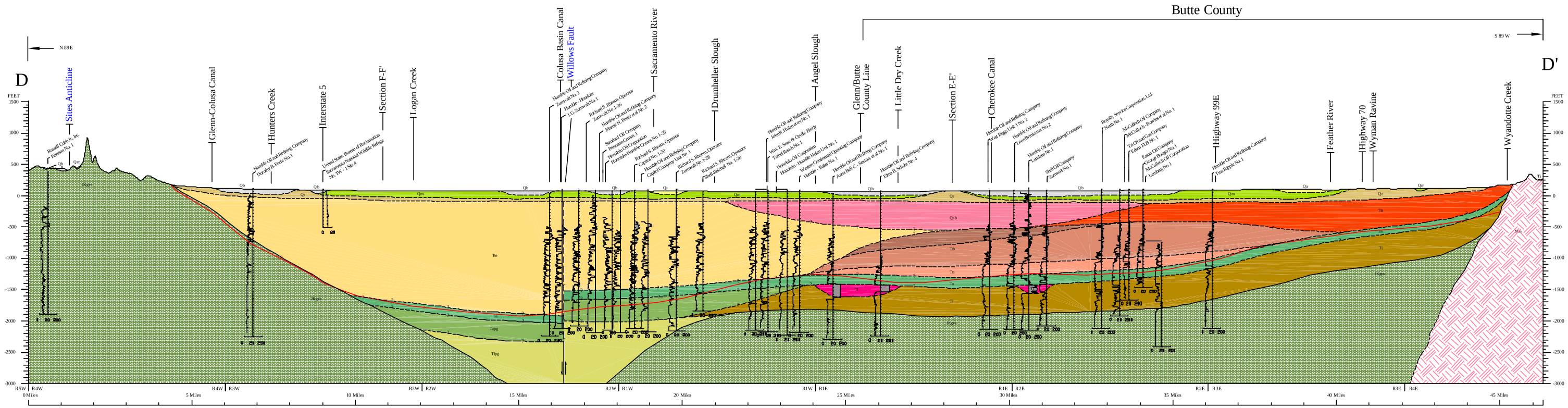
*See Plate 3 for Geologic Legend and location of section lines.



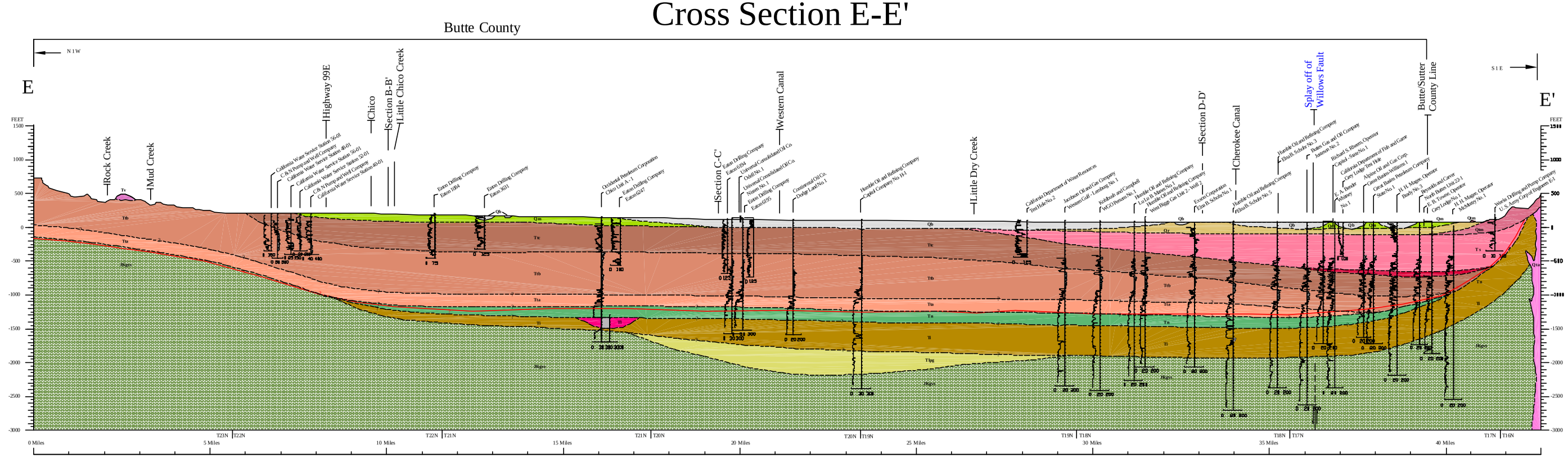
Cross Section C-C'



Cross Section D-D'



Cross Section E-E'



