SHALLOW GROUNDWATER OF EASTERN PLEASANT VALLEY BASIN

Report Prepared for:

Camrosa Water District

Report Prepared by:

Norman N. Brown, Ph.D.

PRELIMINARY DRAFT – FOR DISCUSSION PURPOSES ONLY

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EXECUTIVE SUMMARY

A study of the geology and groundwater characteristics of the eastern Pleasant Valley basin was conducted to assist in determination of shallow aquifer geology and likely groundwater connectivity with other regional aquifers. Particular focus was given to the area immediately north of Round Mountain and the CSU–Channel Islands campus.

In the area of study, principal water-bearing zones correspond with regional shallow aquifers and the regional groundwater basin's Upper Aquifer System. The Lower Aquifer System of the Oxnard Plain and other adjacent basin areas is widely regarded as absent in the study area adjacent to the Santa Monica Mountains. Groundwater of the shallow aquifer in the study area may be in hydraulic connection with Upper Aquifer System strata but is most likely relatively isolated from the regional Lower Aquifer System because:

- Significant thicknesses of clay are recognized in the stratigraphy for much of the study area and for the regional basin, separating the shallow aquifer from portions of the Upper Aquifer System, and separating these units from the Lower Aquifer System,
- In the regional basin adjacent to the study area, groundwater levels in the Upper and Lower Aquifer Systems are substantially different, and
- Seasonal and long-term water level fluctuations have different characteristics for each of the shallow, Upper and Lower aquifer systems.

The special study area north of Round Mountain, while historically characterized by poor water quality and limited supply reliability, also provides an opportunity for managed water resource benefits by providing a location:

- Potentially well separated hydraulically from the Lower Aquifer System of the main groundwater basin,
- Hydraulically connected with Calleguas Creek,
- Directly adjacent to the CSUCI campus and which, if managed, could provide an alternative water supply source to this facility, and

- Potentially well-suited to water quality management of combined surface water and shallow aquifer resources of eastern Pleasant Valley basin.

Recommendations for developing a managed water resource program in the special study area include:

- Survey of borehole conditions and water quality from existing, accessible water wells in the area,
- Characterization of aquifer storage capacity for different target groundwater units in the managed area,
- Characterization of areas or specific wells most important for evaluating potential impacts and benefits of any such water management program,
- Consideration of potential surface water gaging of Calleguas Creek at Round Mountain, and
- Determination of specific monitoring points important for such a water management program.

INTRODUCTION

Study of the groundwater geology of the eastern Pleasant Valley basin was conducted to assist in the understanding of the shallow groundwater regime of this portion of the regional aquifer. In particular, the study was conducted to:

- Identify and characterize geological features that may be important for governing groundwater flow within the area,
- Identify and characterize groundwater conditions within the principal aquifer systems of the area, particularly for improving the technical understanding of connectivity between the aquifer systems,
- Evaluate hydrogeological data specific to the region immediately north of Round Mountain and the CSU–Channel Islands campus ("special study area"),
- Develop preliminary technical findings for the special study area regarding shallow aquifer characteristics and groundwater connectivity with adjacent portions of the regional aquifer system, and
- Develop preliminary recommendations for the special study area pursuant to the use of groundwater resources of this area for regional water management and alternative water supply for the CSU campus.

Initial study was conducted for a portion of eastern Pleasant Valley approximately bounded by Pleasant Valley Road on the north, Calleguas Creek on the west, Round Mountain on the south, and the bedrock rangefront of the Santa Monica Mountains on the east (Figure 1). As discussed below, special focus was given to the area of sedimentary materials immediately north of Round Mountain and the CSUCI campus (formerly the California State Hospital).

Data used for the study includes publicly-available data concerning groundwater levels and groundwater quality, regional groundwater flow modeling, specialized geologic and groundwater studies conducted for nested monitoring well sites in the regional aquifer, and previous technical studies conducted for both the regional basin and the special study area. Work for the study also included acquisition of confidential state water well drillers' reports for portions of the study area; these are attached as Appendix A to the report. Much of the data were assembled and evaluated using standard database and GIS software; associated digital files acquired on behalf of Camrosa Water District are provided under separate cover.

GROUNDWATER GEOLOGY

Flow between aquifer units in any portion of the regional groundwater system is governed by several factors, including the differences in water level between water-bearing units. In addition, flow can occur through, or be inhibited by features such as:

- Sedimentary units, such as sands and gravels that transmit groundwater and clay-rich strata that are barriers to groundwater flow;
- Geological contacts that juxtapose basin strata of different origin or hydrologic character;
- Geological structures such as faults that may control local movement of groundwater through juxtaposition of different rock types and/or through hydrologic characteristics of the fault zone itself; and
- Modern, constructed features such as wells that create hydraulic connections between aquifers that are otherwise separated by aquitards (e.g., discussion in UWCD, 2004 and citations therein).

Discussion of groundwater levels in and around the study area is provided in section "Groundwater Conditions" below, following discussion of geological features such as stratigraphy and structure.

STRATIGRAPHY

Water well lithologic logs and completion reports provide an important basis for evaluating geological elements that localize and control groundwater flow within and between aquifers of the study area. Of particular interest for the goals of this study are:

- Significant thicknesses of coarse- and fine-grained sediments that either transmit or block groundwater flow,
- Laterally-contiguous stratigraphic packages that are recorded in many wells over broad portions of the study area, and
- Differences in stratigraphy that mark sedimentary transitions adjacent to the Santa Monica Mountains rangefront, and across areas of structural disruption, such as the hypothesized Bailey fault.

Stratigraphic Nomenclature

This study follows the interpretations and findings of most previous studies concerning the general basin stratigraphy (e.g., Dibblee and Ehrenspeck, 1990; Hanson et al, 2003). The lowermost strata consist of marine sediments of the Pleistocene Santa Barbara and San Pedro Formations. The San Pedro Formation is unconformably overlain by mixed marine and terrestrial alluvial deposits of late Pleistocene and Holocene age, designated Older Alluvium and Recent Alluvium (Figure 2).

In the study area, basin sediments lie unconformably on bedrock, consisting primarily of Tertiary Conejo volcanic rocks. In adjacent portions of the basin, bedrock basement is comprised of the volcanics and other Tertiary and older sedimentary rocks. None of the bedrock units, whether sedimentary or volcanic, are meaningful sources of groundwater production, except for local water supply from fractured volcanics in some mountain-front areas such as portions of the Santa Rosa valley.

Hydrostratigraphy

For this study, water-bearing units of the study area and adjacent portions of the regional groundwater basin are grouped in three general categories: (*i*) Lower Aquifer System (LAS), (*ii*) Upper Aquifer System (UAS), and (*iii*) shallow aquifers.

In the study area, the shallow aquifers are designated as the uppermost water-bearing units in hydraulic connection with surface and associated stream flow of Calleguas and Conejo Creeks. These aquifers may be semi-perched, unconfined or semi-confined, and are recognized as lenticular and laterally discontinuous in the basin margin area of this study.

In contrast, both the Lower Aquifer System and Upper Aquifer System include productive strata that are regionally contiguous in the study area and in adjacent portions of the regional basin (California DWR, 1971). The Lower Aquifer System consists of regionally-prevalent and important water supply units including the Grimes Canyon and Fox Canyon Aquifers. These confined aquifers correspond with the Santa Barbara and San Pedro Formations and are stratigraphically lower (and older) than other sedimentary aquifers of the Pleasant Valley and adjacent basin areas. Of particular significance for this study, the LAS is mostly absent in the area east of Calleguas Creek, along the eastern margin of the Pleasant Valley basin. Absence of the LAS in the easternmost Pleasant Valley basin of the study area is based on the elevations of regional aquifers, elevation of top-of-bedrock, and water level elevations.

For areas of Pleasant Valley and the adjacent Oxnard Plain that contain both Upper and Lower Aquifer Systems, the UAS is separated from LAS strata by intervening, regionally-contiguous clays up to several hundred feet thick. In some wells, the clays are also interlayered with silty and sandy horizons typically less than 10 or 20 feet thick. The clay strata provide a relatively consistent physical barrier to groundwater flow between the LAS and UAS in the regional basin, but some flow ("leakance") is believed to occur between the two aquifer systems (Turner, 1975; Hanson et al, 2003). Based on head differences between the LAS and UAS during the last several decades, any such flow would be downward, from the UAS units to the LAS (refer also to discussion in section "Groundwater Levels" below).

Regional studies of the groundwater basin may group all of the aquifers above the LAS into the UAS (e.g., Hanson et al, 2003), or may separate the uppermost aquifer, which is commonly designated as a perched or semi-perched aquifer (e.g., Woodward-Clyde, 1997). In the study area, the UAS zone is confined or locally semi-confined, whereas the shallow aquifers are primarily unconfined, with local groundwater level characteristics that may correspond with semi-perched conditions. In general, this study attempts to distinguish to between shallow aquifers in the uppermost 100 to 200 feet of basin strata, characterized by laterally-discontinuous horizons, with more laterally-uniform, and generally confined UAS groundwater horizons underlying the shallow materials in the study area and in adjacent portions of the basin.

STRUCTURE

Regionally, the Simi-Santa Rosa fault zone is responsible for uplift of the Camarillo Hills and related features of the region. Fault segments of this structural zone, including the Springville and Camarillo faults have been active in the late Quaternary or Holocene, based on geological relationships in folded areas transected by the faults (Blake, 1991).

In the study area at the eastern margin of Pleasant Valley basin, geologic structure has an important impact on the location and characteristics of the principal aquifers. In the subsurface, the geometry of the bedrock surface is associated with truncation of the Lower Aquifer System along a zone roughly contiguous with the surface location of Calleguas Creek. In addition, lithologic relationships between wells in this vicinity indicate that portions of the basin close to the mountain-front are geologically irregular and likely disrupted by faulting.

Previous investigations have postulated the presence of a fault – commonly called the Bailey Fault – coincident with this zone of geological complexity, comprising an extension of the Simi-Santa Rosa fault zone. Geological evidence allows the presence of such a fault zone, probably existing as a region of echelon fault segments sub-parallel to the range front (Figures 3 and 4).

Previous investigations have noted differences in water level elevations in alluvial aquifers to either side of the Camarillo fault (Blake, 1991; California Mines and Geology, 2002). Similarly, Boyle Engineering Corp (1997) describes a low-permeability boundary condition in a groundwater model along the Bailey fault, describing the fault as providing resistance to groundwater flow. However, potential fault-related disruption to groundwater flow in the study area is not well supported by hydrologic data.

On that basis, this study assumes that any structural disruption to the basin stratigraphy in the study area does not create special disruption of groundwater flow across the area of possible faulting, and that this structural zone contains sufficient "windows" of hydraulic connection between water-bearing units to either side of the fault to allow groundwater connection between units of similar elevation on either side of the zone.

Despite uncertainty over any groundwater flow disruption caused by faulting in the study area, stratigraphic relationships from wellbore information suggest significant variability and lateral discontinuity of basin strata in this area, producing a heterogeneous flow regime within shallow aquifers and potentially also the Upper Aquifer System in the study area. Drillers' well logs present inconsistent information with regard to the lateral continuity of major water-bearing units of the shallow and UAS strata, but generally support a conceptual model in which sufficiently thick and interlayered clayey units would inhibit vertical migration of groundwater in the study area. This conceptual model is supported by water level information.

GROUNDWATER CONDITIONS

Groundwater levels and water quality in different aquifers provide an indicator of hydrologic separation or connectivity between different aquifer units, and within individual aquifer zones across the area of study.

GROUNDWATER LEVELS

Several important relationships and characteristics of the study area's groundwater regime are noted in water level data:

- In the area west of Calleguas Creek, where the basin stratigraphy includes the Lower Aquifer System, there exists a significant difference in water level between the LAS and UAS. During the last several decades, LAS water levels have been consistently lower than other aquifers, typically in the range 50 to 100 feet below sea level. In recent years, UAS water levels are generally above sea level. Increasing separation in water levels within the two aquifer systems can be seen for two relatively close wells near the study area (Figure 5). Hydrographs of groundwater levels in LAS aquifers exhibit characteristics of confined aquifers; UAS groundwater conditions are also commonly confined but may also have local characteristics of semi-confined aquifers.

- The most shallow aquifers exhibit water level trends expected for either unconfined or semi-perched aquifers. Whereas perched aquifer conditions are cited in many studies addressing regional hydrogeology (e.g., Woodward-Clyde, 1997), few wells in the study area with groundwater level data exhibit true perched aquifer behavior, fluctuating instead in a manner consistent with unconfined aquifer conditions or transient semi-perched behavior (Figure 6). In consideration of the geologic complexity of the area, combinations of semi-perched and unconfined conditions are expected for the most shallow aquifers.

