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September 29, 2008

FILE NO.
27175-02

***POSTED VIA COURT WEBSITE***

To All Counsel

Re: *Antelope Valley Groundwater Litigation*
*Santa Clara County Superior Court Case No. 1-05-CV-049053*
*Judicial Council Coordination Proceeding 4408*

Dear Counsel:

Please be advised that Anaverde's Expert Report is attached hereto and available for review. Feel free to contact me if you have any problems opening or accessing the report.

Very truly yours,

Kimberly A. Huangfu
LEWIS BRISBOIS BISGAARD & SMITH LLP

KAH:me

# Anaverde Creek Groundwater Basin Hydrologic Review

*Antelope Valley Groundwater Cases*

Superior Court of California
County of Los Angeles
(Case Nos.: BC 325 201, S-1500-CV-254-348, RIC 353 840, RIC 344 436, RIC 344 668)

EPUR, llc

September 2008

4061 SW Chesapeake Avenue, Portland, Oregon 97239-1341

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***Prepared For:***

**Anaverde, LLC**

***Prepared By:***


EPUR, llc
**Portland, Oregon**


**September 28, 2006**


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# Anaverde Creek Groundwater Basin Hydrologic Review

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## Exhibits

# Anaverde Creek Groundwater Basin Hydrologic Review

## Introduction

The Antelope Valley is currently undergoing adjudication for groundwater usage amongst various historical users. The Antelope Valley is a large structurally controlled geomorphic basin approximately 1,390 square miles in size. The area to be adjudicated was determined in November 2006 prior to Anaverde Ranch and its owners being a party to the adjudication. According to the Problem Statement Report produced by the Antelope Valley Technical Committee in late June 2008 (Antelope Valley Technical Committee, 2008) the court noted that adjacent valleys left out of the adjudication area have nominal and in some cases virtually nil flow into the Antelope Valley Groundwater Basin. The Anaverde Creek Groundwater Basin is such an adjacent valley that appears to have been incorrectly placed within the area of adjudication. The boundary of the Antelope Valley groundwater adjudication includes portions of the Anaverde Creek watershed as depicted on Exhibit 1.

Anaverde, LLC are the owners of approximately 2,000 acres of land located five miles southwest of downtown Palmdale, California. The property referred to as the Anaverde Ranch has a street address of 2710 Elizabeth Lake Road, Palmdale, California. The location and size of the property is depicted on Exhibit 2 along with the watershed and adjudication boundaries. This parcel is located within and extends slightly to the north of the Anaverde Creek Groundwater Basin.

## Anaverde Creek Watershed and Groundwater Basin

The watershed of the Anaverde Creek is approximately 16 square miles. It is defined by ridge tops in the Pelona Mountains to the south, west, and east and by both the San Andreas Fault and the proximate Ritter Ridge to the north. Exhibits 3A, 3B, and 3C provide oblique views of the watershed looking across these physiographic features that define the Anaverde Creek Watershed. The watershed is approximately 10,260 acres in total drainage.

There are many groundwater wells located in the Anaverde Creek Groundwater Basin and nearby in the Antelope Valley Groundwater Basin. Some of these for which location information and data could be located are depicted on Exhibit 4.

Anaverde Creek is a named feature on topographic maps of the area. It could be more aptly named as the Anaverde Arroyo or Anaverde Watercourse as it does not contain surface water except during large rainfall events. The upper watershed and lower watershed do not carry surface water the vast majority of the time making it an ephemeral creek. The Anaverde Creek Watershed carries open surface water flow off of the property and into the Antelope Valley when the arroyo fills with water and a modest amount of surface water flows out into the Antelope Valley to infiltrate or to be lost there to evapotranspiration. This storm-related surface-water outflow does not connect the two groundwater basins.

Notably, the lower watercourse of Anaverde Creek is a perennial verdant wetland. This is unusual given the dry desert climate of the area. This wetland exists on the Anaverde Ranch property as a result of groundwater base flow that is forced to the surface by the local topography and geology.

The Anaverde Creek Groundwater Basin is a separate and distinct groundwater basin from the Antelope Valley groundwater basin. While the Anaverde Creek Watershed sits within the overall Antelope Valley surface-water watershed, the Anaverde Creek Groundwater Basin is not hydraulically connected to the Antelope Valley Groundwater Basin and does not contribute a meaningful amount of groundwater to the Antelope Valley Groundwater Basin. This report documents some of the data and analysis that support this statement.

### *Topography and Climate of Anaverde Creek Watershed*

The Anaverde Creek Watershed sits in the Sierra Pelona Mountains. The Sierra Pelona Mountains are a rocky transverse range in Southern California. The mountains extend from Interstate 5 at Gorman, to the Antelope Valley Freeway at Vincent. The Sierra Pelona Mountains are bordered by San Gabriel Mountains to the south, Santa Clarita Valley to the southwest, San Emigdio Mountains to the northwest and the Antelope Valley to the north and northeast. The Sierra Pelona Mountains are often considered to be part of the San Gabriel Mountains, but the two are separated by the Soledad Canyon to the south that connects the Santa Clarita and Antelope valleys.

The topography of the Anaverde Creek Watershed is relatively steep. The summit of the watershed in the SW corner is at elevation 5,180 feet and the outlet of the watershed in the NE corner is at approximately 2,750 feet. Grade elevation changes across a distance of approximately 7 miles. This results in an average grade profile of 6% across the watershed.

The climate of the Anaverde Creek Watershed varies substantially with altitude. Rainfall averages range from 18.4 inches in the high elevation areas to 8.8 inches in the lower elevation areas that include the Anaverde Ranch property (Datasource: PRISM Group at OSU, 2006). Snow is frequent in the high areas of Sierra Pelonas during the winter enabling greater infiltration of water to the subsurface. Rainfall is characterized by low frequency storm events. The climate is considered semi-arid with day time temperatures in the winter averaging roughly 45 degrees Fahrenheit and summer average temperatures exceeding 80 degrees in July and August (NCDC, 2008).

