SUMMARY

Title: Geohydrology and Water Availability of the Cuyama Valley, California
Cooperating Agency: Santa Barbara County
Project Chief: Randy Hanson **Period of Project:** FY2009-2012

Problem: Currently, ground water is the sole source of water supply in the Cuyama Valley. Ground-water withdrawals, mainly for the irrigation of agricultural crops, have resulted in water-level declines of as much as 300 ft since the 1940s. To plan for future use, it will be important to define the quantity and quality of the ground-water supply and establish tools to allow users to efficiently utilize the available ground-water resources.

Objective: The objectives of this study are to: (1) refine the geohydrologic framework of the Cuyama Valley, (2) quantify the hydrologic budget of the valley, and (3) develop hydrologic modeling tools to evaluate and manage the ground-water resources. The study will develop a greater understanding of the geohydrology of the Cuyama Valley and evaluate the potential hydrologic effects of future ground-water development on different parts of the valley which would aide in the potential development of a management plan.

Benefits: This study will benefit local water users by providing an improved understanding of the source of water to their existing production wells and predicting the potential effects of continued ground-water overdraft. Benefits to the nation include quantifying the resources of a sole-source aquifer, and developing the information and tools necessary to assess and manage a water resource used for drinking-water supply and irrigation.

Approach: The proposed study will include five main tasks: (1) data compilation, (2) new data acquisition, (3) model development, (4) analysis of water availability, and (5) report preparation. Climate, land-use, geologic, hydrologic, water-quality, and geodetic data will be compiled and assembled into a Geographic Information System and integrated into new monitoring networks. Depth-dependent or aquifer dependent geohydrologic and geochemical data from existing wells will be collected, and from the installation of up to four new multiple-well monitoring sites in the valley. The existing monitoring network maintained by Santa Barbara County and the USGS will be enhanced during the study period and be used to collect temporal and spatial water-level and water-quality data. Streamflow data will be collected at selected streams to help determine the recharge characteristics of the valley. Geodetic data will be collected to determine if subsidence is occurring in the valley. Geohydrologic and hydrologic models will be developed as part of this study to more accurately assess and simulate the storage and flow of water in Cuyama Valley. The hydrologic model will be used to evaluate how selected water-use and climate scenarios affect the availability of ground water in the Cuyama Valley. Of particular importance will be using the hydrologic model to analyze changes in ground-water flow and ground-water storage in different hydrologic regions of the Cuyama Valley caused by current and projected ground-water use.

Geohydrology and Water Availability of the Cuyama Valley, California

By

Randall Hanson, Peter Martin, Dennis Gibbs, and Claudia Faunt

September 3, 2008

Problem and Study Area

The Cuyama Valley is a rural agricultural area about 35 miles north of Santa Barbara in the southern part of the Coast Ranges of California. The valley is bounded on the north by the Caliente Range and on the southwest by the Sierra Madre Mountains and is drained by the Cuyama River. The western edge of the study area is the confluence of Cottonwood Creek and the Cuyama River. The surface-water drainage of the proposed study area encompasses 690 mi^2 of Santa Barbara, San Luis Obispo, Ventura, and Kern Counties (fig. 1).

Currently, ground water is the sole source of water supply in the Cuyama Valley. Ground-water withdrawals, mainly for the irrigation of agricultural crops, have resulted in water-level declines of as much as 300 ft since the 1940s (fig. 2). An evaluation of ground-water overdraft in the Cuyama ground-water basin by the California Department of Water Resources indicated that there was an average ground-water overdraft (loss in ground-water storage) of 14,600 acre-ft/yr during 1982-1993 (Pierotti and Lewy, 1998). A water budget of the Cuyama Valley completed by Santa Barbara County indicated an overdraft of 28,000 acre-ft/yr in 1992.

There is concern by many residents and water managers that if the basin continues to be overdrafted, ground-water levels will decline to a point where it will be uneconomical to produce water and the water quality may deteriorate due to the dewatering of the upper alluvial aquifer deposits. In addition, there is concern that the water-level declines have or will result in land subsidence. Land subsidence could potentially pose a hazard through damage to supply wells, roads, and agriculture.