- In areas adjacent to surface water streams (Calleguas and Conejo Creeks) in the study area, groundwater levels fluctuate roughly in concert with stream discharge, indicating hydraulic connection between the streams and the near-surface aquifers (Figure 7).

- Shallow aquifers that are known from lithologic logs to have fine-grained layers between the aquifer and surface display a range of water level characteristics showing that such shallow aquifers can be locally unconfined, semi-confined or semi-perched (Figure 8).

Groundwater Quality

Like groundwater level information, groundwater quality is a basic standard for comparing aquifers and interpreting inter-aquifer flow regimes. In the area of study, groundwater quality information is relatively limited, but provides information consistent with other hydrogeological data and findings:

- Near-surface aquifers adjacent to surface water stream display water quality parameters consistent with hydraulic connection between surface water and the uppermost aquifers (Figure 9).

- In nested monitoring wells in the Oxnard Plain, individual aquifers can have greatly different water quality characteristics consistent with hydrologic separation between aquifers – as measured in concentration of chloride, for example (Table 1), or by different temporal trends in water quality for different aquifer units.

- Water quality in the shallow aquifers adjacent to the Santa Monica Mountains rangefront is commonly highly mineralized, and in regions adjacent to the southern portion of the study area, is generally higher in constituents such as chloride than groundwater in the LAS or UAS farther west in the main basin (in areas not impacted by seawater or related marine sediment brines; Figures 10 and 13). This difference in water chemistry suggests limited hydraulic connection between the shallow aquifers of the special study area aquifer zones of the adjacent main groundwater basin, and/or limited contribution of groundwater from the local, more mineralized aquifers to the regional groundwater regime. In contrast, portions of the Pleasant Valley basin in the northern portion of the study area and adjacent regions show relatively high TDS and chloride for a broader region including both the rangefront and the basin south of Camarillo Hills (the leftmost – most northern – portions of Figures 10 and 13).

Other Indicators

Other factors are helpful for interpreting groundwater and geologic data in the study area. For example, the US Geological Survey conducted a regional groundwater flow model for the broad area including the eastern portion of Pleasant Valley basin (Hanson et al., 2003). The model differentiates only between the UAS and LAS aquifer zones (shallow aquifers are included in the UAS), and concludes there has been total vertical flow of approximately 15,000 afy (from UAS to LAS) throughout the entire Pleasant Valley basin for the period

1984-1993. This vertical flow is calculated to occur over an area of nearly 30 mi^2, approximately 10 times larger than the study area for this investigation.

In contrast, DWR (1971) estimated only 6,000 afy downward leakance from the uppermost ("semi-perched") aquifer to the UAS's Oxnard Aquifer, over the complete regional groundwater basin.

SHALLOW AQUIFER CHARACTERISTICS IN PLEASANT VALLEY BASIN SPECIAL STUDY AREA

For the study, particular attention was given to the margin of the basin east of Calleguas Creek and north of Round Mountain and the CSU–Channel Islands campus (the "special study area"; Figure 11). The area is historically characterized by relatively poor water quality, and by groundwater level drawdown resulting in water supply reliability concerns during the time that the state hospital was served by a local water supply well (the CSUCI campus now occupies the location of the former state hospital).

Nonetheless, this region has geological and groundwater features that are potentially well-suited to broader water reclamation and management goals being developed by Camrosa Water District. Accordingly, this study provides a preliminary view of groundwater geology of the special study area, with particular emphasis on potential hydrologic connections between the shallow aquifers of this area and regional water supply aquifers, as well as the use of this area in a managed water supply and reclamation project.

The special study area was the focus of a previous data survey and investigation (Woodward-Clyde, 1997); this study updates and expands portions of the data described therein, and provides further geological evaluation of the area in context of water supply and management programs now being developed by Camrosa Water District.

GEOLOGY AND HYDROSTRATIGRAPHY

Water well lithologic logs and well completion reports provide the principal basis for determining geology and aquifer units of the special study area. Consistent with the geologic environment of the area, strata in this margin of the basin are relatively less well correlated laterally than the principal aquifer zones and intervening clay-rich layers of the main basin. As such, shallow aquifers within approximately the upper 150 feet of the basin margin are more likely to be in hydraulic connection with one another and with surface than might be expected in more central portions of the basin.

However, clay horizons with thicknesses of 10 to 70 feet are recognized in the upper 200 to 300 feet of most wells of the special study area, suggesting also that any interconnection between shallow aquifers is largely isolated from groundwater of the main UAS and LAS zones of the basin. Figure 12 (and associated well log information contained in Appendix A's Figure A1) provides a schematic view of the subsurface in this area. The cross sections shown in Figures 12B, 12C and 12D are schematic only, and represent just one of many possible subsurface geometries regarding bedrock structure. The cross-sections are oriented with the Santa Monica Mountains rangefront – the eastern end of the section – on the left. This follows the standard convention of orienting the section so that the viewer is looking down-gradient. The sections note the approximate location and thickness of dominantly clay units in the subsurface (horizontal bands), and bedrock depth where known. Several features of the cross-sections are important for discussion:

- Clay Strata. Depiction of clay units is restricted to fine-grained strata with thickness greater than 10 feet, and wherein the lithologic logs describe such clay horizons without significant sand content. Based on comparison with lithologic logs for portions of the Oxnard Plain where more detailed well logging has occurred (e.g., Densmore, 1996), this approach yields a rather conservative view, understating the number of such fine-grained layers that may inhibit vertical migration of groundwater. In this regard, wells that show minimal or no clay layers are more likely to contain such units, but detailed information concerning this stratigraphy is unknown from existing information.

- Bedrock Geometry. Depictions of faulting and top-of-bedrock geometry are based on reasonable structural geology interpretations for such a basin margin, but are not unique descriptions of possible subsurface conditions. For example, the faults drawn could readily exist with much steeper geometry, or with graben-like features within the rangefront area. In addition, complex faulting patterns are not generally well-described from lithologic logs, and borehole penetrations of broken or brecciated bedrock are subject to uncertainty.

- Age of Faulting. Faulting within the bedrock subsurface is depicted as pre-dating alluvial sediment deposition, but more recent displacement on such structures may disrupt portions of the stratigraphy, as is found for some faults in the northern Pleasant Valley (see section "Structure" above; Blake, 1991)

GROUNDWATER CONDITIONS

Groundwater quality in the special study area is known for high mineral content (limited TDS data indicate concentrations of 1,500 to 2,000 mg/l are typical; Woodward-Clyde, 1997; Bookman-Edmonston, 2000). Whereas other portions of the Pleasant Valley basin also have high-TDS groundwater, areas west of the southern Pleasant Valley basin have relatively less mineralized groundwater in wells producing from UAS and LAS zones of the main groundwater basin (Figure 13). This local difference in dissolved solids and other water quality constituents is consistent with: (*i*) relatively poor hydraulic connection between the shallow aquifers of the special study area and the adjacent UAS and LAS, (*ii*) relatively small amounts of groundwater flow away from the shallow aquifer zones into the main basin, or (*iii*) both limited hydraulic connection and limited groundwater flow away from shallow aquifers of the basin margin to other parts of the basin.

The presence of a limited water resource within the special study area is suggested also by water well completions in the area north of the former state hospital (now CSUCI campus), at least one of which yielded insufficient water for intended use at the facility. Shallow aquifer groundwater supply from other wells near the facility was subject to sufficient drawdown (Figure 14) that water wells became unreliable for continuous water supply.

SURFACE WATER

In contrast to potentially limited connectivity between shallow aquifers and regional UAS and LAS zones, the shallow groundwater-bearing horizons of the special study area are likely to be in relatively close hydraulic connection with streamflow in Calleguas Creek. Such surface water connection is inferred from geologic analysis, and by analogy with upstream portions of Calleguas Creek. For example, calculation of stream gains and losses along different reaches of Calleguas and Conejo Creeks suggest as much as 6,100 afy infiltration to shallow aquifers from Calleguas Creek, for the northern portion of the study area and adjacent upstream reaches of the creek (Hanson et al, 2003). Limited data from shallow aquifer wells immediately adjacent to Calleguas Creek indicate groundwater levels modulated by surface water flow, with consistent seasonal variation and limited groundwater level excursions outside a consistent range of water levels.

Stream gaging is conducted at the upstream margin of the special study area (at University Drive). However, absent a downstream gaging location near Round

Mountain (e.g., at the Potrero Road bridge), any exchange between surface flow in Calleguas Creek and the adjacent and underlying shallow aquifers in the special study area cannot be quantified.

DISCUSSION

The special study area north of Round Mountain, while historically characterized by poor water quality and limited supply reliability, also provides an opportunity for managed water resource benefits by providing a location:

- Relatively well separated from the Lower Aquifer System of the main groundwater basin,
- Hydraulically connected with Calleguas Creek,
- Directly adjacent to the CSUCI campus and which, if managed, could provide an alternative water supply source to this facility, and
- Potentially well-suited to water quality management of combined surface water and shallow aquifer resources of eastern Pleasant Valley basin.

Water well lithologic information suggests that much of the area contains alluvial material to depths of approximately 400 feet (Figure 15), with a portion of this thickness comprised of coarse-grained aquifer materials. As part of a project under consideration by Camrosa Water District, it may be possible to extract a portion of the shallow groundwater within the special study area for treatment and use within the basin. Such a program would likely combine the shallow groundwater and Calleguas Creek surface water in a conjunctively managed program. Potential advantages of the program include water quality improvements and increased utilization of a basin margin area that currently experiences little production or management of poor native water quality.

To the extent that groundwater storage capacity in the shallow aquifers of the study area can be managed with combinations of extraction, replenishment and treatment of water resources, such a program suggests several possible benefits to the basin:

- Improvements to water quality in the basin-margin shallow aquifers,
- Improvements to water supply reliability in the special study area,

- Improvements to water quality of any shallow groundwater that migrates away from the basin margin to other aquifers of the basin, whether these are part of the regional shallow aquifer, or components of the UAS or even LAS.

In addition, in the region immediately adjacent to the special study area, most wells produce groundwater from the Lower Aquifer System, such that extractions from the shallow aquifer would be expected to cause little if any interference with existing groundwater production.

As a potential project focusing on a relatively small area of shallow aquifers in the basin, the amount of potential groundwater storage capacity associated with such a project is relatively small in comparison with groundwater storage and productivity of the Pleasant Valley basin as a whole. The principal advantages of managing water resources in the special study area stem from the combination of its location, existing poor water quality, the opportunity for conjunctive management of surface and groundwater resources, and existing low utilization of groundwater in the area. For the special study area, a preliminary summary of aquifer storage capacity, based on simple assumptions for shallow aquifer geometry, suggests that groundwater storage capacity on the order of 2,000 to 6,000 acre-feet may be possible for a water management project (Table 2).

Initial planning by Camrosa Water District describes a framework in which any treatment and conjunctive management project in the study area would be conducted on a staged basis, with an initial pilot project to assess the characteristics and impacts of a full program. A pilot project would also afford the opportunity to gather information important to determination of aquifer connectivity in the area. Examples of work that could be conducted through such preliminary and pilot work include:

- Survey of borehole conditions and collection of water level data and water quality samples from existing, accessible water wells in the area,

- Detailed lithologic and related borehole logging of new, test wells, including acquisition of water level data and water samples for laboratory analysis of water quality

- Pumping tests utilizing existing and any new wells,

- Establishing a temporary gauging station at the Potrero Road bridge for measurement of streamflow gains/losses in the area, and

- Conduct a small-scale seismic reflection study to improve lateral stratigraphic correlations in the special study area.

Not all these activities may be necessary in a pilot program, but some combination of such work could be used to more accuracy specify shallow aquifer connectivity and lateral continuity, aquifer storage capacities, and linkages between surface water and groundwater.

In addition, the work would help to guide the placement and monitoring for any pilot implementation of a treatment and conjunctive use project. Through resultant understanding of the area hydrogeology and pilot-scale project performance, feasibility and design criteria for a full scale program could be better developed, including determination of important monitoring points and criteria that would be expected to accompany any such program.

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APPENDIX A – CONFIDENTIAL SUPPORTING INFORMATION

Figure A1(A) is identical to Figure 12(A), with corresponding cross-sections providing information concerning significant clay strata and well perforation intervals. Limitations and uncertainties concerning these cross-sections are discussed in section "Geology and Hydrostratigraphy" above, in context of Figure 12. The long perforation intervals of many wells highlights the concern for cross-aquifer flow at individual water wells (see also UWCD, 2004 and discussion therein) and the importance of monitoring and management for any water reclamation project in the special study area.