## *Geology of Anaverde Creek Watershed and Anaverde Ranch Property*

The geology of the Anaverde Creek Watershed has been mapped in detail as part of the work by Thomas Dibblee of the U.S. Geological Survey (Dibblee, 1997). Exhibit 5 depicts the geology of the Anaverde Creek Watershed and Groundwater Basin with the Anaverde Creek Watershed boundary superimposed and the Anaverde Ranch property boundary superimposed.

The Anaverde Creek Watershed is located at the southwestern boundary of the Antelope Valley hydrologic basin. The Anaverde Creek Watershed is located within the Transverse Range geomorphic province of California. This is in contrast to the Antelope Valley Basin which is characterized as the Mojave Desert geomorphic province of California. The Transverse Range geomorphic province is characterized by numerous mountain ranges and intervening structurally-controlled alluvial-filled basins. The Anaverde Creek Groundwater Basin is a structurally-controlled alluvial-filled and other-forms-of-sediment-filled basin.

The geologic structural controls on the Anaverde Creek Groundwater Basin include two named faults depicted on Exhibit 5. The Nadeau Fault and the San Andreas Fault. The San Andreas Fault is a major strike-slip right-lateral fault. Exhibit 6 depicts three major fault types and the sense of movement on them. A right-lateral strike-slip fault indicates that if one was to look across the fault zone that the sense of movement of land on the other side of the fault is to the viewer's right. The San Andreas Fault has a large offset due to its age and magnitude of movement; the central section of the San Andreas Fault is estimated to be over 30 million years old and the southern section of the San Andreas Fault is estimated to be at least 12 million years old in this region. The offset is in some cases over 100 miles. This brings geologic material of different type and origin in juxtaposition across the San Andreas Fault zone. This appears to be the case at the Anaverde Ranch property as rocks that were deposited 5 million years ago, the Anaverde Formation (Tas, Tar, and Tac on Exhibit 5) are juxtaposed along the fault against rocks that were deposited 65 million years ago or more, the Pelona Schist (ps on Exhibit 5). The Nadeau Fault appears to be a small local sister fault to the San Andreas that appears be a right-lateral strike-slip fault along with being a thrust fault. The Nadeau Fault's presence on the Anaverde Ranch property is marked by a small spring and pond at the break in slope roughly where bedrock meets alluvium in the southern portion of the Anaverde Ranch property. It is also noted by a geologic discontinuity where the Nadeau Fault exits the Anaverde Creek Watershed.

The most notable result of the faulting on the Anaverde Ranch property is the presence of metamorphosed granite and quartz monzonite on the north side of the San Andreas Fault (qm and qd on Exhibit 5). This rock type is exposed on the ridge that forms the northern limit of the Anaverde Creek Watershed. This low permeability basement rock likely acts as a hydraulic dam that is thousands of feet in dimension laterally and vertically. Groundwater from the Anaverde Creek Groundwater Basin appears to be forced to the surface on the Anaverde Ranch property by both the effects of the fault structures themselves within geologic formations and by the juxtaposition of low-low permeability rock across the fault from more permeable sandstone (Anaverde Formation) and younger alluvium.

The higher elevation areas of the Anaverde Creek Watershed are underlain by low permeability bedrock, principally the metamorphic Pelona Schist. To the east in the watershed the higher elevation areas consist of metamorphosed quartz monzonite and quartz diorite that form a gneiss complex. The transition to the alluvial area on the Anaverde Ranch property at the foot of the steeper bedrock terrain is subparallel to the aforementioned Nadeau Fault.

The lower elevation areas of the Anaverde Creek Watershed are principally alluvial deposits with adjoining sandstone and claystone, the Anaverde Formation, to the north. The Anaverde Formation is a mixture of non-marine sedimentary rocks of Pliocene age (~2 to 5 million years old). The Anaverde Formation contains a clay-shale unit and two sandstone units, one with gravel conglomerate and one with just sand. The alluvial material has been characterized as alluvial fan deposits of gravel, silt and sand. Dibblee segregated the alluvium at the Anaverde Ranch property into alluvium and older alluvial fan deposits. The alluvium generally consists of dense to very dense sand and silty sand deposits with some gravel. The older alluvial fan deposits consist of silt, sand, and gravel that range from reddish brown to yellowish brown. The older alluvium reportedly has been slightly uplifted and dissected according to the Dibblee geologic map of the area.

Water-supply well logs from the Anaverde Ranch property in the lower elevation areas suggest alluvial and colluvial material to depths of 299 feet or more. Recent drilling for lithologic information at the Anaverde Ranch property (Summit, 2008) demonstrates a fine-grained silt and clay sequence at the land surface to a depth of approximately 25 feet followed by interbedded silty sand layers and other alluvial material to a depth of 299 feet. Below 299 feet the recent borehole encountered weathered bedrock, regolith, of apparent Pelona Schist to a depth of 394 feet. At 394 feet competent bedrock of Pelona Schist was encountered and the boring terminated.

## *Historic Aerial Photos Review of Anaverde Ranch Property*

Review of historic aerial photos of the Anaverde Ranch property from 1928 to 1957 demonstrates that it was in use as agricultural land during those years. Aerial photos from 1928 show two buildings on the Anaverde Ranch property. These coincide with the buildings shown on the Ritter Ridge 7.5'USGS Quadrangle Topographic Map of the area; they are designated as "City Ranch" on the Quad Map. The property and the adjoining property to the west appear to have fence lines up as would be used for livestock grazing. Additionally aerial photographs from 1928 demonstrate a line of trees growing along the apparent trace of the Nadeau Fault at the base of the hills.

Aerial photos of 1940 indicate that planting of crops has been done to the west of the City Ranch buildings on the present Anaverde Ranch property; small trees appear to be present in a regular geometric pattern. Furthermore aerial photographs of 1940 demonstrate a large wetland area on the valley floor of the Anaverde Creek Watershed with several hundred acres of verdant growth.