Previous studies of the Cuyama Valley (Upson and Worts, 1951; Singer and Swarzenski, 1970) documented the geohydrologic conditions of the area when ground-water development was just beginning. Upson and Worts (1951) summarized existing well records, water-level fluctuations, pumpage, natural discharge, and water quality for 1939-1946. Singer and Swarzenski (1970) delineated aquifers and estimated recharge, natural discharge, pumpage, and storage changes for 1947-1966. Since these studies were completed, water levels have declined into the deeper formations that were not previously investigated in detail. Because the Cuyama Valley is a sole-source aquifer, it will be important to define the water-bearing and water-quality properties of the deeper stratigraphic sections of the ground-water basin. To plan for future use, it will be important to define the quantity and quality of the ground-water supply and establish tools to allow users to efficiently utilize the available ground-water resources.

Objectives

The objectives of this study are to: (1) refine the geohydrologic framework of the Cuyama Valley, (2) quantify the hydrologic budget of the valley, and (3) develop hydrologic modeling tools to evaluate and manage the ground-water resources. The study will develop a greater understanding of the geohydrology of the Cuyama Valley and help develop a management and monitoring plan to evaluate the potential hydrologic effects of future ground-water development on different parts of the valley.

Study Area

Climate

Although located within the Coast Ranges, the Cuyama Valley has many of the climatic features of a desert basin because it is surrounded by relatively high mountains. The valley is characterized by hot, dry summers and cold winters. Rainfall averages less than 6 inches per year on the valley floor to about 24 to 30 inches per year in the mountain headwaters of the Cuyama River and along the crest of the Sierra Madre Mountains

Geologic Units

Singer and Swarzenski (1970) generalized the geology of the Cuyama Valley into four main units: (1) non-water-bearing rocks—the basement complex and all sedimentary rocks older than the Morales Formation, (2) the Morales Formation of Pliocene age, (3) older alluvium of Pleistocene age, and (4) younger alluvium of Holocene age. The Morales Formation consists of poorly consolidated deposits of clay, silt, sand, and gravel of more than 3,000 ft thick, which unconformably overlay the more consolidated older non-water-bearing rocks. The older and younger alluvium consists of sand, gravel, and boulders with some clay. The percentage of clay increases in the western part of the valley.

Geologic Structure

The Cuyama Valley is a downfaulted block or graben that is bordered on the north by the Morales and Whiterock faults and on the south by the South Cuyama and Ozena faults (fig. 3). The eastern part of the central valley is underlain by a syncline whose strike is parallel to the elongation of the valley and plunges towards the northwest. The north limb of this fold is truncated against the Morales fault. Faults in the alluvium along Graveyard and Turkey Trap Ridges and at the mouth of the Santa Barbara Canyon affect the movement of ground water (Singer and Swarzenski, 1970).

Aquifer System

The main water-bearing deposits in the study area are the saturated portions of the younger and older alluvium and the Morales Formation (fig. 3). As stated previously, all rocks that are older than the Morales Formation are considered by previous investigators to be non-water-bearing. Historically, most of the water pumped from the study area was yielded from the younger and older alluvium. Large-capacity wells perforated in the alluvium yield 1,000-3,000 gpm. Specific capacities of the alluvium range from 100 to 200 gpm per foot.

The water-bearing properties of the Morales Formation are not well defined, but available data indicates that the hydraulic conductivity of the formation varies greatly both spatially and with depth. Wells perforated in the Morales Formation in the western part of the valley have specific capacities of 5 to 25 gpm per foot; whereas, wells perforated along the northern margin of the central valley have specific capacities of 25-50 gpm per foot. Inspection of available geologic and geophysical logs suggest that the hydraulic conductivity of the Morales Formation decreases with depth.