Water well drillers' reports acquired for this study are also provided:

1N-20W-06

- A1
- B2
- Unlabelled well near B2
- C2
- C3
- E1
- H2
- L1
- P1

1N-20W-07

- H3
- E1
- H2

1N-21W-11

- A1
- D1
- D2
- G1
- G3
- G4
- L1
- P1
- R1
- R2

<u>1N-21W-12</u>

B2
B3
B4
C1
C3
C4
C5
D1
D2
E1
E4
F3
G1
G2
H1

<u>1N-21W-14</u>

A1
B1 (see also 14F2)
B2
B3
C1
F1
F2 (deepening of 14B1)
F3
H1
J1

<u>2N-20W-30</u>

C1
H1
H2
K2
M1
N2
N3

2N-20W-31

- Unlabelled well S of Hwy101
- Unlabelled well N of Hwy101
- B1
- B2
- C2
- E1
- F1
- F2
- F3
- R1

Figure 1. Study area location map.

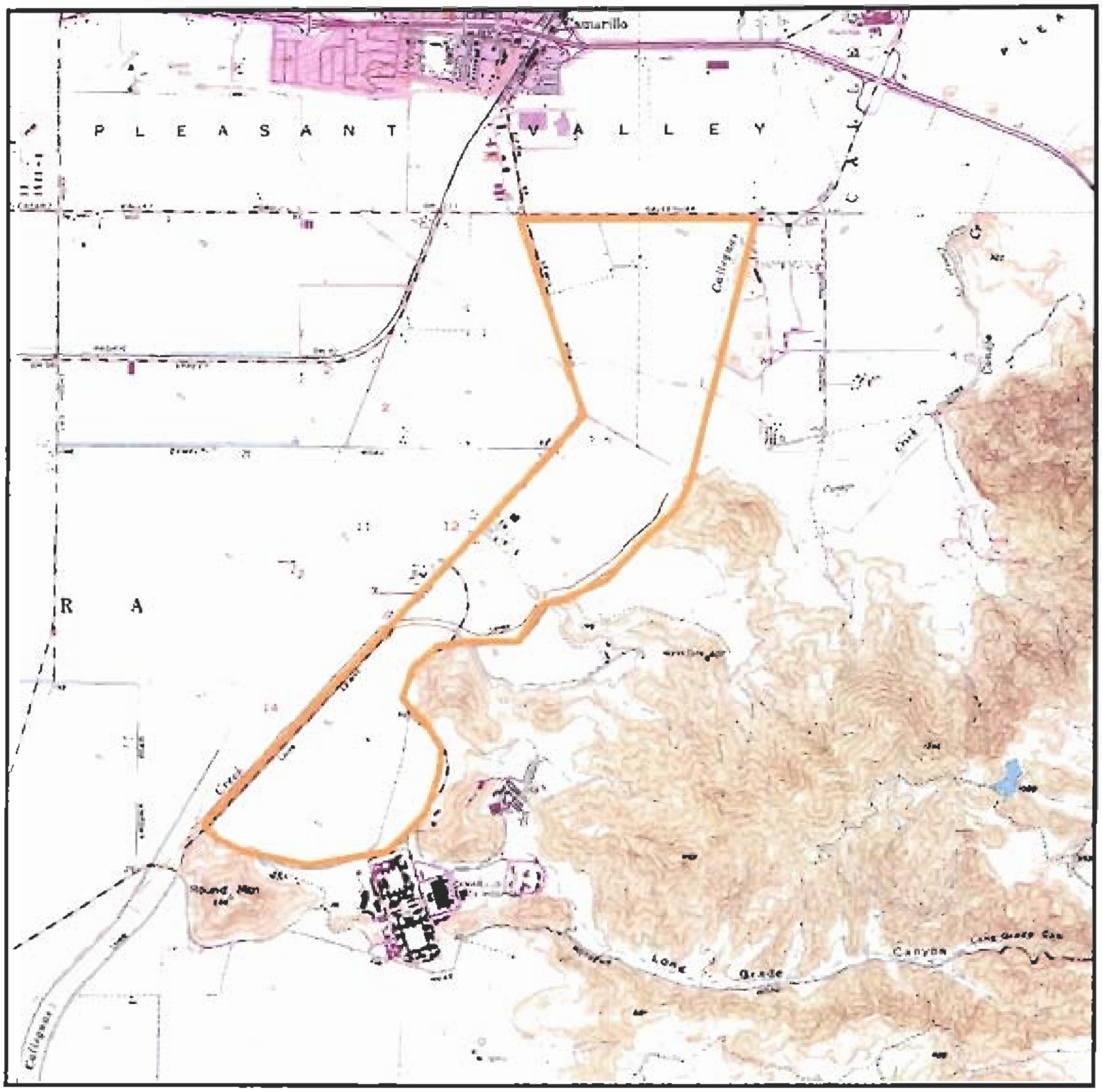


Figure 2. Stratigraphic column of principal Quaternary sedimentary units of the study area, showing aquifer designations (from Hanson et al, 2003).

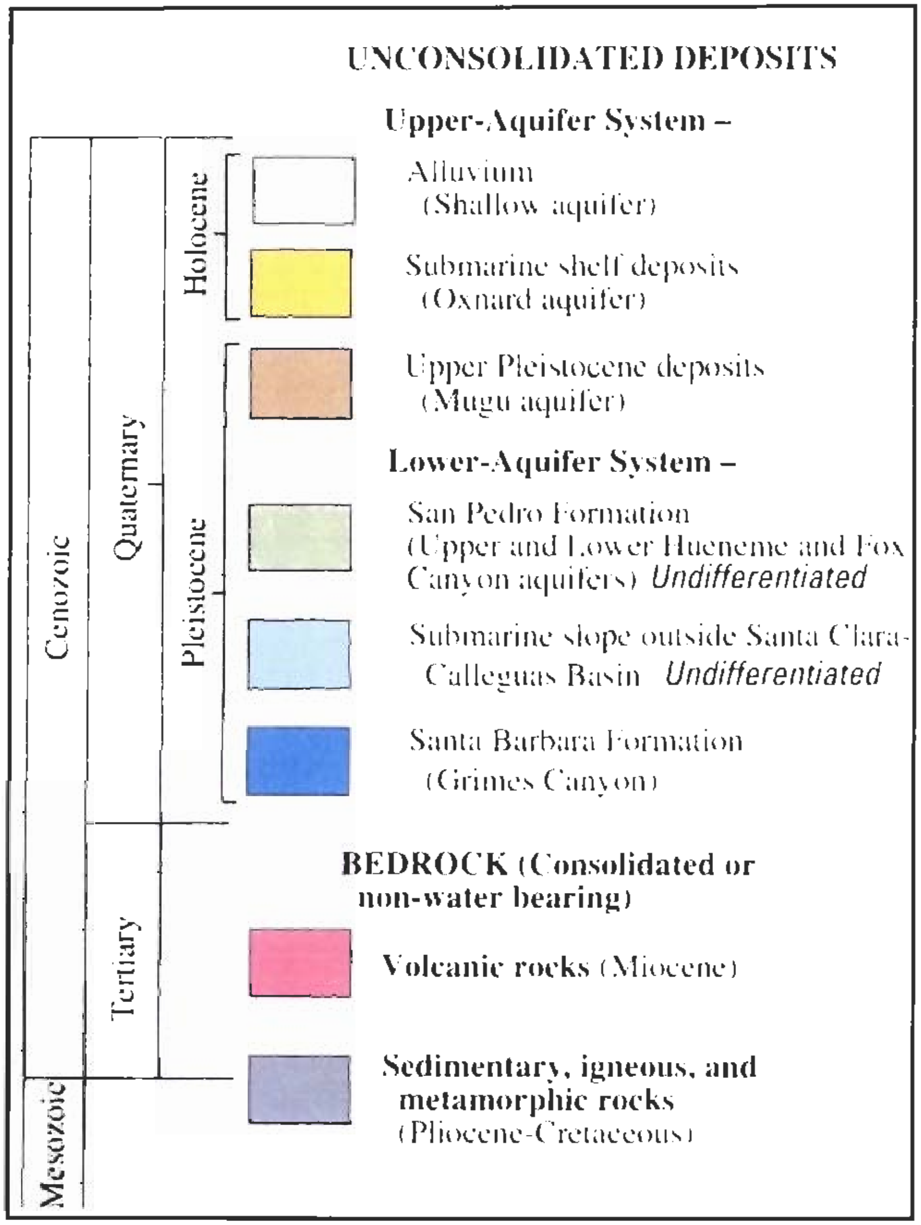


Figure 3. Location map showing well locations and Bailey structure zone (gray-green). Wells with water level or water quality data are displayed in blue. The area of special study is northwest of CSUCI campus and east of the Bailey structure zone, in section 14. Fault segments of the Simi – Santa Rosa fault zone are in light green.

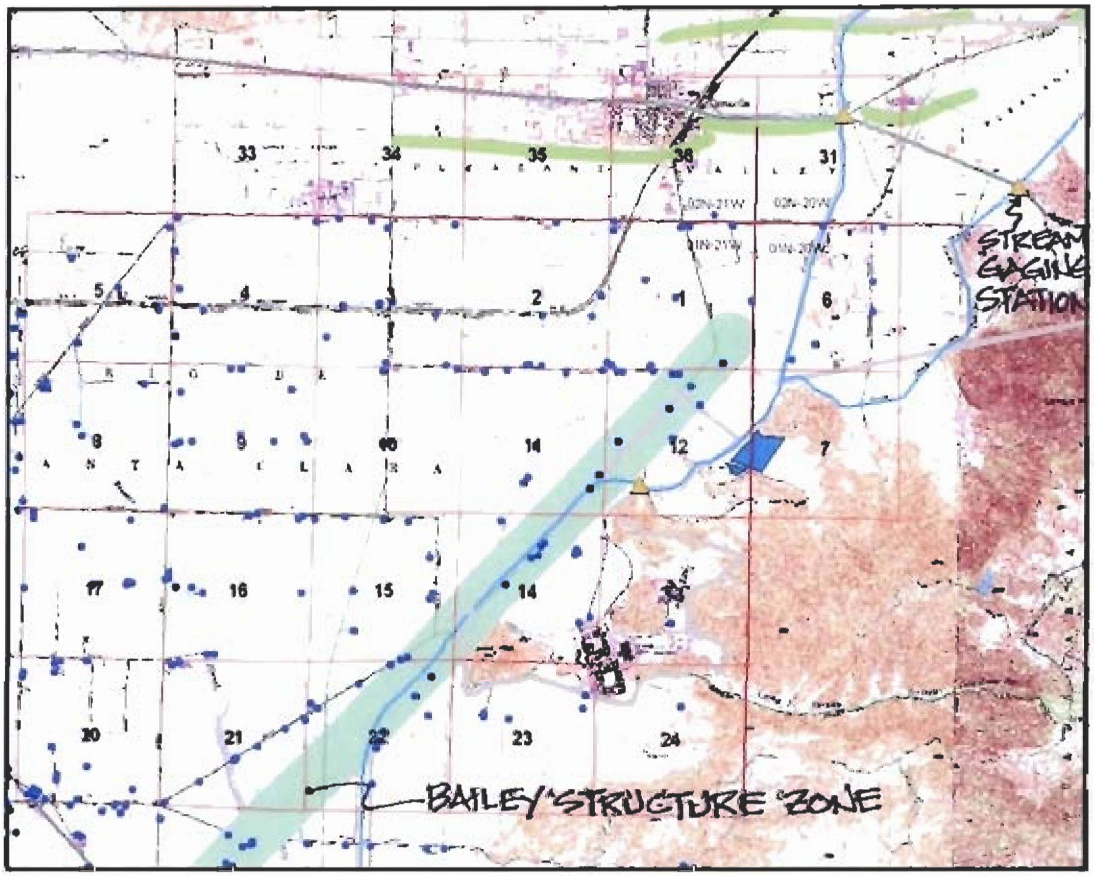
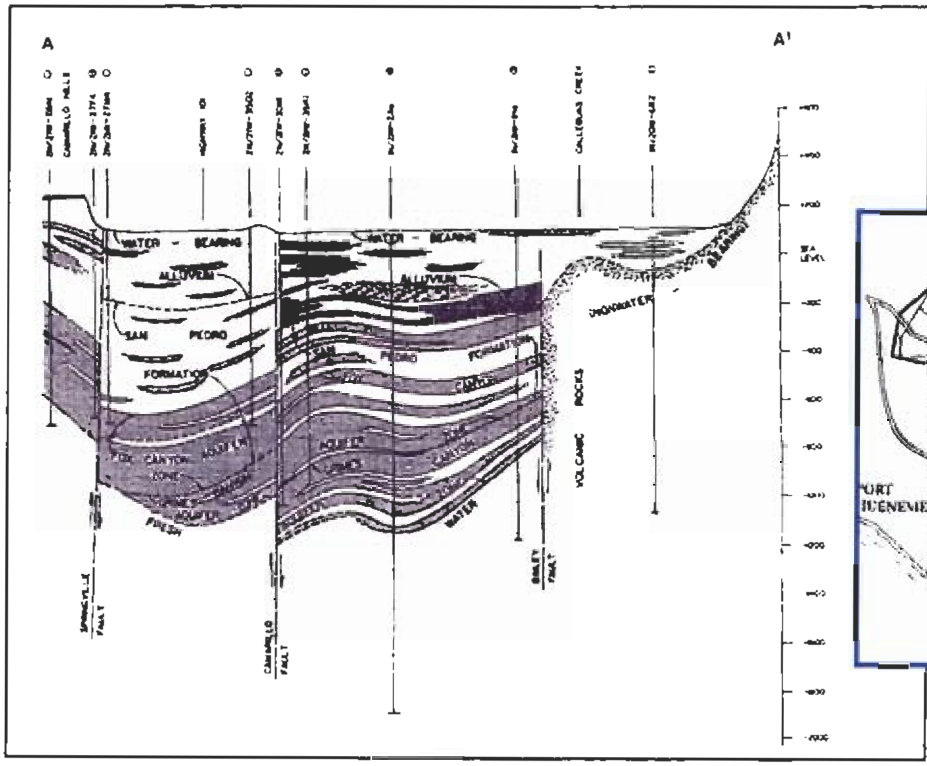
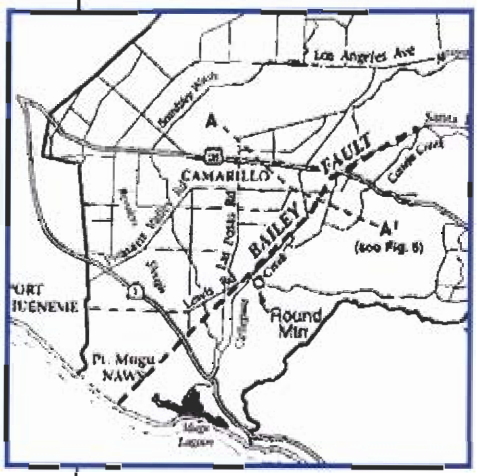