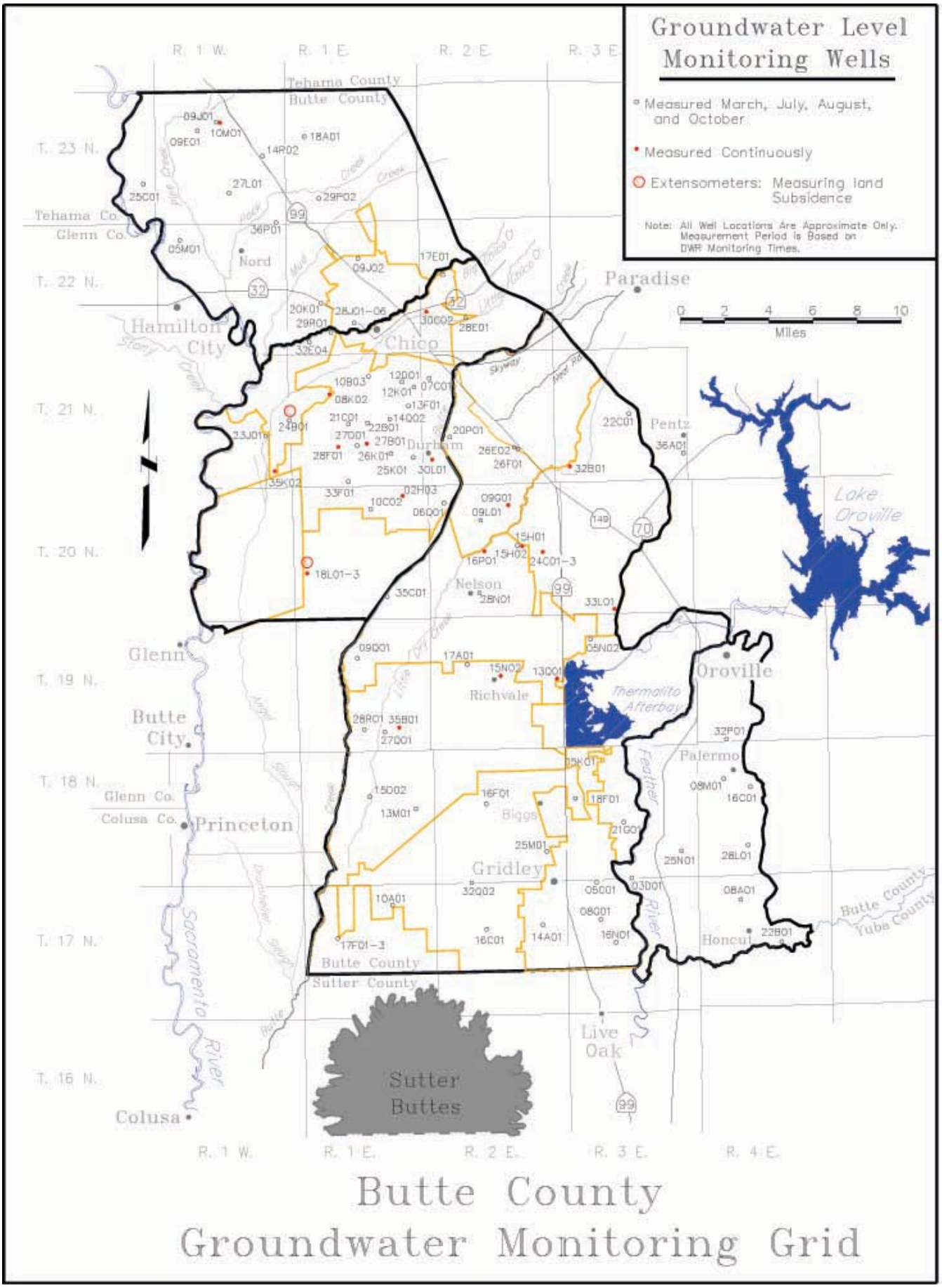
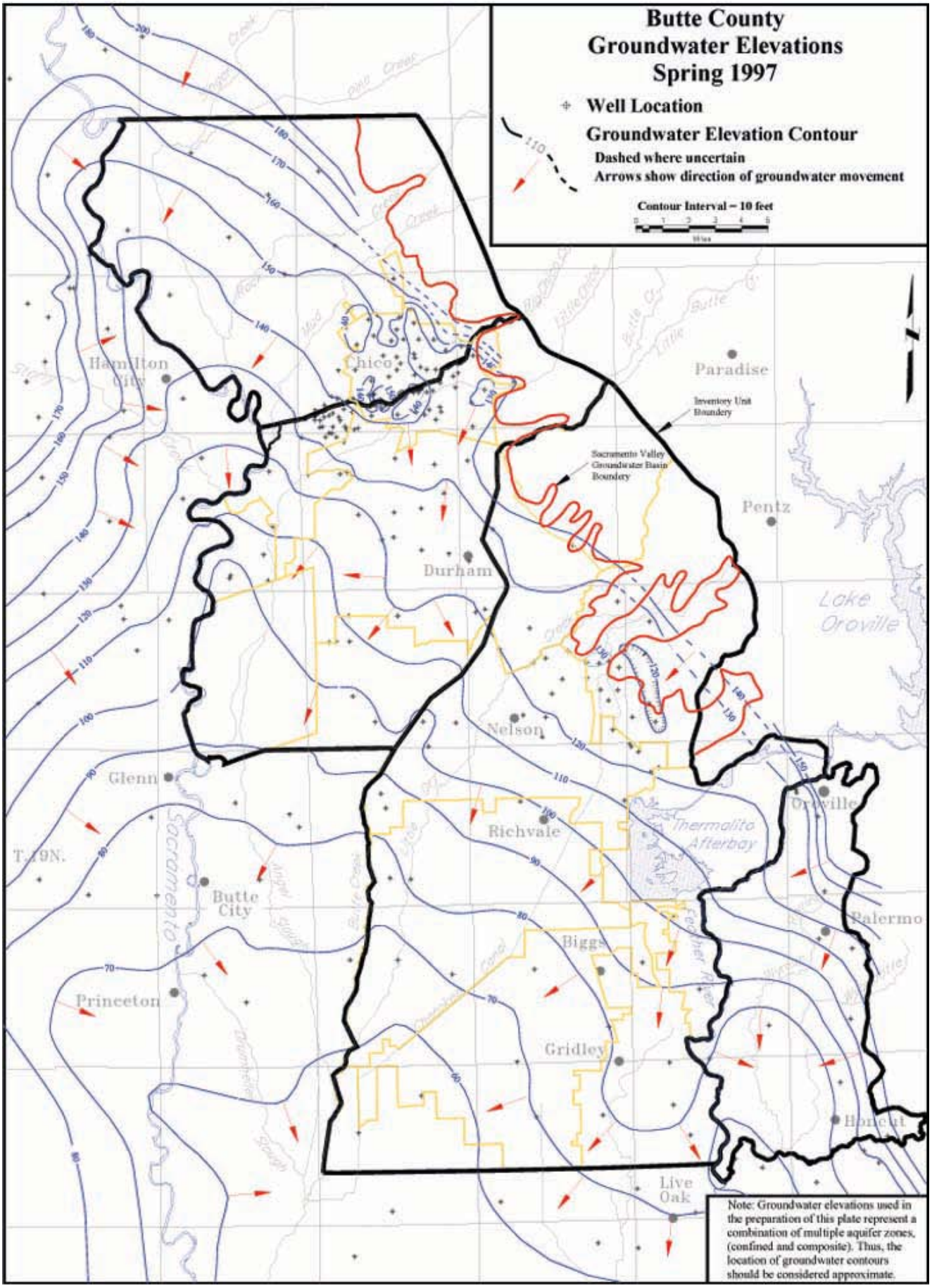

Groundwater Level Monitoring Wells
Measured March, July, August, and October
Measured Continuously
Extensometers: Measuring land Subsidence
Note: All Well Locations Are Approximate Only. Measurement Period is Based on DWR Monitoring Times.
0 2 4 6 8 10
Miles
R. 1 W.
R. 1 E.
R. 2 E.
R. 3 E.
R. 4 E.
T. 23 N.
T. 22 N.
T. 21 N.
T. 20 N.
T. 19 N.
T. 18 N.
T. 17 N.
T. 16 N.
Tehama County
Butte County
Tehama Co.
Glenn Co.
Colusa Co.
Sutter County
Yuba County
Nord
Hamilton City
Chico
Paradise
Durham
Pentz
Nelson
Richvale
Oroville
Palermo
Biggs
Gridley
Honcut
Glenn
Butte City
Princeton
Colusa
Live Oak
Lake Oroville
Thermalito Afterbay
Sutter Buttes
Sacramento River
Feather River
Butte Creek
Butte County
Groundwater Monitoring Grid

PLATE 7


Butte County
Groundwater Elevations
Spring 1997
Well Location
Groundwater Elevation Contour
Dashed where uncertain
Arrows show direction of groundwater movement
Contour Interval = 10 feet
Miles
Hamilton City
Chico
Paradise
Inventory Unit Boundary
Sacramento Valley Groundwater Basin Boundary
Pentz
Durham
Lake Oroville
Nelson
Glenn
Richvale
Thermalito Afterbay
Oroville
T. 19N.
Sacramento
Butte City
Biggs
Palermo
Princeton
Gridley
Honcut
Live Oak
Note: Groundwater elevations used in the preparation of this plate represent a combination of multiple aquifer zones, (confined and composite). Thus, the location of groundwater contours should be considered approximate.