Relevance and Benefits

This study will benefit local water users by providing an improved understanding of the source of water to their existing production wells and predicting the potential effects of continued ground-water overdraft. Benefits to the nation include quantifying the resources of a sole-source aquifer, and developing the information and tools necessary to assess and manage a water resource used for drinking-water supply and irrigation. The study will utilize recently developed model packages (MODFLOW-FMP, UZF, and SFR2) to simulate delayed recharge of the infiltration of streamflow and agricultural return flows through a thick unsaturated zone. This project will also develop a formal connection between the Basin Characteristics Model (BCM) (Flint and Flint, 2007 a,b,c,) and MF-FMP (Schmid and Hanson, 2008) to provide complete coupled hydrologic simulation of ungaged runoff for regional-scaled hydrologic models. The project meets the Strategic Science plan for facing tomorrow's challenges as part of the U.S. Water Census (USGS, 2007, 2008).

Approach

The proposed study will include five main tasks: (1) data compilation, (2) new data acquisition, (3) model development, (4) analysis of water availability, and (5) report preparation.

Task 1: Data Compilation

Existing climate, land-use, geologic (geologic maps, well logs, and geophysical logs), hydrologic (streamflow, water levels, and spring locations), water-quality, and geodetic data will be compiled and assembled into a Geographic Information System (GIS) using ARCINFO. Although much of the development of the GIS will occur early in the study the GIS will be used, updated, and revised throughout the study.

The compilation of GIS information will be done jointly with staff from the County of Santa Barbara and will utilize the USGS membership in the Channel Islands Regional Geographic Information System (CIRGIS) to obtain existing GIS information, as well as collaboration with U.C. Santa Barbara and the counties of San Luis Obispo, Ventura, and Kern. The GIS data system for Cuyama Valley will provide a basis for building the geologic and hydrologic models and for communicating and illustrating our analysis of the water resources and will be the basis for a 3-D visualization of the aquifer system. Data within the GIS will be used to draw geologic sections through the study area that define the areal and vertical extent of aquifer deposits. The geologic sections will be used to help determine where the monitoring wells constructed for this study should be located.

Hydrologic and water quality data will be compiled and integrated into a regional synthesis of water resources. Ground-water-level maps will be prepared showing water levels and the direction of ground-water flow for selected periods. In addition, water-level change maps and water-level hydrographs will be prepared to show the long-term change in ground-water storage. Available water chemistry from domestic, municipal, and agricultural supply wells will be compiled and analyzed to help determine the spatial variation of water quality in the study area. Water-quality maps will be prepared showing the distribution of selected constituents. Where sufficient data are available from individual wells, selected water-quality constituents will be plotted with time to show if there has been a change in ground-water quality.

Task 2: New Data Acquisition

Refining the geohydrologic framework of the valley, as well as developing new geologic and hydrologic models, will require the collection of depth-dependent or aquifer dependent geohydrologic and geochemical data. The existing monitoring network maintained by Santa Barbara County and the USGS will be enhanced during the study period and be used to collect temporal and spatial water-level and water-quality data. Streamflow data will be collected at selected streams to help determine the recharge characteristics of the valley. Geodetic data will be collected to determine if subsidence is occurring in the valley.

Multiple-Well Monitoring Sites

Up to four new multiple-well monitoring sites will be constructed for this study. The completion of new multiple well monitoring sites will provide new and detailed geologic and geophysical data of the aquifer system and provide information on the water-bearing properties of the aquifers. The locations of the well sites will be determined after inspecting available data (Task 1). Each of the monitoring sites will include 2 to 5 wells in a single borehole that will allow for the monitoring of water levels and ground-water chemistry at specific depths (fig. 4). Slug tests will be performed on all monitoring wells after well development is completed. These data will help define the aquifer system in three-dimensions and provide valuable information for development of the hydrologic and geologic models. The depth of these monitoring sites will vary but should include wells completed in the alluvial deposits and the Morales Formation. These well sites provide geologic, hydrologic, geochemical, and water-quality data (ex. Hanson, 2001; Hanson and others, 2002). Additional sites can be added if additional funding through grants becomes available.