Figure 4. Schematic cross-sections of study area. Above, geologic section near confluence of Calleguas and Conejo Creeks, showing absence of LAS east of Bailey structure zone (section from DWR, 1971). Below, section near coastline, from Hanson et al (2003). Unconformity on top of LAS (Upper Hueneme) is highlighted; color schemes follow stratigraphic legend of Figure 2.





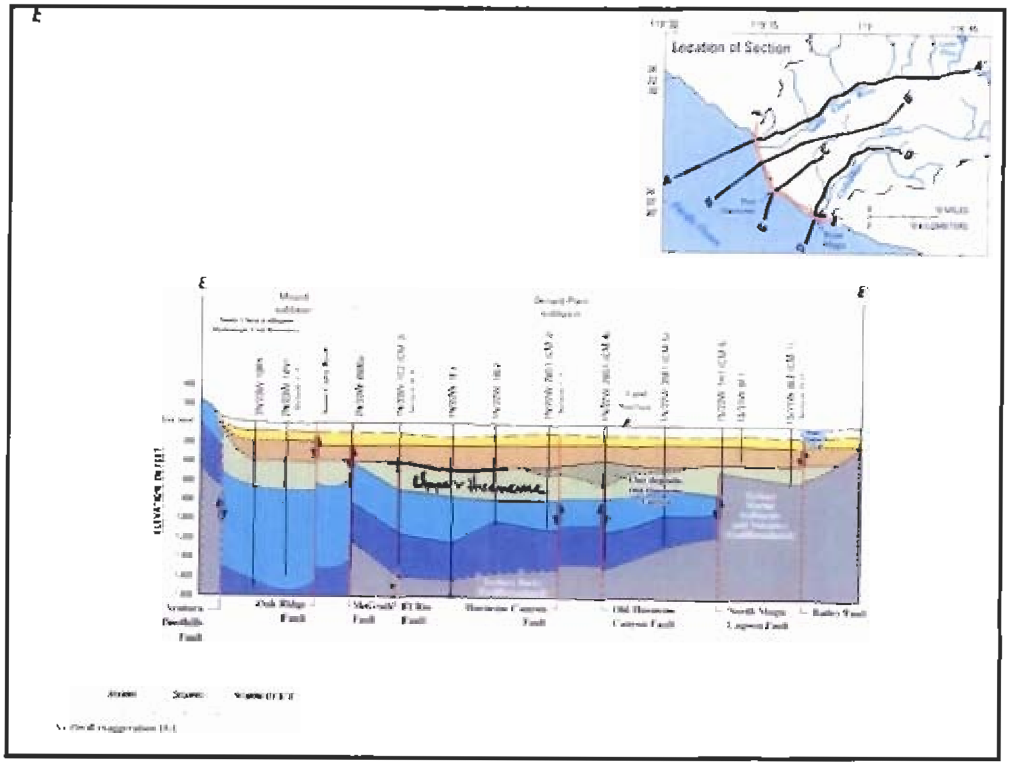
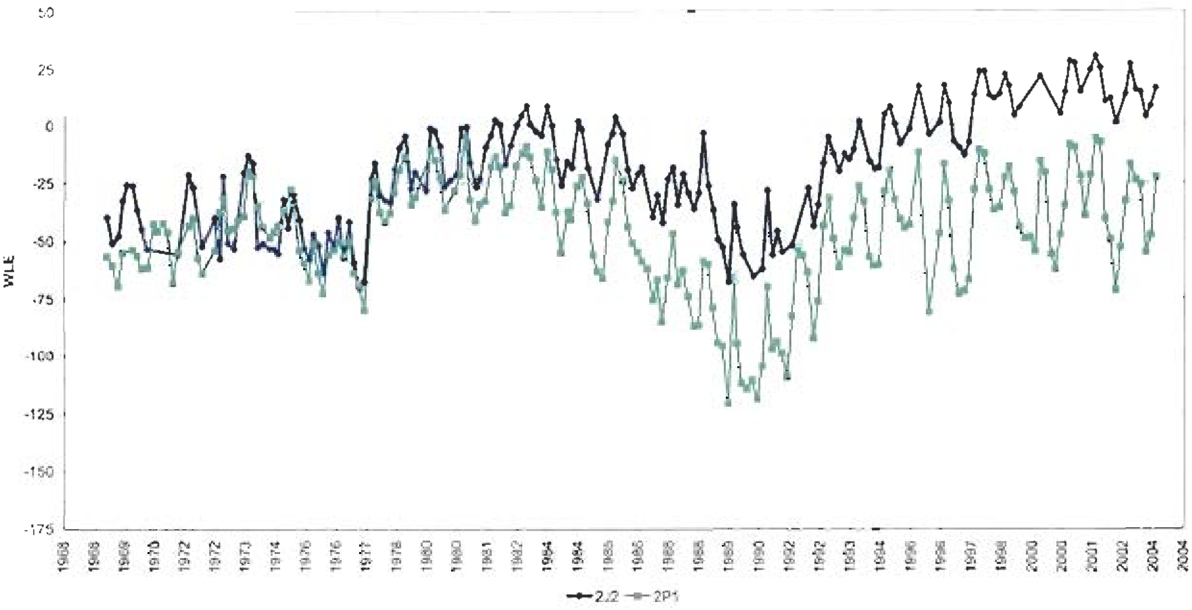


Figure 5. Water levels for 1N/21W-2J2 (UAS; RP- 91') and
1N/21W-2P1 (LAS; RP 68')



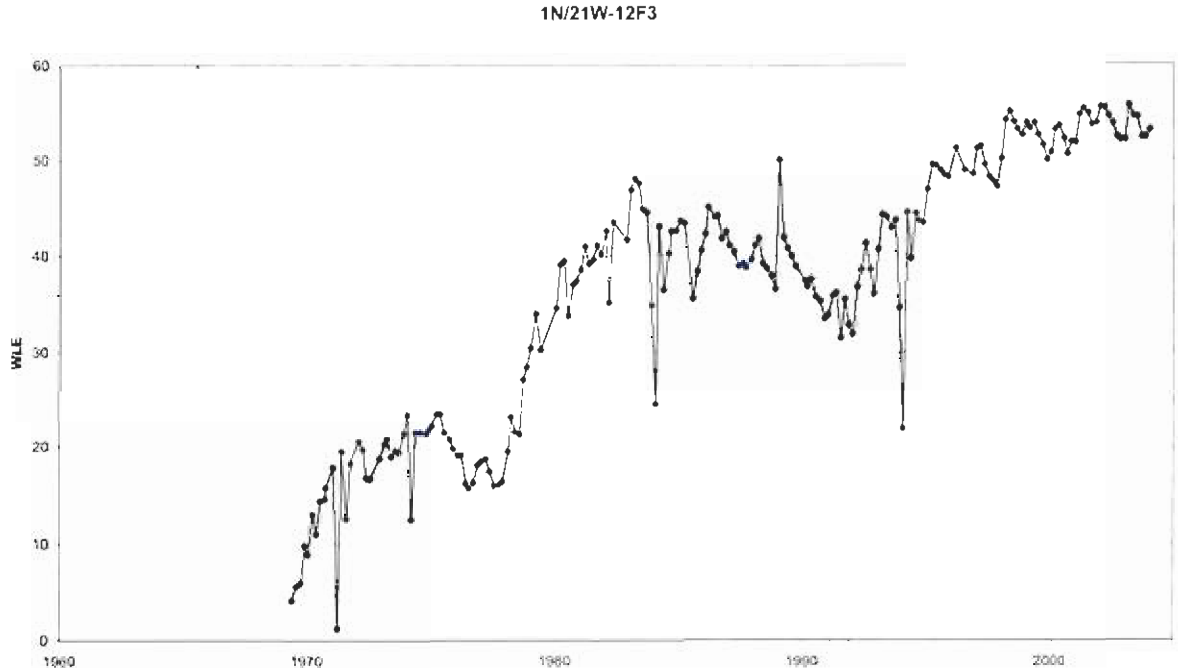


Figure 6. Groundwater Levels, Well 1N-21W-12F3

Figure 7. Calleguas Creek Discharge at University Drive (3-mo-avg); Shallow groundwater levels for wells 14A1 and 12F3

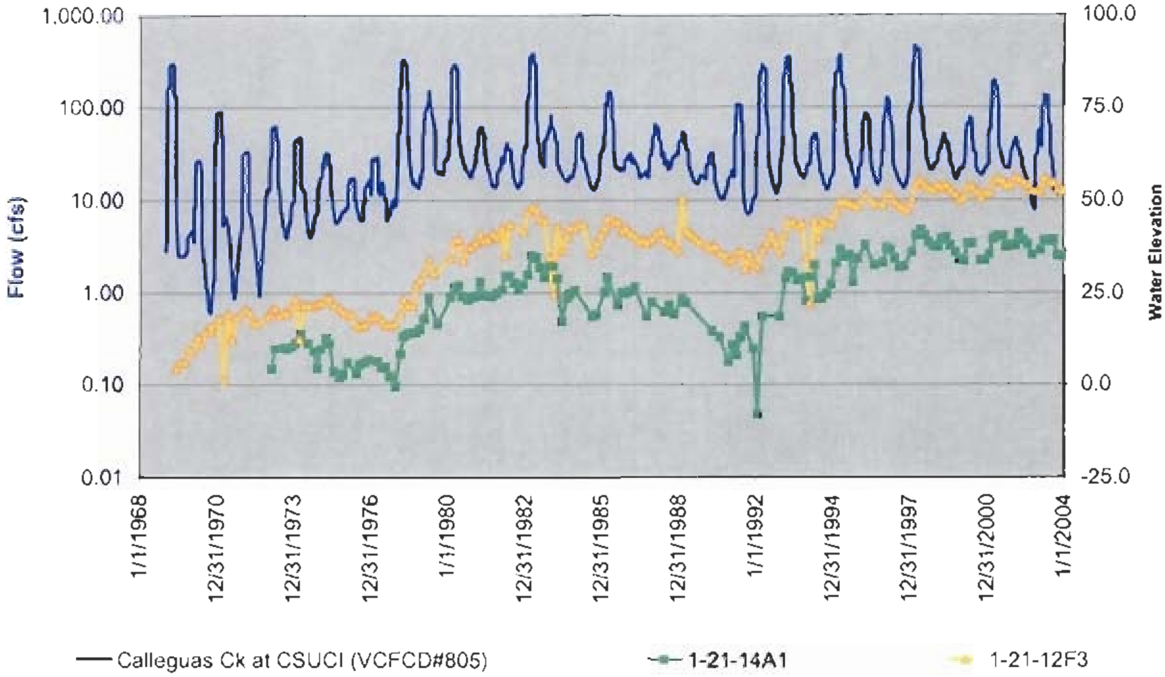
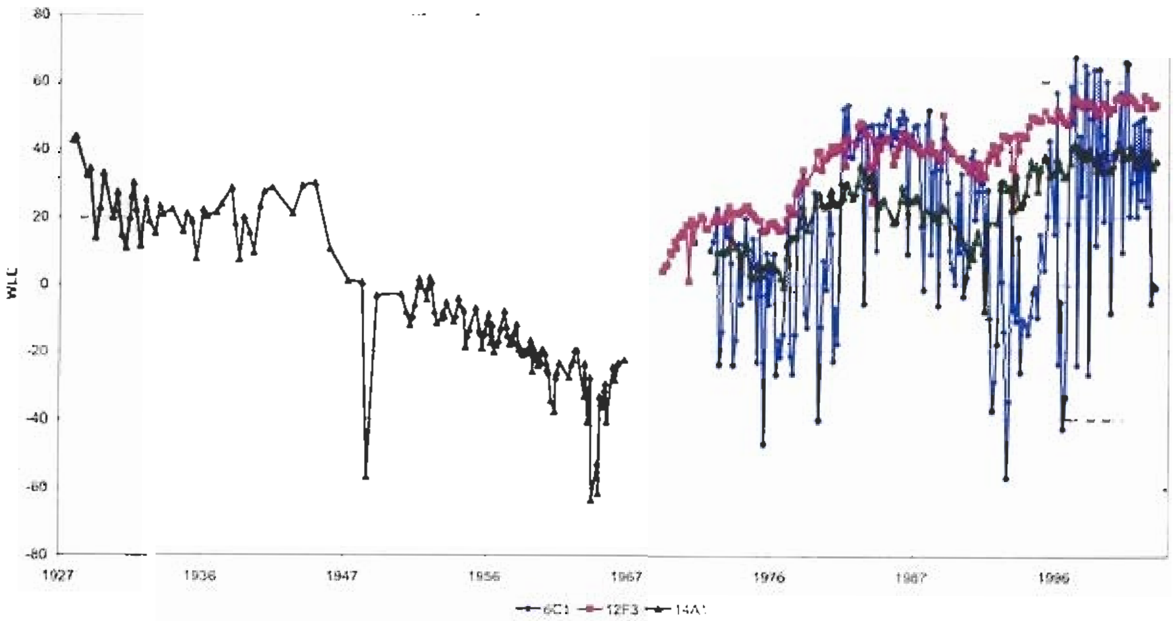