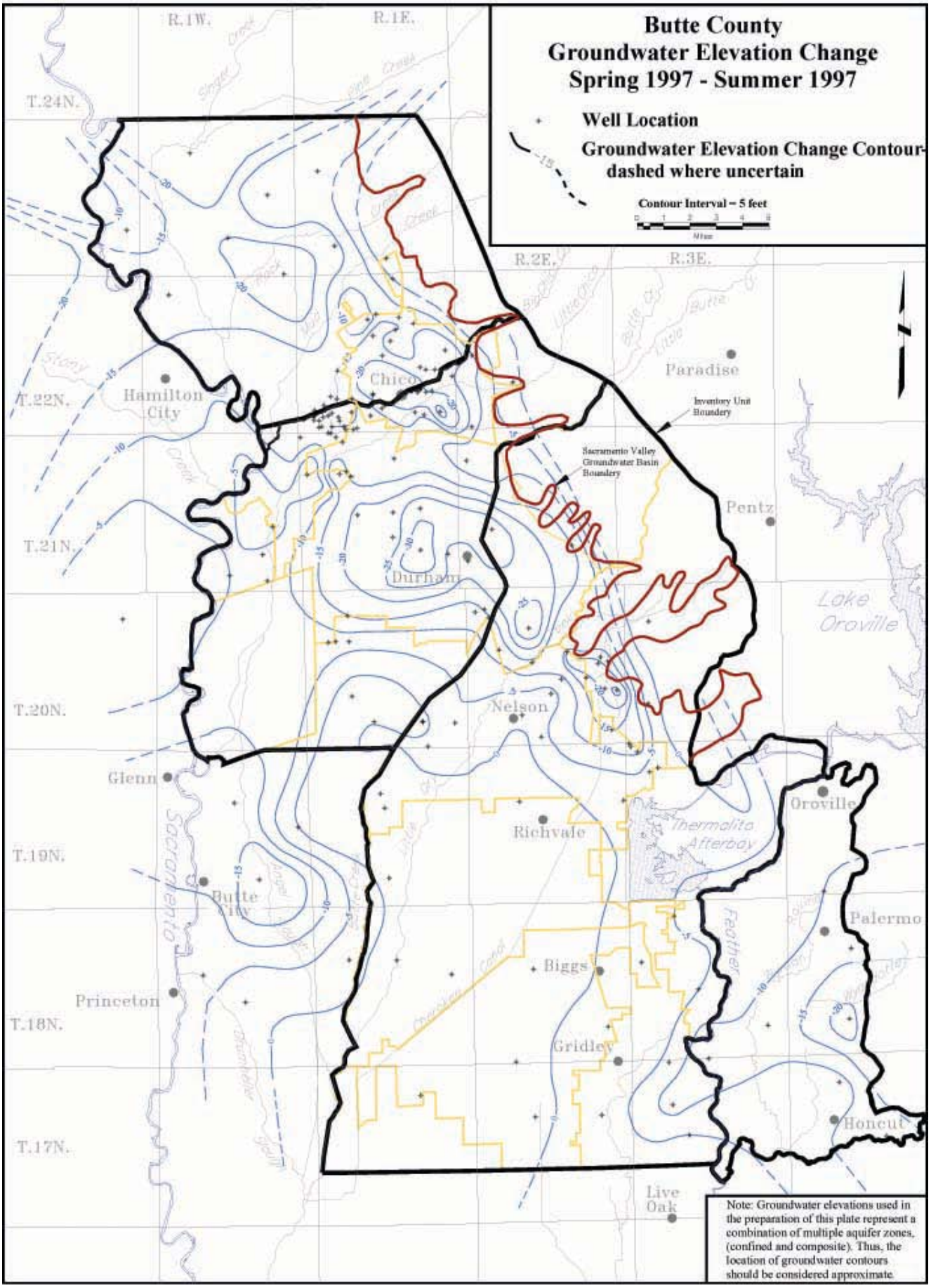
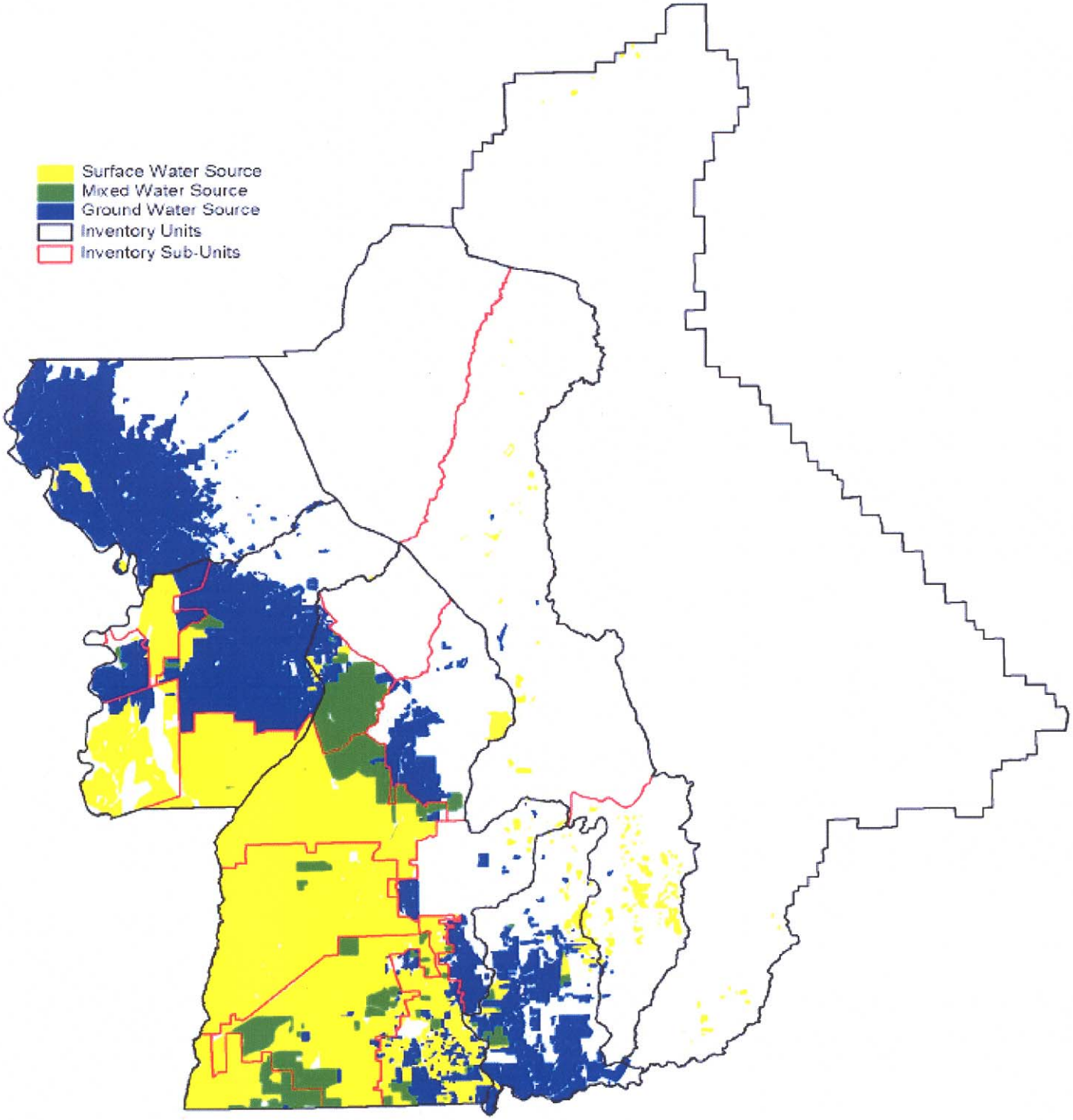