Wellbore Flow and Depth-Dependent Chemistry

Well-bore flow and depth-dependent water-quality data will be collected from several production wells screened in the alluvium and Morales Formation following the USGS methods and procedures for water-supply wells (Izbicki and others, 1999; Izbicki, 2004). These data will help determine if there is a difference in well production and water quality with depth in the alluvium and Morales Formation.

Monitoring Network

As part of this study, the USGS in cooperation with Santa Barbara County will instrument selected wells to provide real-time water-level data. Data will be output through satellites using the Geostationary Observational Environmental System (GOES) and uploaded to the Automatic Data Acquisition System (ADAPS) on California Water Science Center computers. Graphical and tabular data will be available in near-real time through the Internet. Equipment will be calibrated and serviced at 16-week intervals by U.S. Geological Survey personnel.

The existing water-quality data will be supplemented with water chemistry data collected from the multiple-well monitoring sites and selected existing production wells during this study. These data will be used to define the source, movement, and age of water from wells. Samples will be analyzed for major ions, nutrients, selected trace elements, and the stable isotopes of oxygen and hydrogen by the U.S. Geological Survey National Water Quality Laboratory (NWQL) in Denver, CO. Quality assurance will be provided through the use of blank and replicate samples collected as part of the study. Selected samples will be analyzed for tritium and its decay product helium-3 to determine the age of younger (less than 50 years) ground water. Selected samples will be analyzed for carbon-14 and carbon-13 to determine the age of older (greater than 100 years) ground water that does not contain tritium. Laboratories under contract with the U.S. Geological Survey will analyze samples for tritium and carbon-14.

Interferometric Synthetic Aperture Radar (InSAR) Techniques

InSAR data will be evaluated to help determine if land subsidence is occurring in Cuyama Valley and the location of buried faults. InSAR is a technique that allows scientists to measure and map changes on the Earth's surface as small as a few millimeters. By bouncing radar signals off the ground surface from the same point in space but at different times, the radar satellite can measure the change in distance between the satellite and ground (range change) as the land surface uplifts or subsides. Maps of relative ground-surface change (interferograms) are constructed from the InSAR data to understand how ground-water pumping, oil and gas development, or other human and natural activities cause the land surface to uplift or subside. Preliminary InSAR and continuous GPS (Global Positioning System) measurements indicate the some land subsidence is occurring in the Cuyama Valley (fig. 5).

InSAR is a useful technique for locating faults, especially those acting as barriers to flow, when the region is stressed by ground-water pumping. If a fault is a barrier to flow, water-level declines and related land-surface deformation is often greater on the side of the fault nearest to the pumping wells; whereas, water-level declines and related land-surface deformation are often greatly reduced on the opposite side of the fault. Several interferometric synthetic aperture radar maps (interferograms) will be used to determine if land-surface deformation is occurring in the area of the Cuyama Valley and if the land-surface deformation shows evidence of buried faults.

Task 3: Model Development

Geohydrologic and hydrologic models will be developed as part of this study to more accurately assess and simulate the storage and flow of water in Cuyama Valley. The models will be developed utilizing the data compiled and collected in Tasks 1 and 2.

Geohydrologic Model

A geohydrologic model will be developed to help understand the three-dimensional geohydrologic framework of the Cuyama Valley. The model will incorporate information from existing drillers and geophysical logs, cross sections, and geologic maps as well as new information from research drilling at new monitoring-well sites and well-bore flow logs collected for this study (Task 2). The geohydrologic model will be constructed in cooperation with the USGS Geologic Division Western Earth Surface Processes Group (Vickie Langenheim and Don Sweetkind) who have an ongoing regional project to analyze basins adjacent to the San Andreas Fault System called the Coast Ranges Basins Project. The geohydrologic model will delineate the volumes of aquifer system bounded by faults and depositional or formational boundaries within the aquifer systems. The model will define different aquifer layers and their relation to faults and folds. Estimates of textural data from drillers and geophysical logs will be used to characterize the hydraulic properties of the aquifers, similar to previous USGS regional hydrologic models (Hanson and others, 1990; Hanson and Benedict, 1993; Hanson and others, 2003, 2004; Phillips and others, 2007; Faunt and others, 2008). The textural data will be used to estimate the percent coarse-grained and fine-grained sediments for each aquifer or aquifer layer, which will be the basis for estimating the hydraulic properties for the different aquifers in the hydrologic model.