Aerial photos of 1949 and 1957 indicate a different form of crop agriculture across the western and southern areas of the Anaverde Ranch; the pattern of planting is consistent with grain or alfalfa production with mechanized harvesting indicated by the pattern of planting. Also observed in the aerial photographs in 1949 and 1957 is what appears to be sand and gravel or other open-pit rock quarrying just east of City Ranch along the Anaverde Creek watercourse.

# Hydrogeologic Conceptual Model of Anaverde Creek Groundwater Basin

A hydrogeologic conceptual model describes at a broad scale how the surface and groundwater hydrology of a watershed interact with the local geologic regime to allow for the movement of water. The hydrogeologic conceptual model of the Anaverde Creek Groundwater Basin is depicted on Exhibit 7.

The important water bearing units of the Anaverde Creek Groundwater Basin are the alluvial deposits in the valley fill and the underlying and adjoining tertiary age sandstone and conglomerate units of the Anaverde Formation. The hydrogeologic conceptual model depicts upslope recharge to the groundwater basin from the mountains and foothills. The elevated groundwater moves downgradient into the young and old alluvium and into the Anaverde Formation. The groundwater within these permeable geologic units is retained or restricted on the property behind two or more faults that cross the groundwater basin. These faults, the Nadeau Fault and the San Andreas Fault, force the groundwater to the surface both by the sealing action of the faults and by the offset of low permeability basement rock across the down slope mouth of the basin. The groundwater then discharges to the surface as ponds or wetlands and that water is consumed by plant evapotranspiration on the property as there is no perennial flow of surface water in Anaverde Creek.

Groundwater recharge is estimated to occur during the wet months of November to March when average rainfall exceeds potential evaporation. The balance of the year evaporation exceeds average rainfall and little or no net groundwater recharge is estimated to occur.

## *Relationship of Fault Structures*

Geologic faults generally restrict the lateral movement of groundwater. Exhibit 8 depicts a normal fault and a strike-slip fault and the general relationship of groundwater movement across each type of fault. A strike-slip fault like the San Andreas Fault can both restrict the lateral migration of groundwater perpendicular to the fault's strike and enhance the vertical movement upward of water due to the disruption of sedimentary beds within and adjacent to the fault zone. Both these effects on groundwater movement from a strike-slip fault appear to be present on the Anaverde Ranch property. Groundwater is effectively dammed up behind the fault by the granitic basement rock in a manner highly analogous to a surface-water dam. This is demonstrated by the large hydraulic head drop laterally across the San Andreas Fault from the Anaverde Groundwater Basin to the Antelope Valley Groundwater Basin. Further the groundwater is also aided in reaching the surface and near-surface by vertical flow paths from the tearing of the soil and rock fabric by the lateral movement of the fault along vertical or near-vertical (85 degree) fault planes; this is demonstrated by the absence of a vertical head difference between wells on the Anaverde Ranch screened at different depths in the alluvial material. Adjacent wells with a total depth of roughly 50 feet below ground surface (bgs) and 200 feet bgs show the same groundwater elevation.

USGS Open File Report 67-21 by R.M. Bloyd (Bloyd, 1967) provided a reconnaissance level overview of groundwater basins in the Antelope Valley, the fault structures there, and their behavior. It found that some of the faults restricted groundwater movement and some did not. It should be noted that Bloyd and others have omitted the Anaverde Creek Groundwater Basin from the Antelope Valley Groundwater Basin assessments. Exhibit 9 from Bloyd transects the western Antelope Valley from bedrock uplands through the alluvial valley and back to bedrock uplands within the basin. This is analogous to the Anaverde Creek Groundwater Basin. Bloyd depicts the offset of groundwater elevations across these faults as being very large.

Exhibit 10 depicts in plan view the same phenomena as Bloyd depicted in section view. The limited movement of groundwater across a low permeability fault zone produces a refraction of flow-lines or streamtubes across the fault. While some modest quantity of flow crosses the fault in this depiction it is insignificant to the basin beyond as demonstrated by both the angle of refraction and the corresponding size of the streamtube downgradient of the fault. Note that this depiction does not account for vertical losses due to enhanced evapotranspiration. If the groundwater contours reach the surface elevation or near surface plants and evaporation will reduce the quantity of water within a streamtube. In the case of the Anaverde Ranch property most if not all of the groundwater flow that may cross the fault is lost to evapotranspiration.

## *Groundwater Elevation Data*

There are 10 existing groundwater wells located on the Anaverde Ranch property that have been identified. Exhibit 11 provides their location and names. Ten of these wells were outfitted with electronic water-level reading equipment in July 2008. Groundwater elevation data for the Anaverde Creek Groundwater Basin has been collected by Summit Envirosolutions since early August 2008. Exhibit 12 depicts ambient groundwater elevations at these 10 existing well locations from August 22, 2008. These 10 wells were sounded for total depth; five wells appear to be screened to approximately 50 feet bgs and five wells appear to be screened to approximately 200 feet bgs. The groundwater elevation data from these wells indicate groundwater is above a north-northeasterly flow direction. Groundwater elevations are higher above the inferred area of the Nadeau Fault and decline rapidly in the alluvium down slope of that fault.

An exploratory borehole completed by Summit Envirosolutions in September 2008 to a depth of 396 feet is to be converted to a groundwater production well if testing indicates the aquifer in that area can efficiently produce water.

## *Estimated Annual Groundwater Recharge to Anaverde Creek Groundwater Basin*

A working estimate of the annual groundwater recharge to the Anaverde Creek Groundwater Basin is 1,209 acre-feet/year. Using the area weighted average precipitation data from PRISM, one gets an average of 14.14 inches/year of rainfall across the watershed or approximately 1.2 feet/year. Applied over the entire 10,260 acres of the watershed this equals 12,090 acre-feet/year of water. A working estimate of 10% of rainfall as groundwater recharge is supported by soil moisture retention estimates for the climate in the region. This produces a working estimate of 1,209 acre-feet/year of groundwater recharge each year on average in the Anaverde Creek Groundwater Basin.