Butte County
Groundwater Elevation Change
Spring 1997 - Summer 1997
Well Location
Groundwater Elevation Change Contour-
dashed where uncertain
Contour Interval = 5 feet
R.1W.
R.1E.
R.2E.
R.3E.
T.24N.
T.22N.
T.21N.
T.20N.
T.19N.
T.18N.
T.17N.
Hamilton City
Chico
Paradise
Inventory Unit Boundary
Sacramento Valley Groundwater Basin Boundary
Pentz
Durham
Lake Oroville
Nelson
Glenn
Richvale
Thermalito Afterbay
Oroville
Butte City
Palermo
Biggs
Princeton
Gridley
Honcut
Live Oak
Sacramento
Feather
Note: Groundwater elevations used in the preparation of this plate represent a combination of multiple aquifer zones, (confined and composite). Thus, the location of groundwater contours should be considered approximate.

PLATE 9



Water Source Map for Butte County, based on 1997 Land Use Data

BUTTE COUNTY GROUNDWATER INVENTORY

APPENDIX B

TABLES 1 through 11

INVENTORY UNIT	SUB-INVENTORY UNIT	Domestic Wells	Irrigation Wells	Municipal Wells	Monitoring Wells	Other Wells	Totals
Vina	Vina	2,096	621	51	138	299	3,205
West Butte	Durham/Dayton	1,195	568	40	248	310	2,361
	M&T	18	38		2	6	64
	Angel Slough	8	43		2	2	55
	Llano Seco	1	16		5	10	32
	Western Canal (33%)	15	36		1	12	64
	Totals:	1,237	701	40	258	340	2,576
East Butte	Pentz	172	39		12	20	243
	Esquon	291	108		2	26	427
	Cherokee	104	62		2	15	183
	Western Canal (67%)	32	76		2	17	127
	Richvale	87	72		4	21	184
	Thermalito	140	56		9	36	241
	Biggs-West Gridley	246	92	4	10	33	385
	Butte	571	183	8	29	115	906
	Butte-Sink	4	11		1	4	20
	Totals:	1,647	699	12	71	287	2,716
North Yuba	North Yuba	504	178	9	95	81	867
Foothill	Cohasset	885	20	11		37	953
	Ridge	1,081	50	17	47	58	1,253
	Wyandotte	638	16		7	12	673
	Totals:	2,604	86	28	54	107	2,879
Mountain	Mountain	1,954	11	20	13	29	2,027
TOTAL FOR ENTIRE BUTTE COUNTY:		10,042	2,296	160	629	1,143	**14,270**
TOTAL FOR VALLEY AREA:		5,484	2,199	112	562	1,007	**9,364**
Split Area	Cal Water SIU (100%)	907	149	66	252	228	1,602
Split Area	Western Canal (100%)	47	112	0	3	29	191

NOTE: "Municipal Wells" include wells listed as municipal and/or public. "Other Wells" include wells listed as stock, industrial or unknown.