Hydrologic Models

A precipitation-runoff model will be linked with a ground-water flow model to simulate recharge and ground-water flow in the Cuyama Valley. The precipitation-runoff model BCM (Flint et al., 2007a,b,c) will be used to estimate a time series of ungaged runoff from the mountains that surround Cuyama Valley within the entire watershed. This model will be calibrated, in part, on the inflow and outflow stream gage data on the Cuyama River Creek between 1947 and 1958. The runoff from this watershed-scale model will be linked to a hydrologic model of the ground-water basin.

Basin Characterization Model (BCM)--The BCM uses a mathematical deterministic water-balance approach that includes the distribution of precipitation and the estimation of potential evapotranspiration, along with soil-water storage and bedrock permeability (Flint and others, 2004). The BCM will be used with available GIS data (digital elevation model, geology, soils, vegetation, precipitation, and air temperature maps). The BCM can be used to identify locations and climatic conditions that allow for excess water, quantifying the amount of water available either as runoff or as in-place recharge on a monthly basis, and allows inter-basin comparison of recharge mechanisms. The BCM can use average meteorological conditions, although time series analyses of basin recharge provide more accurate estimates of recharge because of the non-linear influence of precipitation on recharge. The Cuyama Valley has significant year to year variability in precipitation which can lead to highly variable recharge. Wet years greatly influence the sequence of years with significant recharge. The Southern California area is greatly influenced by the Pacific Decadal Oscillation and El Niño and La Niña events. These together have a marked effect on recharge.

Hydrologic Flow Model-- The ground-water flow model will be developed using MODFLOW-2005 (MF) Harbaugh (2005), which is a three-dimensional finite-difference hydrologic model. The model simulates steady and nonsteady flow in an irregularly shaped flow system in which aquifer layers can be confined, unconfined, or a combination of confined and unconfined. Inflows and outflows related to stresses, such as flow to wells, areal recharge, evapotranspiration, flow to drains, and flow through river beds, can be simulated. Hydraulic conductivities or transmissivities for any layer may differ spatially and be anisotropic (restricted to having the principal directions aligned with the grid axes), and the storage coefficient may be heterogeneous. Specified head and specified flow boundaries can be simulated as can a head-dependent flow across the model's outer boundary that allows water to be supplied to a boundary block in the modeled area at a rate proportional to the current head difference between a "source" of water outside the modeled area and the boundary block.

The hydrologic flow model will utilize MF-FMP (Schmid and others, 2006; Schmid and Hanson, 2008) to simulate agricultural processes, UZF1 (Niswonger and others, 2006) to simulate the delay of recharge through a thick unsaturated zone, SFR2 (Niswonger and

Prudic, 2005) to simulate streamflow routing, the Multi-node well package to simulate wells screened over multiple aquifers (Halford and Hanson, 2002), and SUB (Hoffmann, 2003) to simulate land subsidence. The hydrologic model will simulate complex agricultural use and return agricultural flows through a thick unsaturated zone using the combination of the FMP and UZF1. The hydrologic model will be constructed on the structure and layering delineated from the geohydrologic model (Task 3) and calibrated to historical water-level and water-use data for the period of 1939-2008 (Task 1). The calibrated model will provide an analysis of the historical ground-water use and an analysis of future water availability under different water-use scenarios.