## *Evapotranspiration of Water at the Anaverde Ranch Property*

An estimate was prepared of the consumptive use of water by the verdant plants on the lower portions of the Anaverde Ranch Property using the Blaney-Criddle method (Blaney and Criddle, 1962). An areal estimate was made of the verdant area from georeferenced aerial photography from 2005 of the property area. It is estimated that 276 acres of the property is supplied with sufficient water from below to keep it green year round. Exhibit 13 depicts this verdant area of the Anaverde Creek Groundwater Basin.

Plant evapotranspiration is one of the major consumptive uses of water in the hydrologic cycle. Plant evapotranspiration is the principal fate of groundwater in the Anaverde Creek Groundwater Basin. Exhibit 14 is an enlargement of the hydrologic conceptual model for the basin. It demonstrates the upwelling of groundwater near the fault and bedrock structures in the low lying areas of the basin. This brings the groundwater table at and near the surface in these verdant areas. Drilling by Summit Envirosolutions revealed evidence of active root systems to a depth of 20 feet at the margin of the verdant area.

The effect of evapotranspiration on groundwater levels in the Anaverde Creek Groundwater Basin has been observed in the field. Exhibit 15 depicts data collected in August 2008 from 4 existing groundwater wells at the property and an on-site barometric pressure and atmospheric temperature recorder. There is a diurnal fluctuation in each of three wells located in the verdant area, Wells 5, 6, and 8. It correlates to the daily peak temperature. Conversely, the same is not seen for Well 4 located outside the verdant area; for Well 4 it is observed that water elevation changes inversely with barometric pressure and not with air temperature. This data demonstrates the daily pumping of groundwater by the wetland plant life.

A consumptive use estimator from the Arizona Dept. of Environmental Quality that uses the Blaney-Criddle method for modeling plant consumptive use of water was utilized to estimate net evapotranspiration from the verdant areas in the basin. Exhibit 16 depicts the results of this analysis. The estimator is built to allow for consumption of water in an arid environment by grasses; it defaults to Bermuda grass and Rye grass as the plant types for consumptive use. It also allows for trees as consumptive users in addition to the grass. The average monthly temperature and rainfall data for the area was input (NCDC, 2008) and the results generated. An artificial input of water was used to zero balance the model and evaluate what quantity of groundwater is being used by the native and planted vegetation. Consumptive use for the area was calculated as approximately 1,300 acre-feet/year for the grasses, and 10 acre-feet year for roughly 25 trees. This equals a total quantity of water available then of 1 million gallons per day (MGD) or 705 gallons per minute (gpm). This consumptive use estimate of 1,307 acre-feet/year by planted and native vegetation is in good agreement with the working estimate of groundwater recharge of 1,209 acre-feet/year. The verdant area size would likely increase and decrease at the edges based upon a wet or dry year(s) condition.

Thus groundwater base flow is consumed by evapotranspiration on the Anaverde Ranch property and no groundwater base flow is estimated to leave the Anaverde Ranch. This consumptive use on the property is groundwater that can be available for utilization for supply water with some return flow to the verdant area to sustain it. For example water utilized at the properties could be recycled from a reclaimed water facility that furnishes the wetlands with water.

## *Aquifer Testing on the Anaverde Ranch Property and Estimated Conductivity*

Aquifer testing was conducted on an existing well at the Anaverde Ranch Property, named Well 5. The well construction is not fully known. It was sounded in the field and found to be 215 feet deep. A nearby observation well, Well 6, was sounded and found to be 55 feet deep. Well 6 is located 100 feet from Well 5. It is believed that both wells are in the same hydrologic unit. A step discharge test was conducted on Well 5 ranging from 100 to 300 gpm on August 22, 2008. A sustainable yield of 200 gpm was estimated from that test and a 7-day constant-rate-discharge test conducted at 187 gpm on August 28, 2008 and went through September 4, 2008 with observation of the recovery phase until Monday September 8, 2008. Data were recorded at regular intervals in the 10 existing groundwater wells located on the Anaverde Ranch. Hydraulic responses were clearly observed in wells 5 and 6 and a small response was observed in Wells 1 and 4 after taking into account base-flow recession and barometric pressure changes.

Analysis of the drawdown and recovery response at both Well 5 and Well 6 demonstrates that the aquifer exhibits unconfined behavior. The early drawdown is followed by a decrease in the rate of drawdown and then a subsequent increase in the rate of drawdown. This is symptomatic of a delayed yield release from storage in the aquifer pores. What is most notable is that the drawdown increase deviates above the expected value. This is indicative of a bounding condition on the aquifer such as a fault. Exhibit 17 depicts the drawdown and recovery curve for Well 6 while Well 5 is pumping nearby. The presence of the fault and confinement of the unit laterally creates an enhanced drawdown in the latter time data.

The transmissivity of the upper 200 feet of the aquifer on the Anaverde Ranch appears to be on the order of 40,000 gallons per day per foot of drawdown. The storage coefficient is on the order of 0.002 for the confined response and a meaningful delayed yield was not observed due to the bounding condition on the aquifer; the late time solution is not considered valid. Hydraulic conductivity for the sediments could not be estimated for this test absent boring log information for the wells.

### Groundwater Geochemistry in the Anaverde Creek Basin and the Antelope Valley Basin

The geochemistry of groundwater differs between the Anaverde Creek Basin and the Antelope Valley Basin. Water quality data for general mineral parameters was obtained from the USGS database for the region (LSCE, 2008). The data for major cations and anions in solution were averaged over time into a representative value for each location. Eleven locations were evaluated in all, two from the Anaverde Creek Basin and nine from the Antelope Valley Basin. A Piper Diagram of the percentage of the charge balance for anions and cations is shown in Exhibit 18. The water from the two basins is different in mineral composition. Exhibit 18 demonstrates that the groundwater in the Anaverde Creek Basin has higher calcium (Ca) content than the groundwater in the Antelope Valley. Further it demonstrates that groundwater in the Antelope Valley has distinctly more sodium and potassium than that in the Anaverde Creek Basin. Other ion types such as the major anions, sulfate, chloride, and bicarbonate overlap in their range but the composition of the ion balance distinguishes the Anaverde Creek groundwater from that of the Antelope Valley. This is likely due to the different mineralogy of the geologic formations that make up the respective basins.