TABLE 1. NUMBER OF WELLS BY INVENTORY UNIT AND SUB-INVENTORY UNIT

ARE	WELL TYPE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	TOTALS
VINA																											
	Irrigation Wells	14	16	22	25	30	25	26	11	1	3	1	4	3	5	1	3	5	6	5	5	2	8	4	3	1	152
	Domestic Wells	47	49	109	81	64	66	48	17	31	64	41	46	72	54	78	54	44	32	7	15	26	30	20	10	10	829
	Miscellaneous Wells	5	2	4	5	1	1	5	0	0	0	1	2	0	9	0	2	18	0	40	18	13	13	2	15	21	161
	Total:	66	67	135	111	95	92	79	28	32	67	43	52	75	68	79	59	67	38	52	38	41	51	26	28	32	1,142
WEST BUTTE																											
	Irrigation Wells	19	30	39	34	23	31	19	15	6	1	0	3	5	11	5	10	12	12	4	9	9	3	6	6	1	191
	Domestic Wells	25	55	90	37	38	32	27	7	18	33	26	26	33	42	29	22	28	23	8	14	13	18	14	17	13	481
	Miscellaneous Wells	2	4	3	2	0	1	2	0	0	0	0	0	0	19	18	25	23	22	41	24	25	13	13	1	17	244
	Total:	46	89	132	73	61	64	48	22	24	34	26	29	38	72	52	57	63	57	53	47	47	34	33	24	31	916
EAST BUTTE																											
	Irrigation Wells	14	12	60	35	42	33	31	26	7	5	2	3	3	6	2	3	33	44	9	8	5	5	6	6	2	281
	Domestic Wells	41	58	35	30	34	33	43	16	15	15	15	20	43	39	30	49	34	42	12	15	25	23	20	17	12	552
	Miscellaneous Wells	2	5	2	10	0	0	0	0	2	0	0	63	4	4	8	6	8	1	3	13	8	17	10	7	0	154
	Total:	57	75	97	75	76	66	74	42	24	20	17	86	50	49	40	58	75	87	24	36	38	45	36	30	14	987
NORTH YUBA																											
	Irrigation Wells	4	2	12	16	29	34	28	9	12	11	9	12	2	0	0	3	2	2	0	2	1	1	1	1	4	163
	Domestic Wells	10	7	21	22	4	3	16	7	1	1	0	1	8	9	12	9	27	17	2	6	3	9	3	6	8	152
	Miscellaneous Wells	1	0	4	1	0	0	0	0	1	5	4	8	12	17	4	4	8	4	4	5	5	15	5	2	4	107
	Total:	15	9	37	39	33	37	44	16	14	17	13	21	22	26	16	16	37	23	6	13	9	25	9	9	16	422
FOOTHILL																											
	Irrigation Wells	0	5	3	3	6	7	8	1	7	4	2	0	0	4	0	2	1	1	0	2	4	0	0	1	0	50
	Domestic Wells	43	103	198	147	145	132	110	38	73	78	98	41	86	102	127	91	165	112	74	84	81	49	66	50	48	1,850
	Miscellaneous Wells	1	2	5	4	0	2	2	1	1	0	1	6	1	5	6	7	4	4	0	10	14	7	4	4	0	79
	Total:	44	110	206	154	151	141	120	40	81	82	101	47	87	111	133	100	170	117	74	96	99	56	70	55	48	1,979
MOUNTAIN																											
	Irrigation Wells	0	0	0	0	1	3	0	0	0	2	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	8
	Domestic Wells	5	29	53	98	122	102	80	64	39	52	64	45	83	62	63	79	112	108	82	84	79	75	73	61	30	1,559
	Miscellaneous Wells	0	3	1	1	0	0	0	3	0	0	0	0	2	7	0	1	0	0	0	0	2	0	0	4	4	23
	Total:	5	32	54	99	123	105	80	67	39	54	65	45	85	69	63	80	112	108	82	84	82	75	73	65	34	1,590
TOTAL FOR COUNTY																											
	Irrigation Wells	51	65	136	113	106	102	100	60	22	16	6	11	13	26	8	21	53	65	18	26	22	17	17	17	8	**734**
	Domestic Wells	171	301	506	415	432	399	336	151	188	253	253	190	325	308	339	304	410	334	185	218	227	204	196	161	121	**5,534**
	Miscellaneous Wells	11	16	19	23	1	4	9	4	4	5	6	79	19	61	36	45	61	31	88	70	67	65	34	33	46	**768**
	Totals:	233	382	661	551	539	505	445	215	214	274	265	280	357	395	383	370	524	430	291	314	316	286	247	211	175	**7,036**
TOTAL FOR VALLEY																											
	Irrigation Wells	51	60	133	110	124	123	104	61	26	20	12	22	13	22	8	19	52	64	18	24	17	17	17	16	8	**787**
	Domestic Wells	123	169	255	170	140	134	134	47	65	113	82	93	156	144	149	134	133	114	29	50	67	80	57	50	43	**2,014**
	Miscellaneous Wells	10	11	13	18	1	2	7	0	3	5	5	73	16	49	30	37	57	27	88	60	51	58	30	25	42	**666**
	Totals:	184	240	401	298	265	259	245	108	94	138	99	188	185	215	187	190	242	205	135	134	135	155	104	91	93	**3,467**

Note: Micellanuous Wells Include: Municipal, Public, Industrial, stock or unknown.

TABLE 2. NUMBER OF BUTTE COUNTY DOMESTIC, IRRIGATION, AND MISCELLANEOUS WELL COMPLETION REPORTS FILED WITH THE DEPARTMENT OF WATER RESOURCES BETWEEN 1975 AND 1999.

Inventory Unit	Sub Inventory Unit	Irrigated Acres *	Annual GW Extraction (TAF)						Annual GW Deep Perc. (TAF)		
			Sum. Ag.	M&I	Fall Ag.	Refuges	Totals	af/acre*	Ag	M&I	Totals
Vina	Vina	35,800	118.5	19.7	0.0	0.0	138.2	3.3	21.1	6.2	27.3
West Butte	Durham/Dayton	26,600	84.1	10.3	0.6		95.0	3.2	15.4	3.2	18.6
	M&T	2,100	6.8				6.8	3.2	1.6		1.6
	Angel Slough	3,700	10.0				10.0	2.7	1.5		1.5
	Llano Seco	1,100	1.8		0.5		2.3	1.6	0.3		0.3
	Western Canal (33%)	1,000	4.1		2.8		6.9	4.1	0.7		0.7
	Totals:	34,500	106.8	10.3	3.9	0.0	121.0	3.1	19.5	3.2	22.7
East Butte	Pentz			0.1			0.1				
	Esquon	3,100	14.2	0.5	2.5		17.2	4.6	3.8	0.3	4.1
	Cherokee	4,900	23.1	0.4	0.5		24.0	4.7	5.9	0.2	6.1
	Western Canal (67%)	2,300	12.2	0.1	2.8		15.1	5.3	3.7		3.7
	Richvale	35	0.2	0.1			0.3	5.9	0.1	0.1	0.2
	Thermalito	4,500	18.8	1.5	1.7		22.0	4.2	4.3	0.5	4.8
	Biggs-West Gridley	2,500	12.7	0.4			13.1	5.1	3.6	0.2	3.8
	Butte	6,100	22.1	4.4			26.5	3.6	4.4	1.6	6.0
	Butte-Sink	100	0.8		0.4	5.1	6.3	8.0	0.3		0.3
	Totals:	23,535	104.1	7.5	7.9	5.1	124.6	4.4	26.1	2.9	29.0
North Yuba	North Yuba	12,000	47.1	2.4	0.7	0.0	50.2	3.9	11.8	2.0	13.8
Foothill	Cohasset			0.5			0.5			0.3	0.3
	Ridge	100	0.3	1.7			2.0	3.0	0.1	1.0	1.1
	Wyandotte	40	0.1	0.6			0.7	2.5	0.1	0.3	0.4
	Totals:	140	0.4	2.8	0.0	0.0	3.2	2.9	0.2	1.6	1.8
Mountain	Mountain	100	0.2	1.8	0.0	0.0	2.0	2.0	0.1	1.0	1.1
TOTAL FOR BUTTE COUNTY:		106,075	377.1	44.5	12.5	5.1	**439.2**	19.6	78.8	16.9	**95.7**
TOTAL FOR VALLEY AREA:		105,835	376.5	39.9	12.5	5.1	**434.0**	14.8	78.5	14.3	**92.8**
Split Areas	Cal Water SIU (100%)	15,424	0.0	30.0	0.0	0.0	30.0	1.9	0.0	9.4	9.4
	Western Canal (100%)	3,300	16.3	0.1	5.6	0.0	22.0	4.9	4.4	0.0	4.4

* Irrigated Acres Equals Acreage for Summer Agricultural Application of Groundwater, except in Cal Water SIU. Cal Water SIU equals M&I Service Area.

** Acre-Feet per Acre Equals: Summer Ag GW Extraction Divided by Irrigated Acres, except for Cal Water SIU. Cal Water SIU used M&I GW use.