Task 4: Analysis of Water Availability

The hydrologic model developed in Task 3 will be used to evaluate how selected water-use and climate scenarios affect the availability of ground water in the Cuyama Valley. Potential water-use scenarios include changes in cropping patterns, increased urbanization, and artificial recharge. The USGS will meet with water managers and other stakeholders to help define the water-use and climate scenarios that will be evaluated for this study. The assessment of these scenarios will provide the stakeholders with a clearer picture of the limits of the resources, the connection between the supply and demand components of water use, and the potential availability of the water resources under current and alternative climatic and cultural water-use scenarios. Of particular importance will be using the hydrologic model to analyze changes in ground-water flow and ground-water storage in different hydrologic regions of the Cuyama Valley caused by current and projected ground-water use. The geohydrologic and hydrologic models will be used to estimate the volume of water resources that have been depleted, still remain, and may be unusable owing to poor water quality. The use of optimization techniques will facilitate the analysis of land use and related ground-water pumpage (Ahlfeld and others, 2005; Barlow; 2005). These types of assessment of alternative water use and future climate scenarios also are similar to the analysis performed for the Santa Clara-Calleguas Basin to the south of Santa Barbara County (Hanson and others, 2003; Hanson and Dettinger, 2005).

Data collected on the three-dimensional character of the aquifer flow and chemistry could constrain future water use in the valley. For example, if data collected from this study indicates that the effective porosity of the Morales Formation decreases with depth and/or water-quality is degraded with depth then the estimates of potable water in ground-water storage could be reduced significantly. The effect of poor water quality in the Morales Formation will be evaluated using a particle tracking analysis.

Task 5: Report Preparation

A Scientific-Investigation Report summarizing the geohydrologic framework, hydrologic budget, chemical and isotopic data, and results from the linked precipitation-runoff/hydrologic-flow model will be published by September 30, 2012. A report describing the water-availability analysis from new data and model results will help to answer the stakeholder's questions of zone interaction and would provide the technical information for stakeholders to pursue a basin wide groundwater management plan to protect water resources of the basin. A web site also will be developed in cooperation with the County of Santa Barbara to allow direct access to analysis and real-time data for the residents of Cuyama Valley.

Staffing

The project chief will be Randy Hanson and will also include Claudia Faunt, Alan Flint, and Peter Martin as part of the team that will complete the project. Wolfgang Schmid, from the University of Arizona, will also assist with hydrologic model and water-use/climate scenario development. Assistance for selected field tasks will also include staff from the Santa Maria Field office and Chuck Lamb (or his replacement) from our Sacramento Office.

Cooperators/Collaborators

The cooperating agency will be the Water Agency Division of the Santa Barbara County Public Works Department. Dennis Gibbs at this agency has taken the initiative to develop this study and address the water-resource issues in Cuyama Valley even though no water management agency presently exists in Cuyama Valley and the Valley straddles parts of four counties. The Western Earth Surface Process Team of the USGS Geologic Discipline will contribute to data collection, analysis, and assist with geohydrologic model construction. The USGS Groundwater Ambient Monitoring Assessment Program will also contribute additional water chemistry sampling, analysis, and interpretation of selected water-supply wells in the Cuyama Valley as part of their ongoing statewide project on assessment of water quality for water supply (Belitz and others, 2003). Finally, the Plate Boundary Observatory Project will contribute continuous land-surface deformation data to the geodetic data needed to ascertain the potential and extent of land subsidence owing to ground-water withdrawals (http://pboweb.unavco.org/).

Budget

The budgets for the different study tasks are listed below by Federal fiscal year (table 1). The total cost for FFY 2009 is $539,600, with a total cost to Santa Barbara County of $458,400 and an additional potential USGS match of $81,200 (table 2). The total cost of the project for the four years for is $1,641,100 (table 2). The potential Federal matching funds for all four years is $293,200. These matching funds estimates are based on the estimates made by the USGS California Water Science Center. These are preliminary budget estimates by task for FFY-09 through FFY-12 and include preliminary estimates of the maximum federal matching funds of 30 percent for selected categories such as labor and travel. Federal matching funds are awarded competitively and are subject to cooperator funding, merit and transfer value of science, and availability of funds. The cooperative agreement signed with the County of Santa Barbara will span the Federal Fiscal Years 2009 through 2012.