### Groundwater Elevations and Flow Directions

Groundwater elevations in the Anaverde Creek Basin are high relative to the Antelope Valley. Exhibit 19 depicts groundwater elevations in 2008 from both the Anaverde Creek Basin and the nearby portions of the Antelope Valley Basin. Groundwater elevations in the Anaverde Creek Basin are above 2,900 feet mean sea level (MSL). Groundwater elevations nearby in the Palmdale area are below 2,200 feet MSL. This large vertical head difference is indicative of hydraulically distinct water bearing units. Areas to the west and east of Palmdale have higher groundwater elevations and the contours on Exhibit 19 demonstrate this flow toward the groundwater production wells located in and around Palmdale. The large vertical head difference is indicative of the bounded condition of the aquifer on the southern boundary.

Earlier contouring of groundwater elevations for 1988 by Law Environmental (Law, 1991) demonstrates the low or no-flow nature of the faults along the southern boundary of the Antelope Valley Basin. Exhibit 20 depicts groundwater contours that are perpendicular or nearly perpendicular to the west-northwest trending fault near Palmdale, California. Perpendicular contours to a boundary indicate no flow across that boundary. Thus there is little or no groundwater movement from the Anaverde Creek Basin to the Antelope Valley Basin indicated by these groundwater elevation contours.

Groundwater elevations for the Antelope Valley from 1965 were located in the regional database. Groundwater elevations in the lower Anaverde Creek Basin were measured as greater than 2,830 feet MSL and groundwater in the Palmdale area was measured as below 2,300 feet MSL.

Extraction in the Antelope Valley Basin by large scale production wells appears to have no effect on groundwater elevations in the Anaverde Creek Basin. Groundwater elevations near Palmdale decreased by over 100 feet from 1965 to 2008 while groundwater elevations increased by nearly 100 feet in the Anaverde Creek Groundwater Basin for the same period. Conversely, it is expected that production level extraction from the Anaverde Creek Basin will have no effect on the groundwater elevations in the Antelope Valley Basin.

## Summary of Key Findings

The Anaverde Creek Basin and the Antelope Valley Basin are distinct and separate groundwater basins. There are multiple lines of evidence that support this finding.

- There is a major fault, the San Andreas, between the Anaverde Creek Basin and the Antelope Valley Basin that juxtaposes rock of very low permeability at the juncture of the two basins.
- Hydraulic stress-testing of the Anaverde-Creek-Basin shallow-aquifer revealed a boundary condition on both the drawdown and recovery phases consistent with a lateral no-flow boundary being encountered by the cone of depression from the applied pumping.
- The geochemistry of the groundwater in the Anaverde Creek Basin is distinctly different from that in the Antelope Valley Basin. The former is calcium dominated and the latter is sodium dominated.
- The geology of the aquifer material in the Anaverde Creek Basin is different from that in the Antelope Valley Basin.
- Large volume extraction in the Antelope Valley Basin for the past 40 years has not drawn down the aquifer in the Anaverde Creek Basin.

There is an appreciable and commercially useful quantity of groundwater that is available for use on the Anaverde Ranch Property due to its overlying this constrained or bounded aquifer.

- Wetlands appear to have existed on the property continuously since at least 1928.
- Evapotranspiration by wetland vegetation consumes groundwater in the Anaverde Creek Basin. Modeling of the consumptive use by grasses and trees suggest it is approximately 1,300 acre-feet per year.
- Estimates of the average groundwater recharge for the Anaverde Creek. Groundwater Basin suggest the available quantity of groundwater is on the order of 1,200 acre-feet per year.
- No appreciable quantity of groundwater flows from the Anaverde Creek Basin to the Antelope Valley basin as upwelling groundwater at the bedrock and fault structures is consumed by evapotranspiration.
- Aquifer testing of the shallow aquifer at 190 gallons per minute indicates that useful quantities of groundwater can be produced from this aquifer on the order of 1,000 gallons per minute or more.

### *Recommendation*

It is recommended that the Antelope Valley Groundwater Adjudication Boundary be revised to exclude the Anaverde Creek Groundwater Basin. Exhibit 22 provides a recommendation on where the revised adjudication boundary could be located.