TABLE 3. ESTIMATED GROUNDWATER EXTRACTION AND DEEP PERCOLATION, 1997 NORMAL WATER YEAR

Inventory Unit	Sub Inventory Unit	Irrigated Acres *	Annual GW Extraction (TAF)						Annual GW Deep Perc. (TAF)		
			Sum. Ag.	M&I	Fall Ag.	Refuges	Totals	af/acre**	Ag	M&I	Totals
Vina	Vina	35,800	142.6	22.2	0.0	0.0	164.8	4.0	25.5	6.8	32.3
West Butte	Durham/Dayton	26,900	106.7	11.6	0.6		118.9	4.0	17.6	3.5	21.1
	M&T	2,200	8.9				8.9	4.0	2.0		2.0
	Angel Slough	3,700	12.8				12.8	3.5	1.9		1.9
	Llano Seco	1,200	2.7		0.5		3.2	2.3	0.6		0.6
	Western Canal (33%)	2,500	12.3		11.0		23.3	4.9	1.0		1.0
	Totals:	36,500	143.4	11.6	12.1	0.0	167.1	3.9	23.1	3.5	26.6
East Butte	Pentz			0.1			0.1				
	Esquon	4,500	24.6	0.6	4.6		29.8	5.5	6.5	0.3	6.8
	Cherokee	5,100	26.2	0.5	0.5		27.2	5.1	6.6	0.2	6.8
	Western Canal (67%)	7,100	40.7	0.1	11.0		51.8	5.7	7.8	0.1	7.9
	Richvale	5,100	30.3	0.2			30.5	5.9	0.1	0.1	0.2
	Thermalito	4,500	21.4	0.5	2.2		24.1	4.8	4.8	0.5	5.3
	Biggs-West Gridley	4,500	25.0	0.5		2.5	28.0	5.6	7.1	0.3	7.4
	Butte	6,800	29.7	4.9			34.6	4.4	5.8	1.8	7.6
	Butte-Sink	300	1.6		0.4	13.1	15.1	5.3	0.5		0.5
	Totals:	37,900	199.5	7.4	18.7	15.6	241.2	5.3	39.2	3.3	42.5
North Yuba	North Yuba	12,400	58.8	2.6	0.7	0.0	62.1	4.7	14.2	2.3	16.5
Foothill	Cohasset			0.4			0.4			0.3	0.3
	Ridge	100	0.3	1.8			2.1	3.0	0.1	2.0	2.1
	Wyandotte	40	0.1	0.6			0.7	2.5	0.1	0.3	0.4
	Totals:	140	0.4	2.8	0.0	0.0	3.2	2.9	0.2	2.6	2.8
Mountain	Mountain	100	0.1	2.0	0.0	0.0	2.1	1.0	0.0	0.9	0.9
TOTAL FOR BUTTE COUNTY:		110,440	544.8	48.6	31.5	15.6	**640.5**	21.8	102.2	19.4	**121.6**
TOTAL FOR VALLEY AREA:		122,600	544.3	43.8	31.5	15.6	**635.2**	17.9	102.0	15.9	**117.9**
Split Areas	Cal Water SIU (100%)	15,424	0.0	33.8	0.0	0.0	33.8	2.2	0.0	10.3	10.3
	Western Canal (100%)	9,600	53.0	0.1	22.0	0.0	75.1	5.5	8.8	0.1	8.9

* Irrigated Acres Equals Acreage for Summer Agricultural Application of Groundwater, except in Cal Water SIU. Cal Water SIU equals M&I Service Area.

** Acre-Feet per Acre Equals: Summer Ag GW Extraction Divided by Irrigated Acres, except for Cal Water SIU. Cal Water SIU used M&I GW use.

TABLE 4. ESTIMATED GROUNDWATER EXTRACTION AND DEEP PERCOLATION, 1997 DROUGHT WATER YEAR

INVENTORY UNIT	SUB-INVENTORY UNIT	IRRIGATION					DOMESTIC					MUNICIPAL					Well Totals
		Count	Max	Min	Median	Ave.	Count	Max	Min	Median	Ave.	Count	Max	Min	Median	Ave.	
Vina	Vina	621	1,050	42	250	332	2,096	754	14	137	145	51	830	72	580	531	2,768
West Butte	Durham Dayton	568	750	40	325	348	1,195	680	15	124	134	40	924	36	541	511	1,803
	M&T	38	920	115	350	397	18	640	54	120	147						56
	Llano Seco	15	592	110	301	311	1	56	56	56	56						16
	Angel Slough	43	400	60	223	229	8	125	35	92	86						51
	Average:	166	666	81	300	321	306	375	40	98	106	40	924	36	541	511	512
	Inventory Unit Total:	664	920	40	315	342	1,222	680	15	123	134	40	924	36	541	511	1,926
East Butte	Pentz	39	740	62	255	299	172	860	35	150	245						211
	Esquon	108	883	74	341	368	291	482	25	120	125						399
	Cherokee	62	871	89	506	446	104	575	35	165	181						166
	Western Canal (100%)	112	880	108	500	470	47	540	50	125	145						159
	Richvale	72	855	80	260	303	87	500	40	104	114						159
	Thermalito	56	460	36	132	158	140	480	37	80	98						196
	Biggs-West Gridley	92	707	40	196	221	246	243	32	87	92	4	362	260	344	328	342
	Butte	183	750	35	136	165	571	399	32	80	83	8	381	70	250	228	762
	Butte Sink	11	616	130	500	446	4	200	90	110	127						15
	Average:	82	751	73	314	320	185	475	42	113	134	6	372	165	297	278	272
	Inventory Unit Total:	735	883	35	245	299	1,662	860	25	97	120	12	381	70	314	261	2,409
North Yuba	North Yuba	178	983	28	271	288	504	575	25	120	139	9	210	98	181	171	691
Foothill	Cohasset	20	875	55	102	228	885	1,060	25	121	227	11	930	100	670	562	916
	Ridge	50	770	30	190	215	1,081	1,030	18	190	258	17	740	100	325	381	1,148
	Wyandotte	16	580	88	215	252	638	860	25	200	226						654
	Average:	29	742	58	169	232	868	983	23	170	237	14	835	100	498	472	911
	Inventory Unit Total:	86	875	30	190	225	2,604	1,060	18	175	240	28	930	100	415	452	2,718
Mountain	Mountain	11	450	45	174	204	1,954	970	11	180	205	20	970	100	240	240	1,985
TOTAL FOR BUTTE COUNTY:		2,295	1,050	28	266	316	10,042	1,060	11	146	175	160	970	36	456	435	***12,497***
TOTAL FOR VALLEY AREA:		2,198	1,050	28	270	321	5,484	860	14	121	135	112	924	36	526	466	**7,794**
Split Area	Cal Water SIU (100%)	149	620	40	235	262	907	754	14	129	138	66	924	380	581	596	1,122

Note: "Municipal" includes wells listed as municipal and/or public. Wells listed as "other" are not included in the depth statistics.