Table 1. Detailed cost of work-plan tasks[1]

TASK	SUBTASKS	FFY2009	FFY2010	FFY2011	FFY2012	Total Cost
Task 1— Data Compilation	a. GIS	40,000	5,000	0	0	45,000
	b. Geologic Data	20,000	10,000	0	0	30,000
	c. Hydrologic/QW Data	15,000	10,000	0	0	25,000
Total Cost Task 1		**75,000**	**25,000**	**0**	**0**	**100,000**
Task 2— New Data Acquisition	**a. New Monitoring Sites**	216,000	226,600	237,700	0	**680,300**
	b. Water-Level Data	19,000	11,000	11,300	0	**41,300**
	c. Wellbore Flow/Depth-Dependent QW Data	55,000	47,000	15,500	0	**117,500**
	d. Streamflow Data	18,600	9,100	3,500	0	**31,200**
	e. Remote Sensing Data	13,000	3,800	4,000	0	**20,800**
Total Cost Task 2		**321,600**	**297,500**	**272,000**	**0**	**891,100**
Task 3—Model Development	**a.) Conceptual Model**	12,500	0	====	====	**12,500**
	b.) Geohydrologic Model	37,500	35,000	0	0	**72,500**
	c.) Basin Characteristic Model	58,500	35,000	0	0	**93,500**
	d.) Hydrologic Model	12,500	80,000	100,000	0	**192,500**
Total Cost Task 3		**121,000**	**150,000**	**100,000**	**0**	**371,000**
Task 4—Analysis of Water Availability		====	0	0	100,000	**100,000**
Total Cost Task 4		**0**	**0**	**0**	**100,000**	**100,000**
Task 5 — Reports/Web		**22,000**	**14,000**	**60,000**	**65,500**	**161,500**

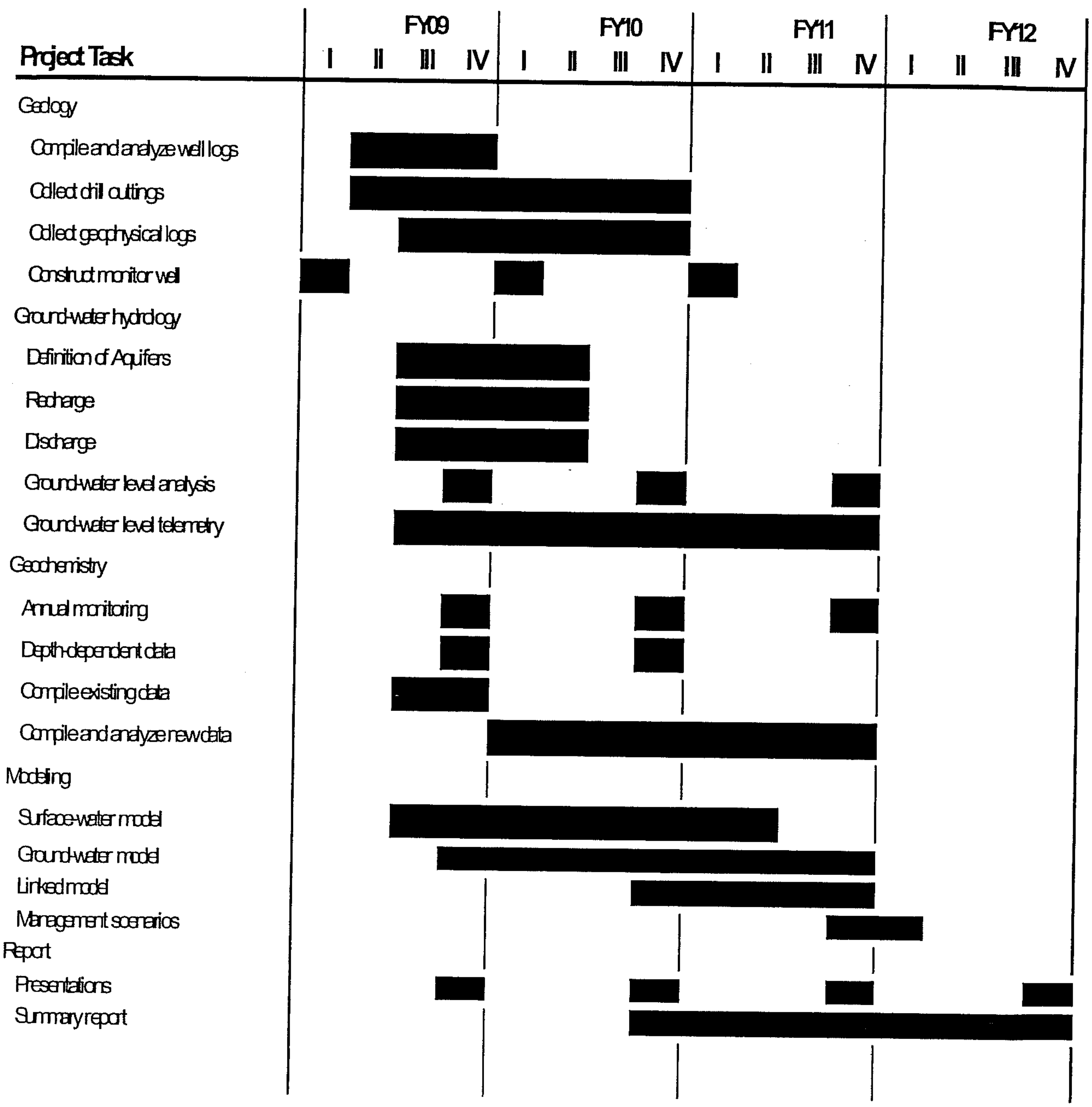
[1]All funding estimates reported in Federal Fiscal Years (FFY) October 1 – September 30.