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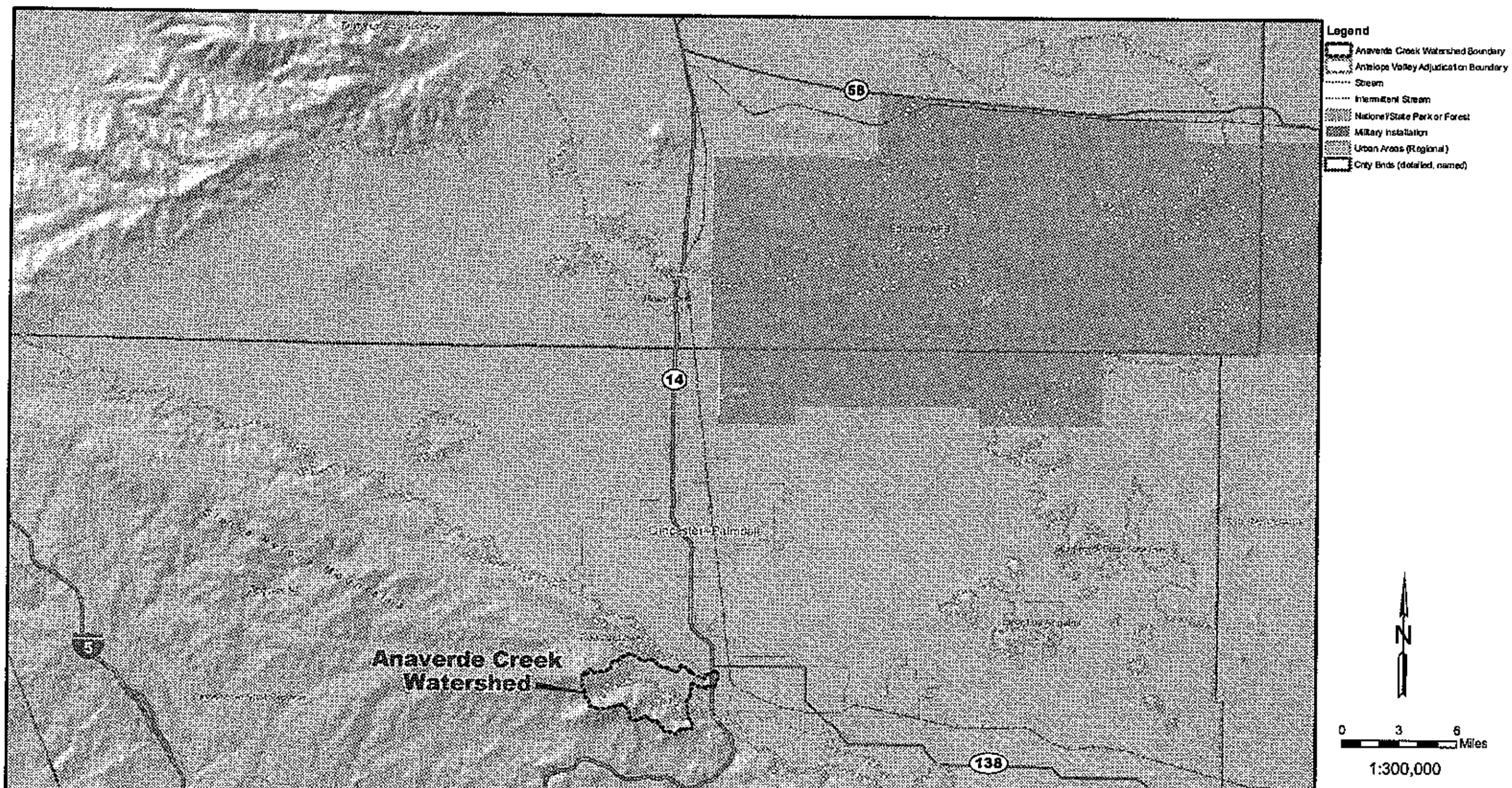