TABLE 5. BUTTE COUNTY WELL DEPTH STATISTICS SUMMARY

INVENTORY UNIT	WELL COMPLETION REPORTS					1961 USGS STUDY		1989-1998 UTILITY PUMP TEST DATA				
	Number Reports	Number Tests	WELL YIELD			Number Tests	WELL YIELD Mean	Number Tests	Number Wells	WELL YIELD		
			Min	Max	Mean					Min	Max	Mean
Vina	676	22	100	3,850	1,227	498	1,000	788	314	88	4,473	1,395
West Butte	705	19	100	3,000	1,699			822	319	53	5,382	1,152
East Butte	748	38	100	4,500	2,605	119	980	890	227	65	5,459	1,602
North Yuba	187	6	80	400	225	23	840	162	84	84	4,178	976
Sac Valley Region	**2,316**	**85**	80	4,500	1,878	**640**	990	**2,662**	**944**	53	5,459	1,325

Note: Wells having more than one Utility Pumping Test were averaged.
Correlation of USGS Study Areas are as follows: Chico = Vina and West Butte, Gridley = East Butte, Honcut = North Yuba.

TABLE 6. WELL YIELD DATA FOR THE VALLEY PORTION OF BUTTE COUNTY

INVENTORY UNIT	1989-1998 UTILITY PUMP TEST DATA					1961 USGS STUDY	
	Number Tests	Number Wells	SPECIFIC CAP.			Number Tests	SPEC.CAP. Mean
			Min	Max	Mean		
Vina	284	155	9	244	87	498	51
West Butte	291	143	9	299	71		
East Butte	335	97	11	340	84	119	58
North Yuba	64	38	7	170	48	23	60
Sac Valley Region	**974**	**433**	7	340	78	**640**	53

Note: Wells having more than one Utility Pumping Test were averaged.
Correlation of USGS Study Areas are as follows: Chico = Vina and West Butte,
Gridley = East Butte, Honcut = North Yuba.

TABLE 7. SPECIFIC CAPACITY DATA FOR THE VALLEY PORTION OF BUTTE COUNTY

INV. UNIT	SUB-INVENTORY UNIT	Area (acres)	S.Y. %	Estimated Average Depth to GW	Average Base FW	GW Storage Capacity (taf)
Vina	Vina	74,935	7.1%	10	1,600	**8,459**
West Butte	Durham Dayton	39,783	6.6%	10	1,500	3,932
	M&T	8,184	6.6%	10	1,500	809
	Llano Seco	18,378	6.6%	10	1,500	1,816
	Angel Slough	5,346	6.6%	10	1,500	528
	Western Canal (33%)	14,767	6.6%	10	1,500	1,460
	Totals:	86,458	6.6%	10	1,500	**8,545**
East Butte	Pentz	1,885	6.3%	10	1,400	164
	Esquon	11,604	6.3%	10	1,400	1,010
	Cherokee	14,704	6.3%	10	1,400	1,279
	Western Canal (67%)	29,980	6.3%	10	1,400	2,609
	Richvale	39,401	6.3%	10	1,400	3,428
	Thermalito	25,468	6.3%	10	1,400	2,216
	Biggs-W. Gridley	33,971	6.3%	10	1,400	2,956
	Butte	21,370	6.3%	10	1,400	1,859
	Butte Sink	10,273	6.3%	10	1,400	894
	Totals:	188,656	6.3%	10	1,400	**16,416**
North Yuba	North Yuba	47,521	8.8%	10	600	**2,467**
Split Areas	Cal Water SIU (100%)	15,425	6.3%	10	1,500	1,448
	Western Canal (100%)	44,747	6.5%	10	1,450	4,188
ESIMATED VALLEY TOTAL:		**397,570**	6.8%	10	1,335	**35,888**

TABLE 8 . GROUNDWATER STORAGE CAPACITY ESTIMATES, BUTTE COUNTY

INV. UNIT	SUB-INVENTORY UNIT	Area (acres)	S.Y. %	Estimated Average Depth to GW	Average Base FW	GW Storage Capacity (taf)
Vina	Vina	74,935	7.1%	26	1,600	**8,374**
W.Butte	Durham Dayton	39,783	6.6%	22	1,500	3,900
	M&T	8,184	6.6%	22	1,500	802
	Llano Seco	18,378	6.6%	22	1,500	1,802
	Angel Slough	5,346	6.6%	22	1,500	524
	WCWD (33%)	14,767	6.6%	22	1,500	1,448
	Totals:	86,458	6.6%	22	1,500	**8,476**
E. Butte	Pentz	1,885	6.3%	13	1,400	164
	Esquon	11,604	6.3%	13	1,400	1,008
	Cherokee	14,704	6.3%	13	1,400	1,277
	WCWD (67%)	29,980	6.3%	13	1,400	2,603
	Richvale	39,401	6.3%	13	1,400	3,421
	Thermalito	25,468	6.3%	13	1,400	2,211
	Biggs-W. Gridley	33,971	6.3%	13	1,400	2,950
	Butte	21,370	6.3%	13	1,400	1,855
	Butte Sink	10,273	6.3%	13	1,400	892
	Totals:	188,656	6.3%	13	1,400	**16,380**
N. Yuba	North Yuba	47,521	8.8%	37	600	**2,354**
Split Areas	Cal Water SIU (100%)	15,425	6.3%	22	1,500	1,436
	Western Canal (100%)	44,747	6.5%	16	1,450	4,171
ESTIMATED VALLEY TOTAL:		**397,570**	6.8%	20	1,335	**35,585**