Figure 8. Water Levels for wells 1N/20W-6C1, 1N/20W-12F3, 1N/20W-14A1



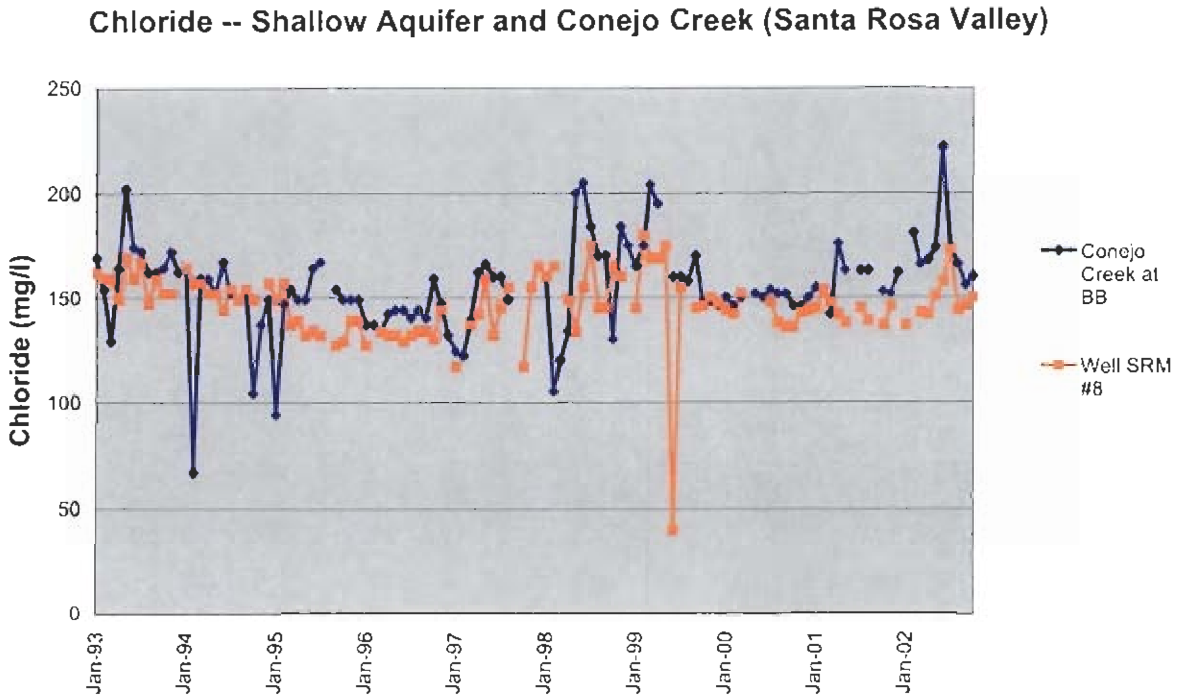


Figure 9. Comparison of shallow groundwater and surface water chloride concentrations.

Figure 10. Representative water chemistry in the eastern margin of Pleasant Valley basin (TDS concentrations; from Woodward-Clyde, 1997).

TDS concentration (mg/l) is written beneath the short well number. Numbers in parentheses describe period of record for averaged data.

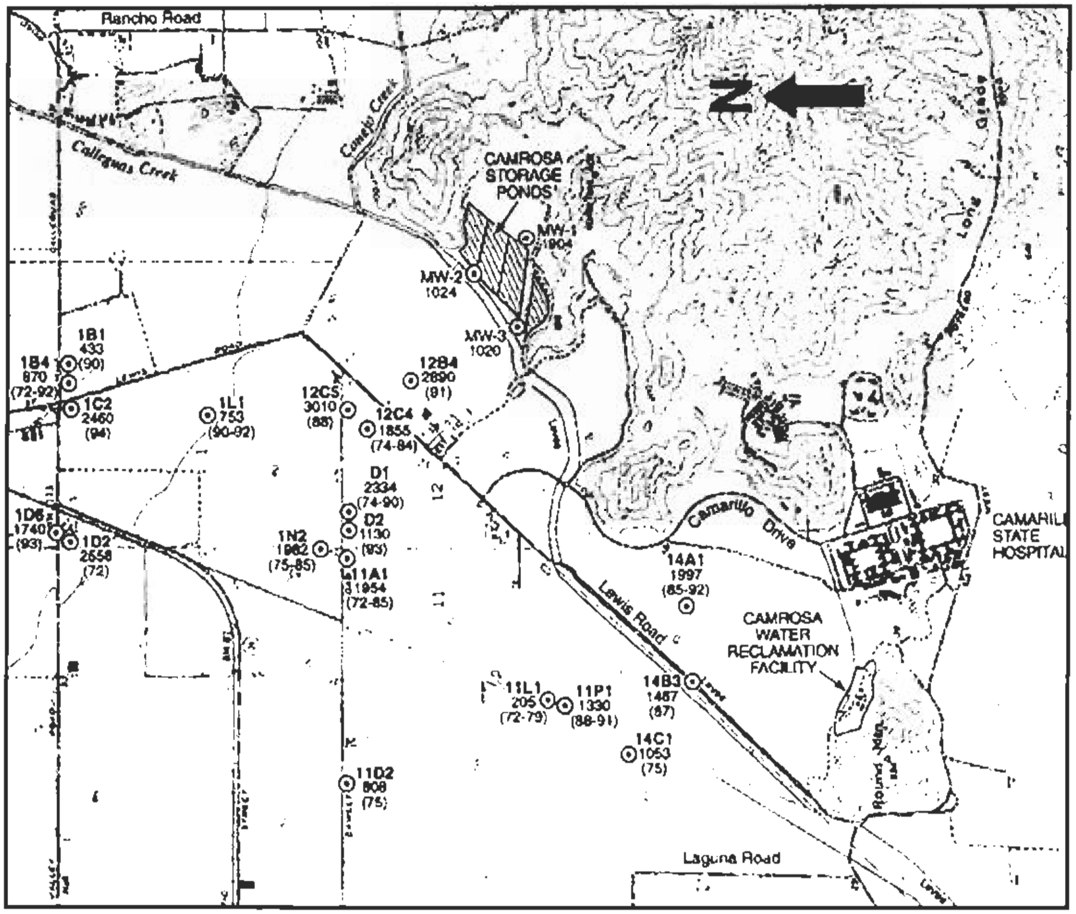


Figure 11. Location map for special study area.

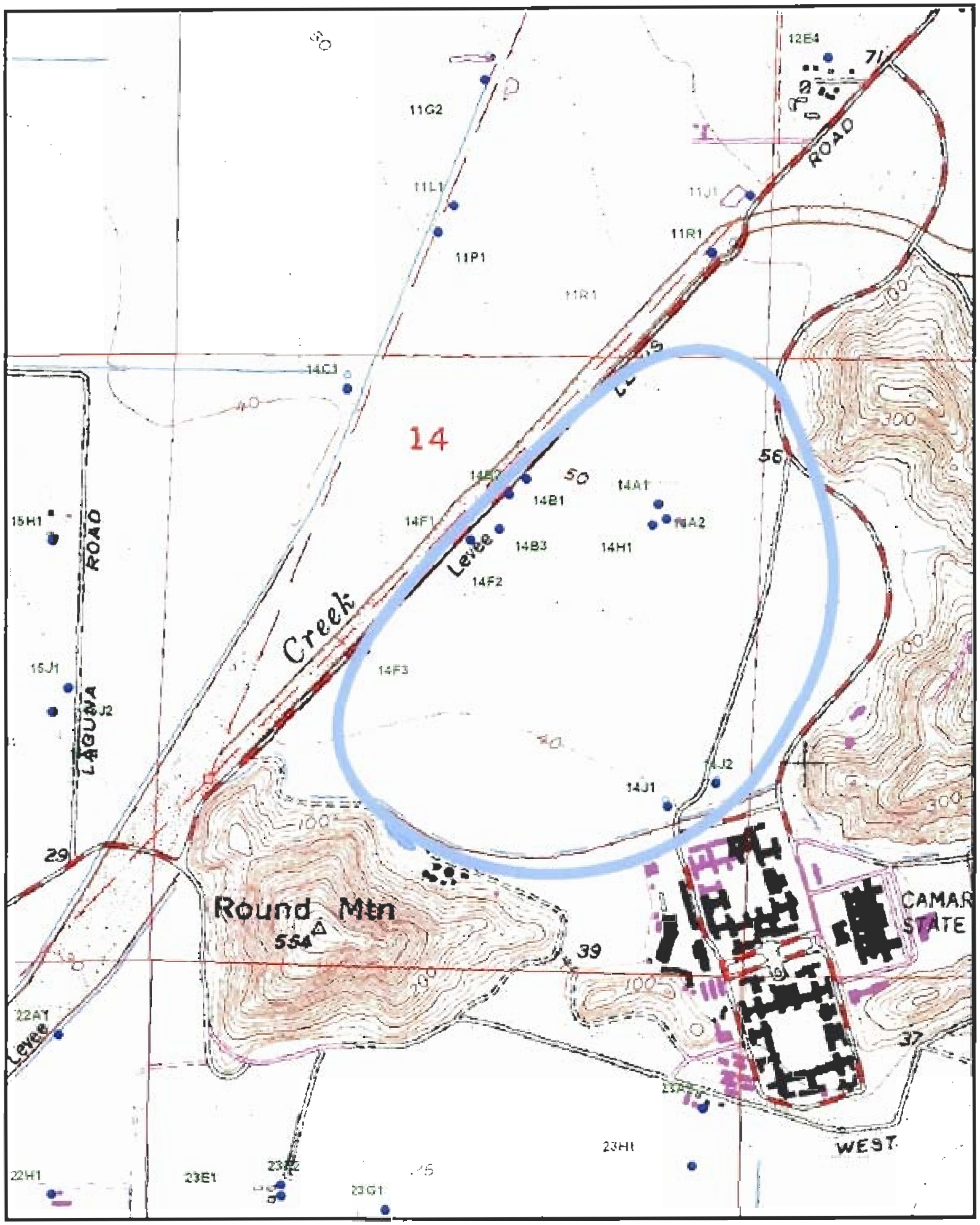


Figure 12A. Map showing schematic cross-section locations for special study area.