**Exhibit 1**
**Anaverde Creek Watershed within Antelope Valley Adjudication Area**

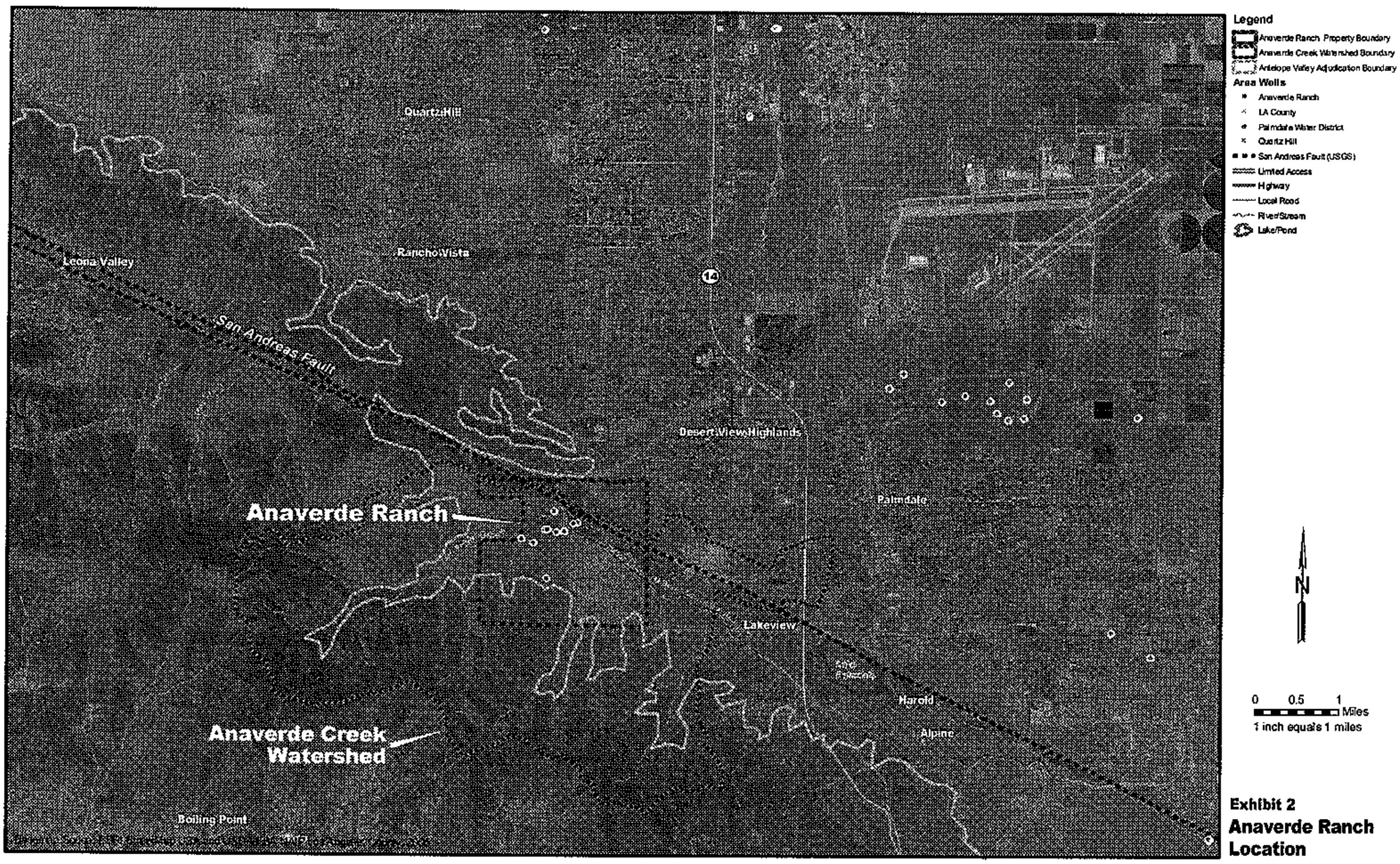



**Exhibit 2**
**Anaverde Ranch Location**

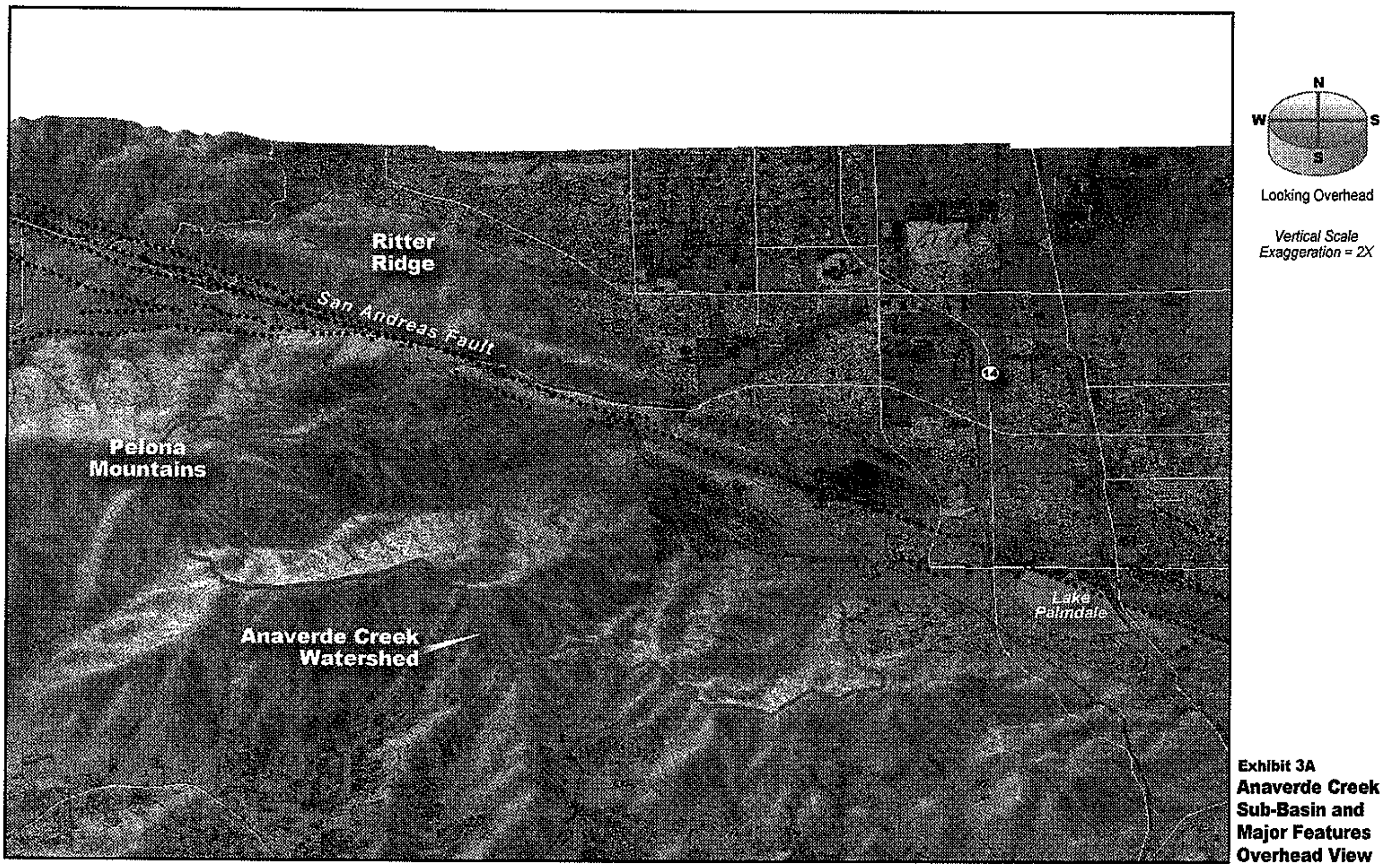
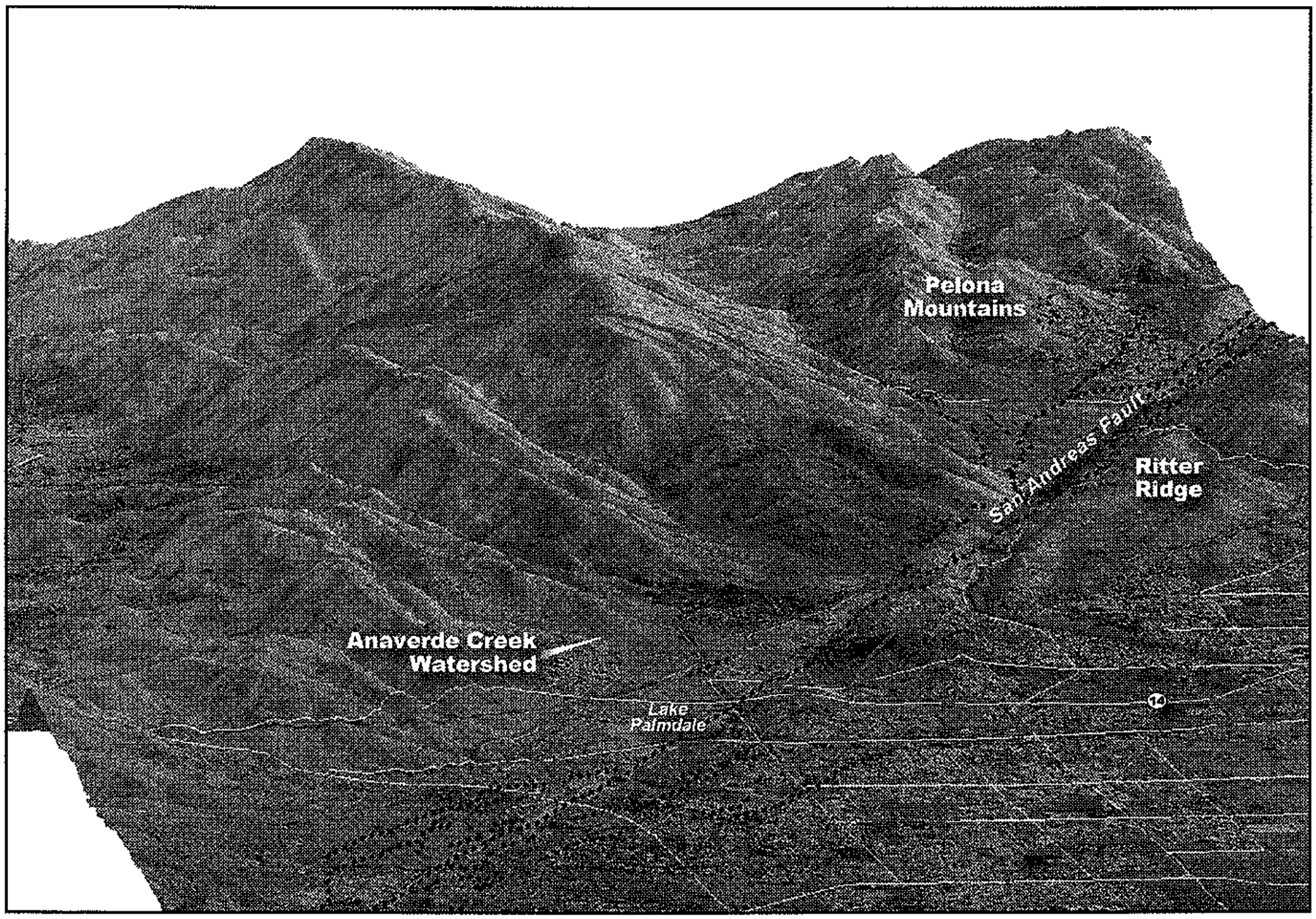
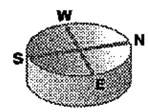