TABLE 9. GROUNDWATER IN STORAGE ESTIMATES, BUTTE COUNTY

INVENTORY UNIT	SUB-INVENTORY UNIT	Surface Area (acres)	Specific Yield	GW Extraction * Normal Year (acre/feet)	GW Extraction * Drought Year (acre/feet)	Average Change in GW Elevations (feet)	
						Normal Year	Drought Year
Vina	Inventory Unit Total/Average:	74,935	7.1%	124,100	148,390	-23	-28
West Butte	Durham Dayton	39,783	6.6%	84,470	107,470	-32	-41
	M&T	8,184	6.6%	5,180	7,040	-10	-13
	Llano Seco	18,378	6.6%	1,160	1,590	-1	-1
	Angel Slough	5,346	6.6%	9,550	12,230	-27	-34
	Western Canal (33%)	14,767	6.6%	1,640	9,720	-2	-10
	Inventory Unit Total/Average:	86,458	6.6%	102,000	138,050	-18	-24
East Butte	Pentz	1,885	6.3%	70	70	-1	-1
	Esquon	11,604	6.3%	12,000	21,900	-17	-30
	Cherokee	14,704	6.3%	21,370	24,420	-23	-27
	Western Canal (67%)	29,980	6.3%	3,810	31,170	-2	-17
	Richvale	39,401	6.3%	-5,730	25,640	2	-10
	Thermalito	25,468	6.3%	18,350	20,070	-12	-13
	Biggs-west Gridley	33,971	6.3%	2,510	16,560	-1	-8
	Butte	21,370	6.3%	18,940	27,430	-14	-21
	Butte Sink	10,273	6.3%	170	1,060	0	-2
	Inventory Unit Total/Average:	188,656	6.3%	71,490	168,320	-6	-14
North Yuba	North Yuba	47,521	8.8%	44,100	55,040	-11	-13
Split Areas	California Water Service	15,425	6.3%	18,180	20,570	-19	-21
	Western Canal	44,747	6.5%	5,450	40,890	-2	-14
Valley Area	**Valley Total/Average:**	**397,570**	6.8%	**341,690**	**509,800**	-13	-19

***Seasonal Groundwater Extraction equals: summer agricultural extraction, plus 70% of annual M&I extraction, minus 30% of annual deep percolation.**

TABLE 10. ESTIMATED SEASONAL CHANGES IN THE VOLUME OF GROUNDWATER IN STORAGE AND THE ASSOCIATED CHANGES IN GROUNDWATER ELEVATIONS FOR 1997 NORMAL AND DROUGHT YEAR SCENARIOS

INVENTORY UNIT	AREA (acres)	SY (%)	ESTIMATED ANNUAL CHANGE IN THE VOLUME OF GROUNDWATER STORAGE (acre-feet)																			
			1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00
VINA	74,935	7.1%	-18,712	15,029	36,888	-8,759	-45,027	30,213	-12,714	-25,560	10,281	-3,669	-27,454	14,849	19,000	-15,654	41,031	-5,396	-3,107	22,882	-15,647	-10,026
WEST BUTTE	86,458	6.6%	-17,550	17,338	29,916	-14,632	-28,059	27,718	-22,121	-36,189	17,000	-9,051	-10,122	9,386	19,879	-12,259	35,666	-7,398	-12,249	30,086	-18,871	-11,105
EAST BUTTE	188,656	6.3%	-11,045	18,938	20,224	-11,132	-20,318	30,557	-10,980	-30,499	20,609	-1,123	-4,252	-3,869	10,867	-10,071	12,443	584	-6,268	22,823	-13,671	-1,635
NORTH YUBA	47,521	8.8%	-9,188	12,987	17,631	8,534	-19,551	17,479	-15,149	-3,409	4,020	-4,629	-2,014	-5,770	9,611	-3,089	10,624	-257	-415	6,445	-6,246	-167
Total:	**397,570**	**6.8%**	**-56,495**	**64,292**	**104,660**	**-25,989**	**-112,955**	**105,967**	**-60,965**	**-95,657**	**51,910**	**-18,472**	**-43,842**	**14,595**	**59,358**	**-41,073**	**99,764**	**-12,467**	**-22,039**	**82,236**	**-54,436**	**-22,933**

INVENTORY UNIT	AREA (acres)	SY (%)	ESTIMATED CUMMULATIVE CHANGE IN THE VOLUME OF GROUNDWATER IN STORAGE (acre-feet)																			
			1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00
VINA	74,935	7.1%	-18,712	-3,683	33,205	24,447	-20,580	9,633	-3,082	-28,642	-18,361	-22,030	-49,484	-34,635	-15,635	-31,289	9,742	4,346	1,238	24,120	8,473	-1,553
WEST BUTTE	86,458	6.6%	-17,550	-212	29,704	15,072	-12,987	14,731	-7,391	-43,579	-26,579	-35,630	-45,752	-36,366	-16,487	-28,746	6,920	-478	-12,727	17,359	-1,513	-12,617
EAST BUTTE	188,656	6.3%	-11,045	7,894	28,117	16,985	-3,332	27,225	16,244	-14,255	6,354	5,231	979	-2,891	7,977	-2,095	10,348	10,933	4,665	27,488	13,817	12,182
NORTH YUBA	47,521	8.8%	-9,188	3,798	21,430	29,964	10,412	27,892	12,743	9,334	13,354	8,725	6,711	941	10,552	7,463	18,087	17,831	17,416	23,862	17,615	17,448
Total:	**397,570**	**6.8%**	**-56,495**	**7,797**	**112,457**	**86,468**	**-26,487**	**79,480**	**18,515**	**-77,143**	**-25,232**	**-43,705**	**-87,547**	**-72,951**	**-13,593**	**-54,666**	**45,098**	**32,631**	**10,592**	**92,828**	**38,393**	**15,460**

INVENTORY UNIT	AREA (acres)	SY (%)	ESTIMATED CHANGE IN GROUNDWATER ELEVATION BASED ON CUMMULATIVE CHANGE IN THE VOLUME OF GROUNDWATER IN STORAGE (feet)																			
			1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00
VINA	74,935	7.1%	-3.5	2.8	6.9	-1.6	-8.5	5.7	-2.4	-4.8	1.9	-0.7	-5.2	2.8	3.6	-2.9	7.7	-1.0	-0.6	4.3	-2.9	-1.9
WEST BUTTE	86,458	6.6%	-3.1	3.0	5.2	-2.6	-4.9	4.9	-3.9	-6.3	3.0	-1.6	-1.8	1.6	3.5	-2.1	6.3	-1.3	-2.1	5.3	-3.3	-1.9
EAST BUTTE	188,656	6.3%	-0.9	1.6	1.7	-0.9	-1.7	2.6	-0.9	-2.6	1.7	-0.1	-0.4	-0.3	0.9	-0.9	1.1	0.0	-0.5	1.9	-1.2	-0.1
NORTH YUBA	47,521	8.8%	-2.2	3.1	4.2	2.0	-4.7	4.2	-3.6	-0.8	1.0	-1.1	-0.5	-1.4	2.3	-0.7	2.5	-0.1	-0.1	1.5	-1.5	0.0
Average:	**397,570**	**6.8%**	**-2.1**	**2.4**	**3.9**	**-1.0**	**-4.2**	**3.9**	**-2.3**	**-3.5**	**1.9**	**-0.7**	**-1.6**	**0.5**	**2.2**	**-1.5**	**3.7**	**-0.5**	**-0.8**	**3.0**	**-2.0**	**-0.8**

TABLE 11. SPRING-TO-SPRING CHANGES IN THE VOLUME OF GROUNDWATER IN STORAGE, VALLEY PORTION OF BUTTE COUNTY, 1980 to 2000

BUTTE COUNTY GROUNDWATER INVENTORY

APPENDIX C

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