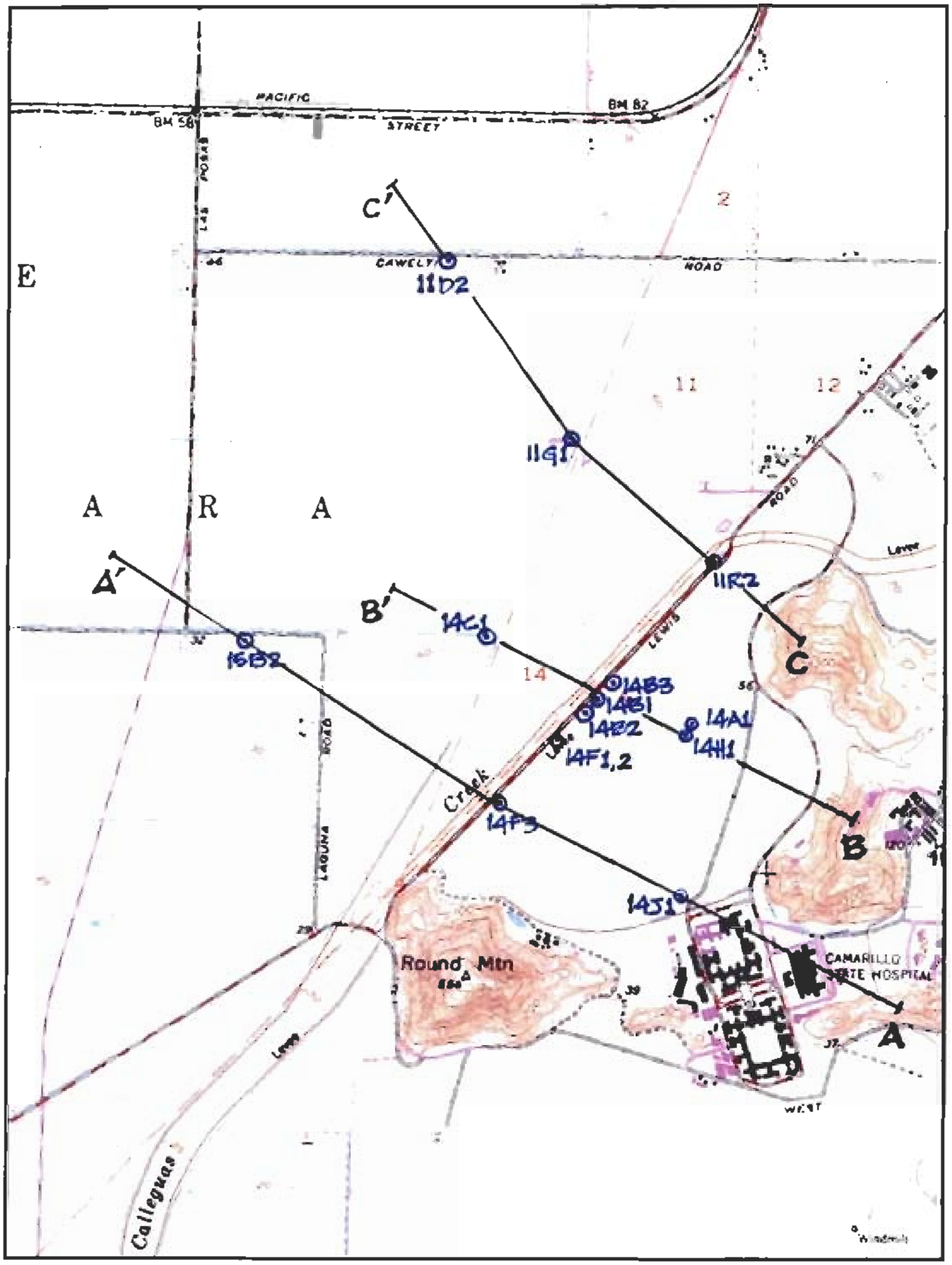


Figure 12B. Schematic cross-section A-A'. Subsurface geology is representative and schematic only; many other geometries of basement structure are possible.

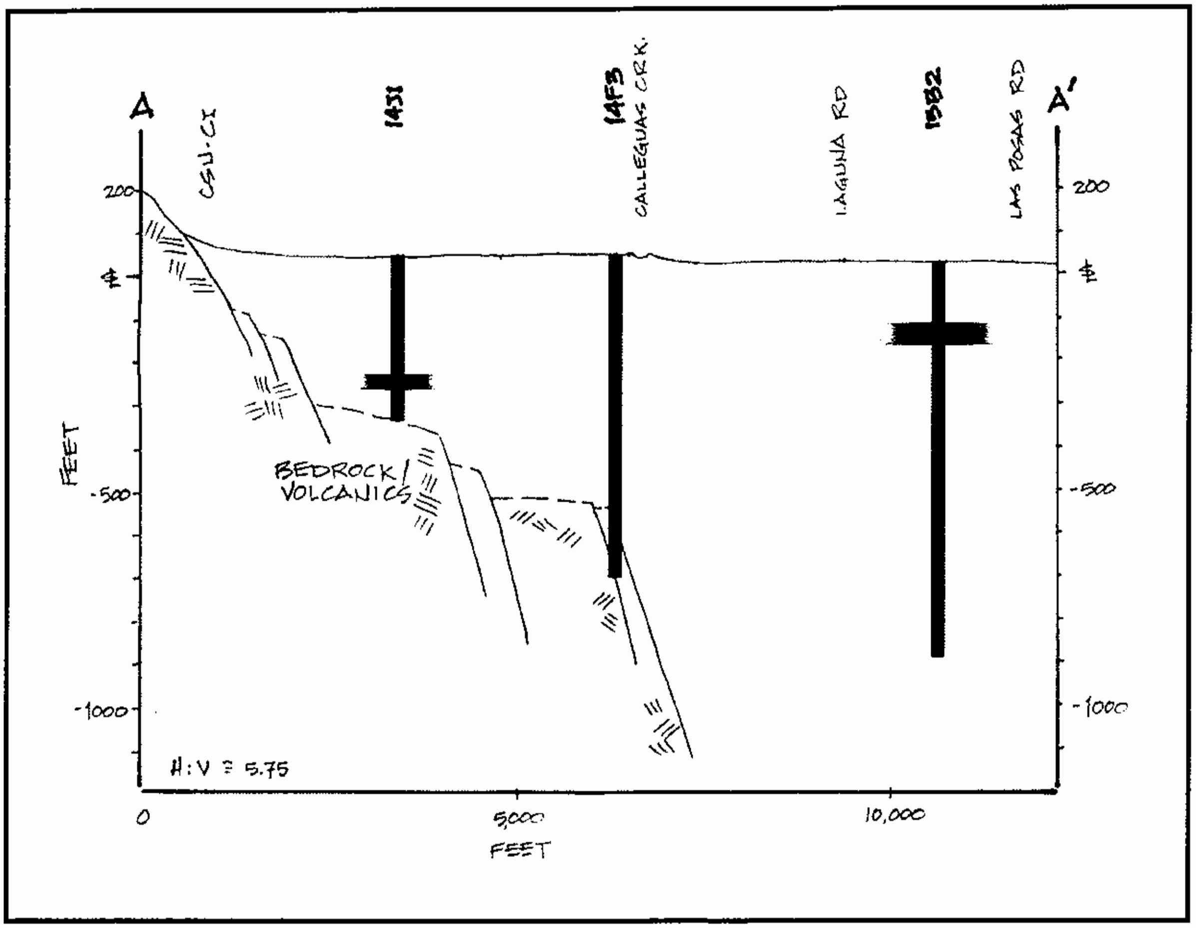


Figure 12C. Schematic cross-section B-B'. Subsurface geology is representative and schematic only; many other geometries of basement structure are possible.

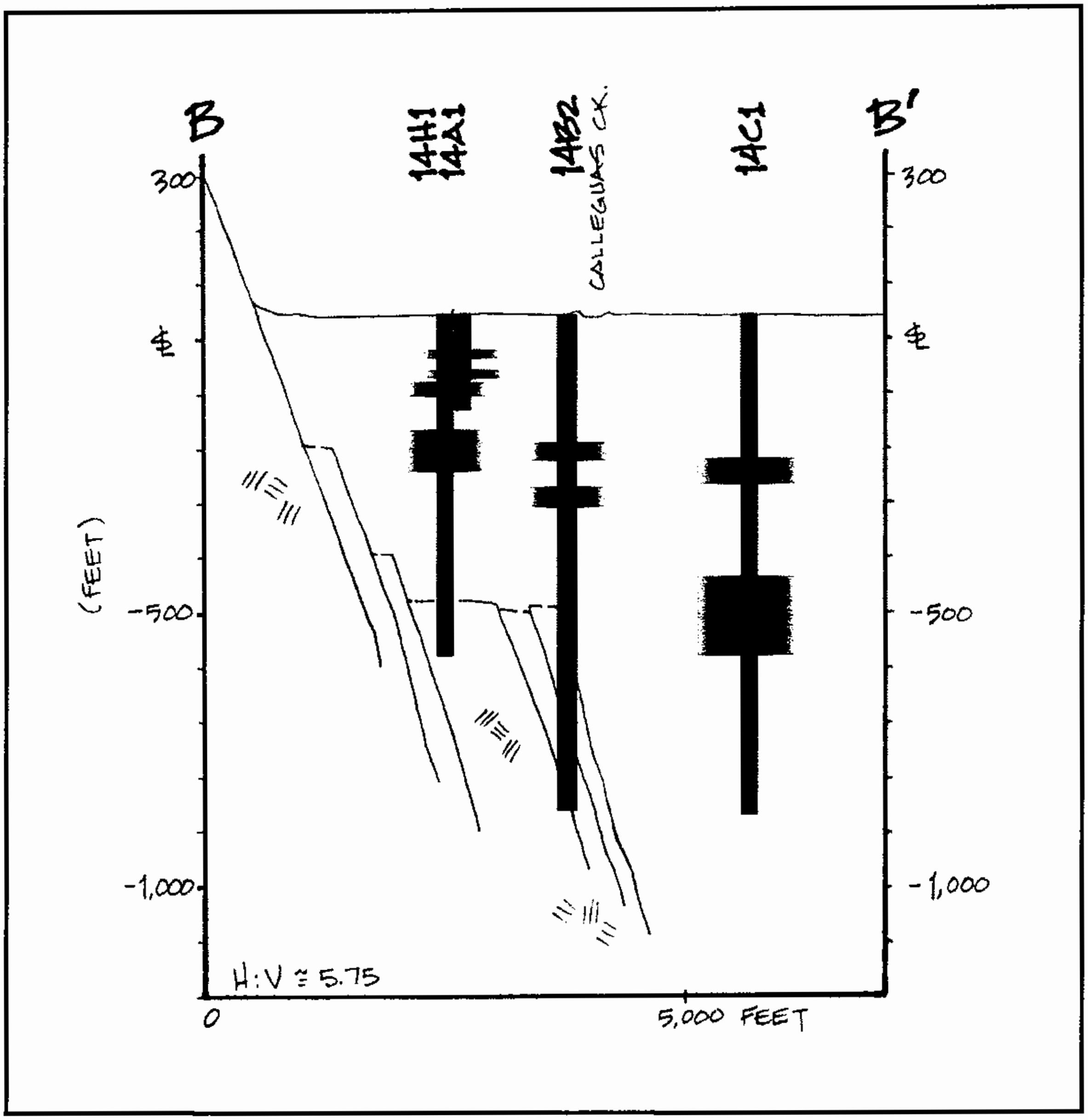


Figure 12D. Schematic cross-section C-C'. Subsurface geology is representative and schematic only; many other geometries of basement structure are possible.