Exhibit 3A

**Anaverde Creek Sub-Basin and Major Features Overhead View**




Looking Northwest

*Vertical Scale Exaggeration = 2X*

**Exhibit 3B**
**Anaverde Creek Sub-Basin and Major Features Oblique View Looking NW**

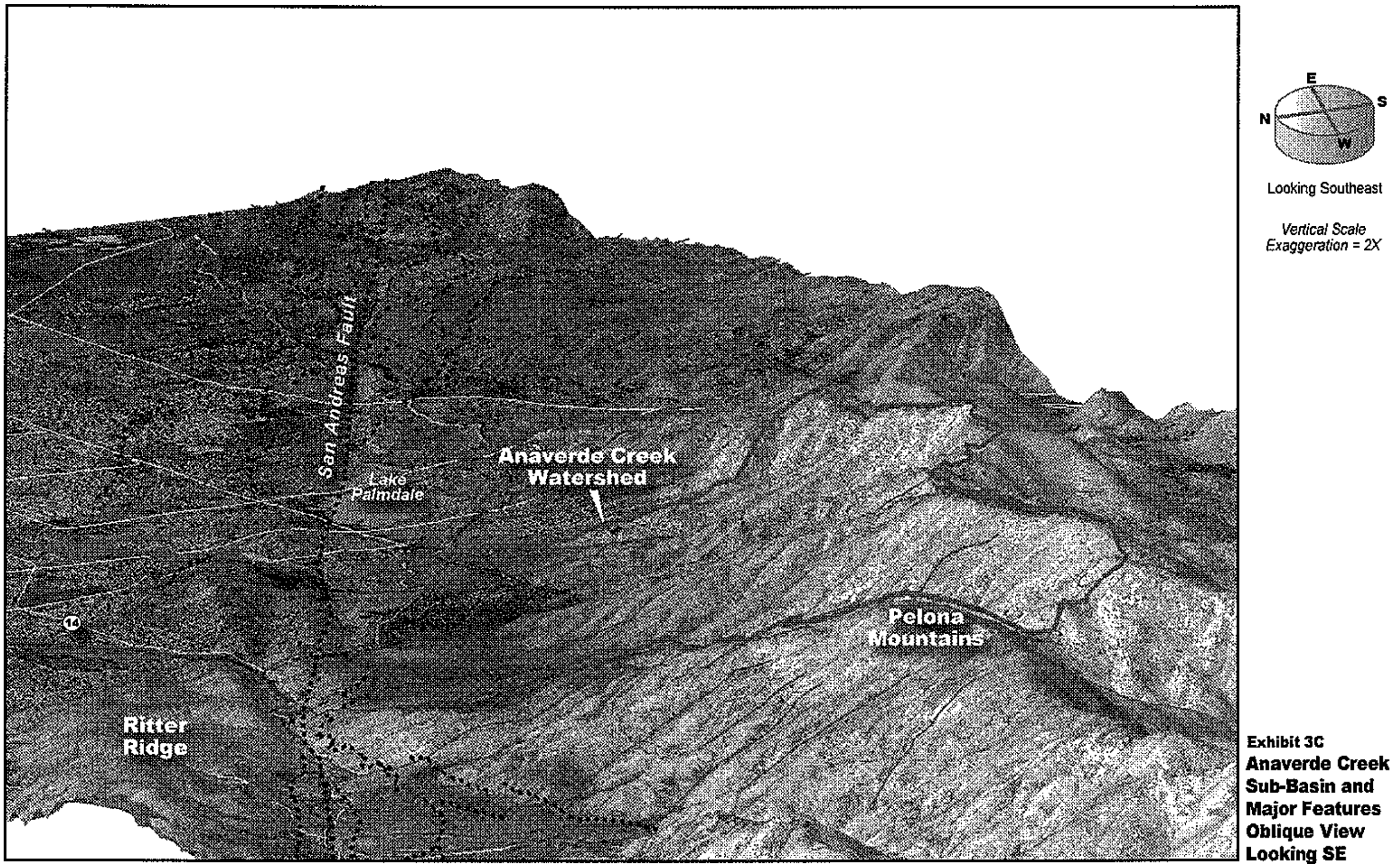



**Exhibit 3C**
**Anaverde Creek Sub-Basin and Major Features Oblique View Looking SE**