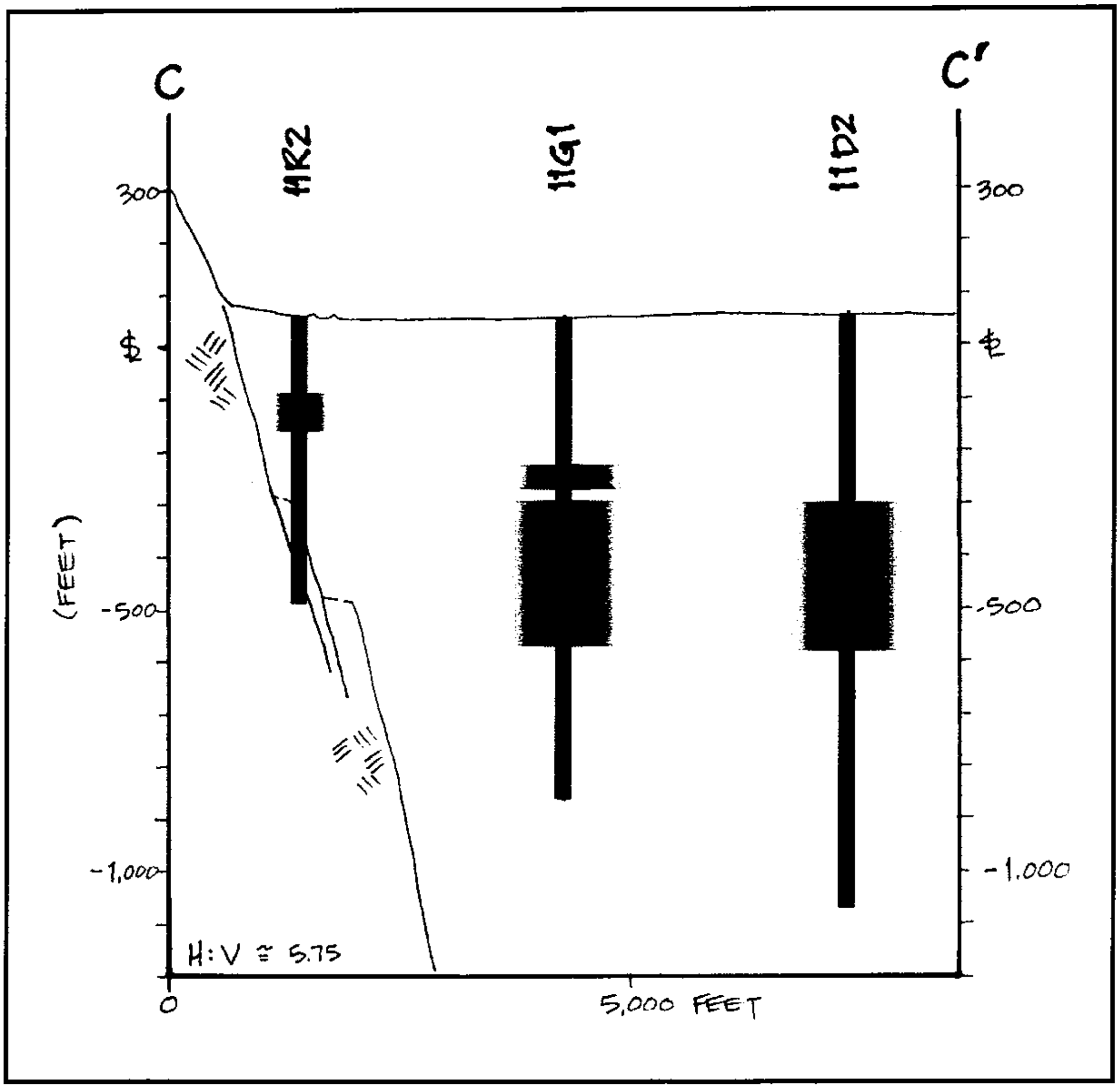


Figure 13. Chloride concentrations within and adjacent to the special study area (from Woodward-Clyde, 1997).

Cl concentration (mg/l) is written beneath the short well number. Numbers in parentheses describe period of record for averaged data.

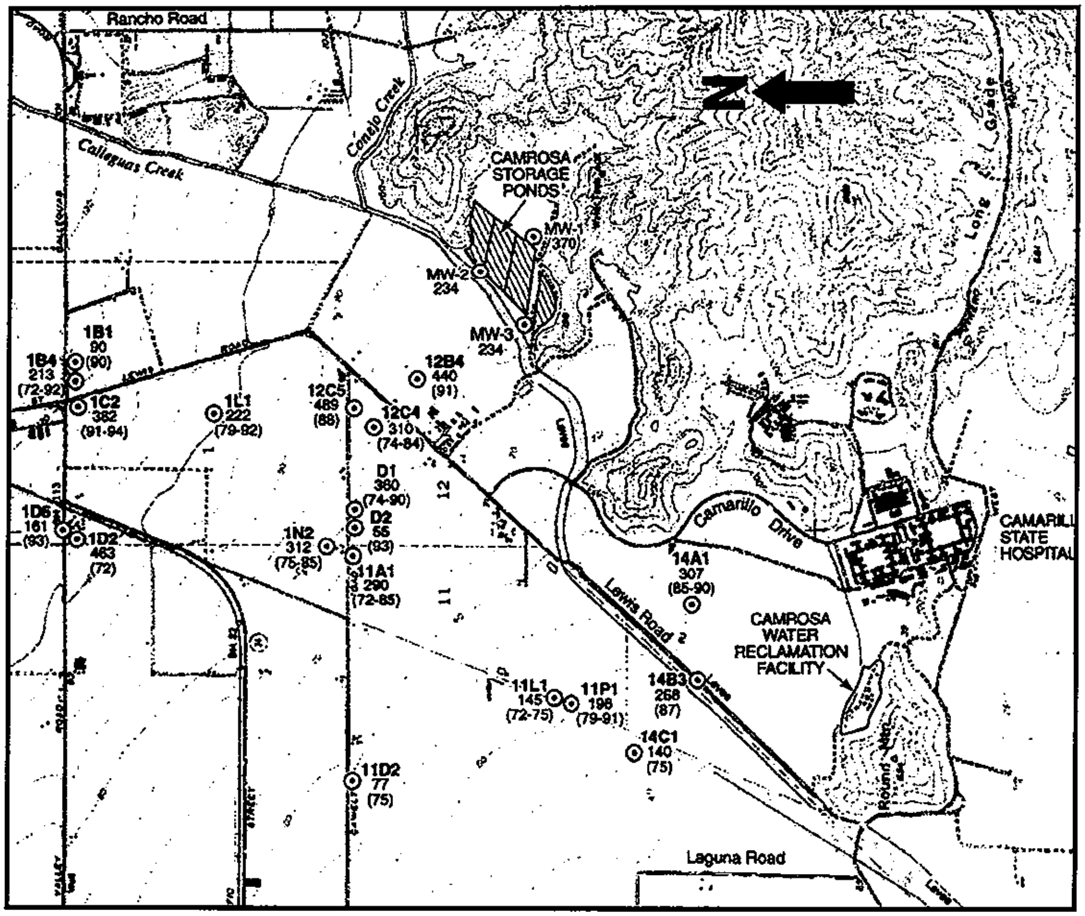


Figure 14. Groundwater levels, well 1N/21W-14A1

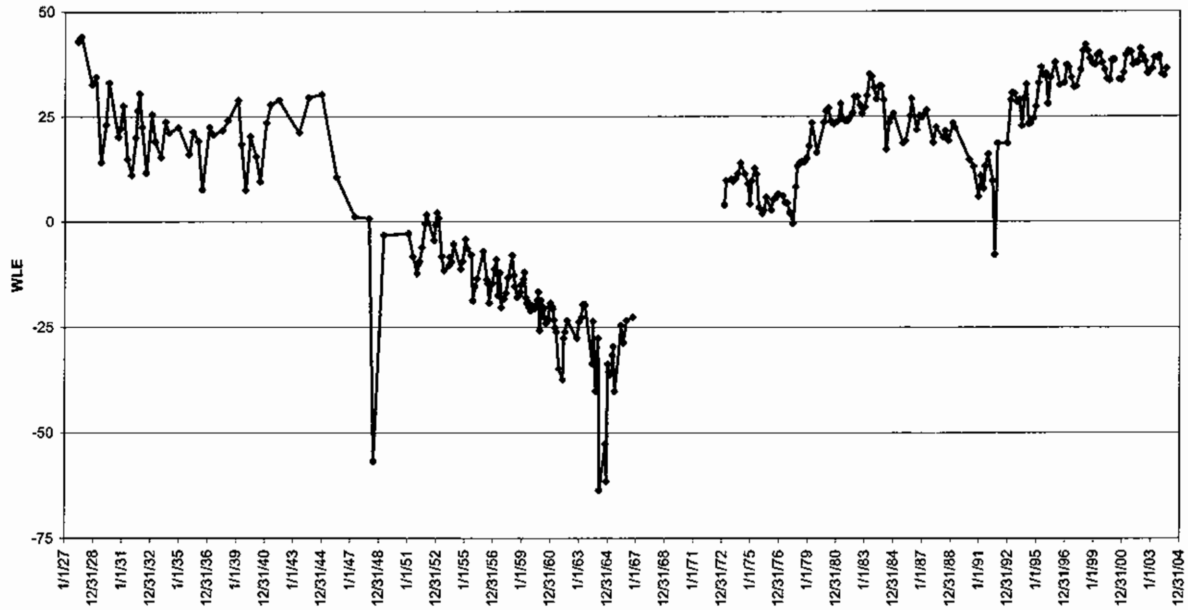


Figure 15. Depth to bedrock (ft) in special study area.

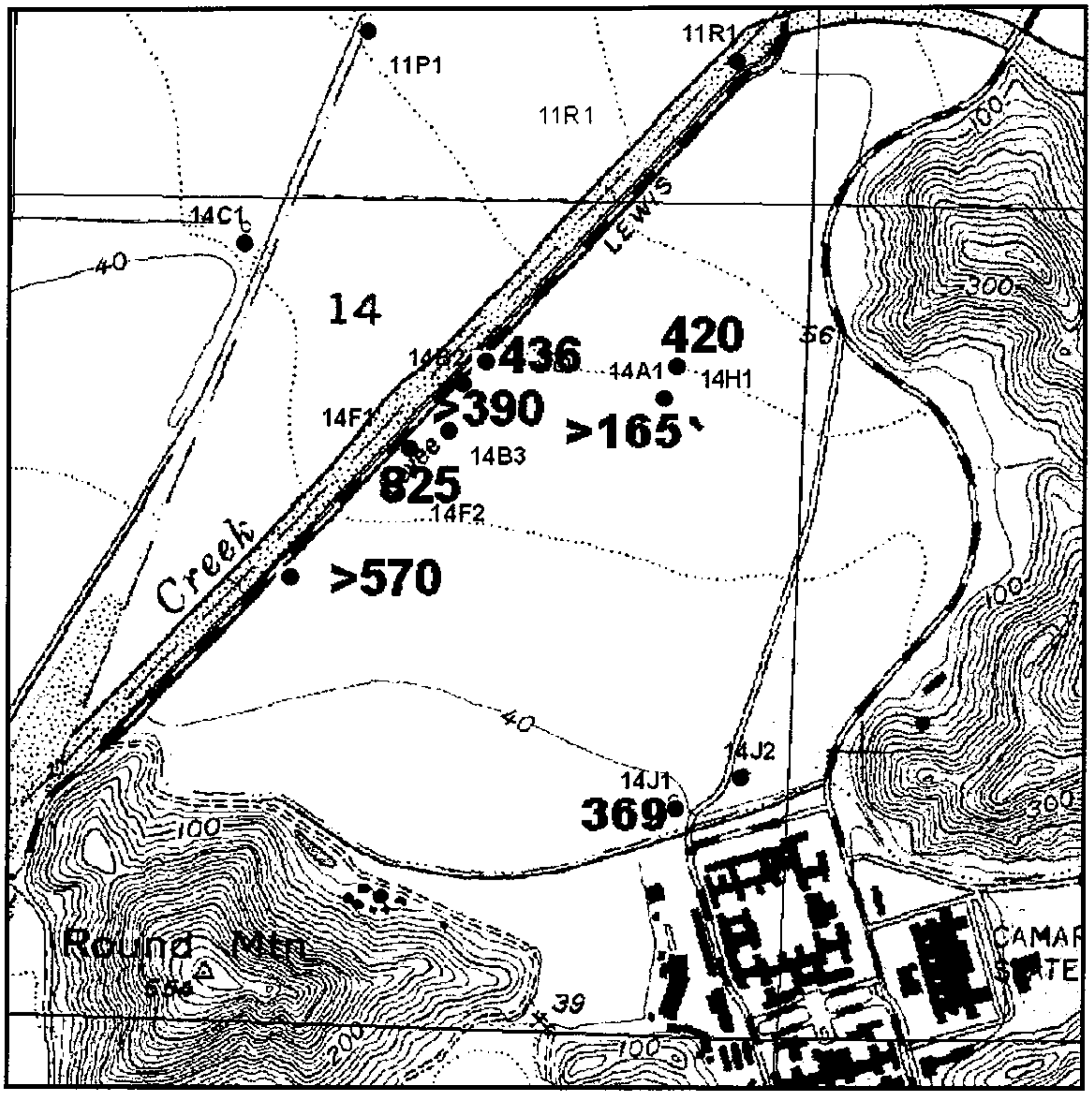


Table 1. USGS Nested Monitoring Well 1N-21W-32Q, with representative water quality.

Well Designation	*Perforation Interval (Depth)*	*Representative TDS (mg/l)*	*Representative Chloride (mg/l)*
Q6	180' - 220'	920	105
Q7	275' - 285'	5,810	2,600
Q5	330' - 370'	5,000	2,100
Q4	600' - 640'	10,700	4,900
Q3	800' - 840'	24,200	12,500
Q2	930' - 970'	6,800	3,600

Table 2. Schematic aquifer storage capacity for shallow aquifers of the special study area (sample calculations)

Calculations are based on simplifying assumptions of uniform thickness and hydraulic properties for each water-bearing horizon. The area of all aquifer materials is assumed to be approximately 200 acres for these schematic calculations.

Depth to top of water-bearing unit (ft)	***Thickness (ft)***	***Specific Yield (%)***	***Storage Capacity (acre-feet)***
Schematic Calculation 1:			
42	18	5%	180
90	12	15%	360
111	7	15%	210
118	41	25%	2,050
			2,800 Total (af)
Schematic Calculation 2:			
95	13	5%	130
155	57	20%	2,280
417	103	20%	4,120
			6,530 Total (af)
Schematic Calculation 3:			
21	53	20%	2,120
74	48	5%	480
122	9	25%	450
131	127	5%	1,270
258	5	25%	250
263	51	5%	510
314	15	25%	750
329	40	5%	400
			6,230 Total (af)

Figure A1(A). Map showing schematic cross-section locations for special study area.

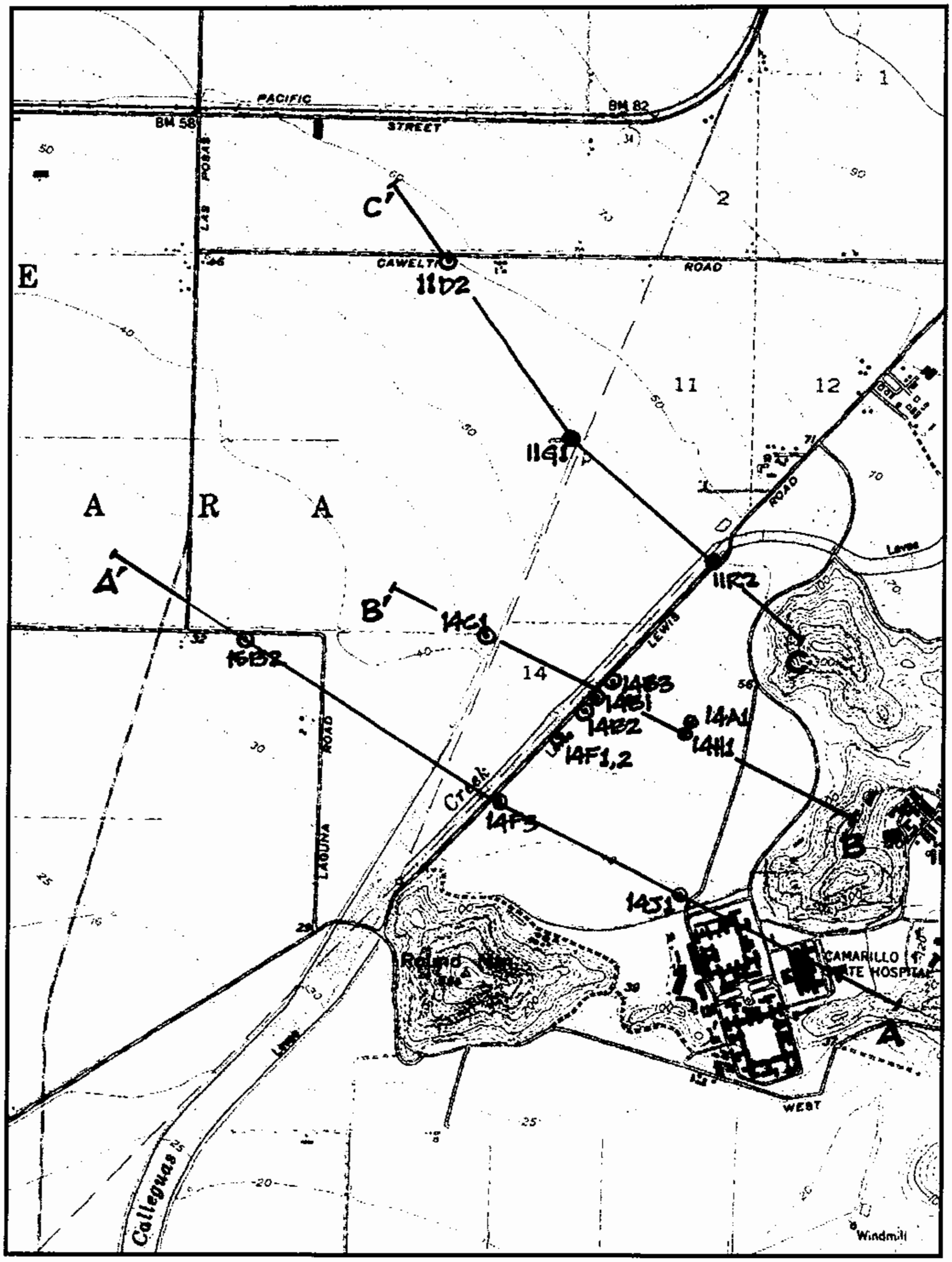


Figure A1(B). Schematic cross-section A-A'. Subsurface geology is representative and schematic only; many other geometries of basement structure are possible.

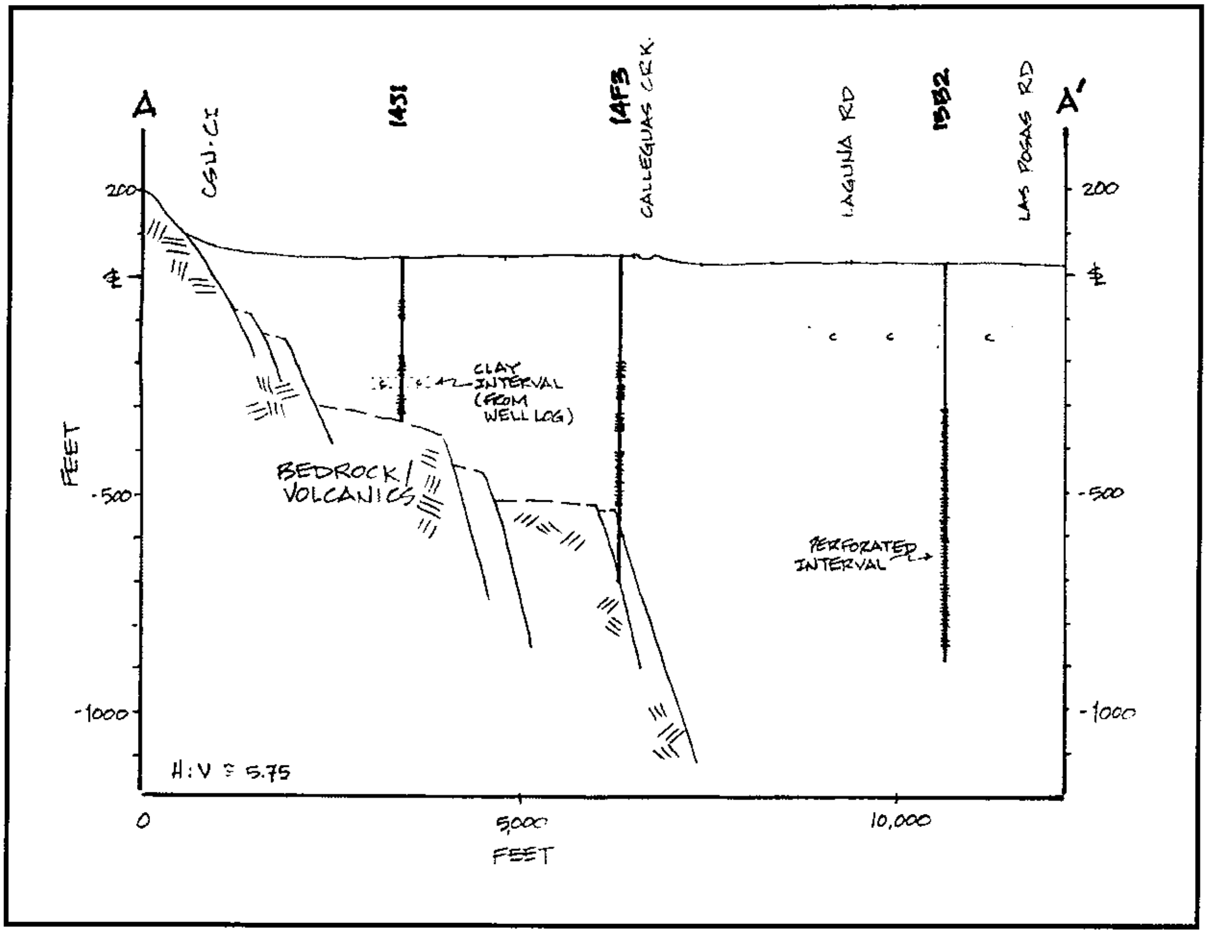


Figure A1(C). Schematic cross-section B-B'. Subsurface geology is representative and schematic only; many other geometries of basement structure are possible.

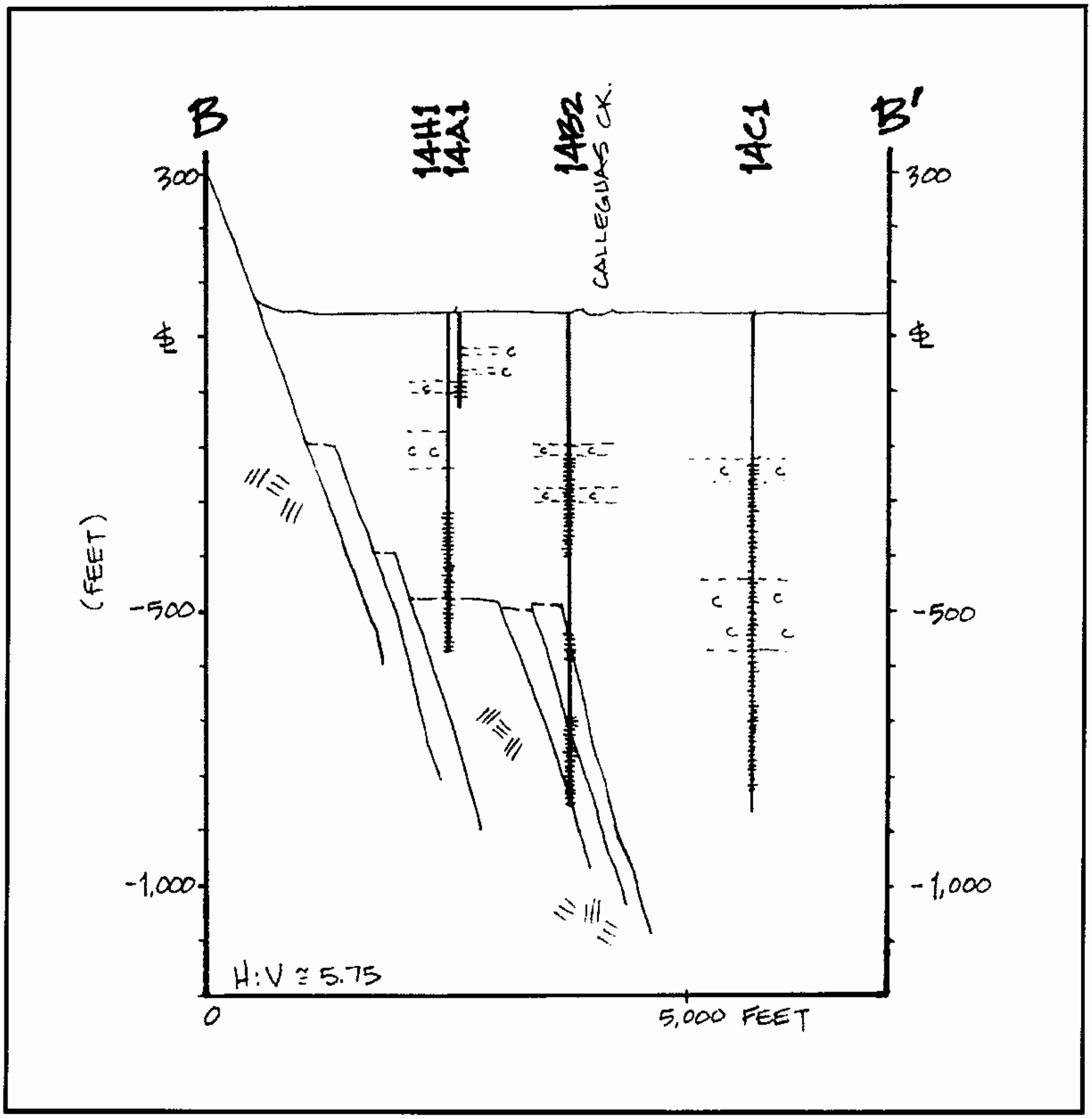


Figure A1(D). Schematic cross-section C-C'. Subsurface geology is representative and schematic only; many other geometries of basement structure are possible.