Table 2. Summary of shared costs by task and federal fiscal year.

Task	Agency	FFY2009	FFY2010	FFY2011	FFY2012	Total
Task 1	SB County	52,500	17,500	0	0	70,000
Task 1	USGS	22,500	7,500	0	0	30,000
Task 1 total		**75,000**	**25,000**	**0**	**0**	**100,000**
Task 2 Reinb Drilling	SB County	174,000	182,300	191,400	0	547,700
Task 2 Fixed Drilling	SB County	29,400	31,300	32,300	0	93,000
Task 2 Fixed Drilling	USGS	12,600	13,000	14,000	0	39,600
Task 2 Fixed other	SB County	93,000	55,900	24,300	0	173,200
Task 2 Fixed other	USGS	12,600	15,000	10,000	0	37,600
Task 2 total		**321,600**	**297,500**	**272,000**	**0**	**891,100**
Task3	SB County	94,000	105,000	70,000	0	269,000
Task 3	USGS	27,000	45,000	30,000	0	102,000
Task 3 total		**121,000**	**150,000**	**100,000**	**0**	**371,000**
Task 4	SB County	0	0		70,000	70,000
Task 4	USGS	0	0		30,000	30,000
Task 4 total		**0**	**0**	**0**	**100,000**	**100,000**
Task 5	SB County	15,500	9,500	58,000	42,000	125,000
Task 5	USGS	6,500	4,500	25,000	18,000	54,000
Task 5 total		**22,000**	**14,000**	**83,000**	**60,000**	**179,000**
Total	**SB County**	**458,400**	**401,500**	**376,000**	**112,000**	**1,347,900**
Total	**USGS**	**81,200**	**85,000**	**79,000**	**48,000**	**293,200**
Total	**Total**	**539,600**	**486,500**	**455,000**	**160,000**	**1,641,100**
Total nondrilling		365,600	304,200	263,600	160,000	1,093,400

Work Plan

This proposed study will require parts of four Federal Fiscal Years (FY) to complete. A generalized work plan (by quarter, with I = Fall, II = Winter, III = Spring, and IV = Summer) is as follows:



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LIST OF FIGURES

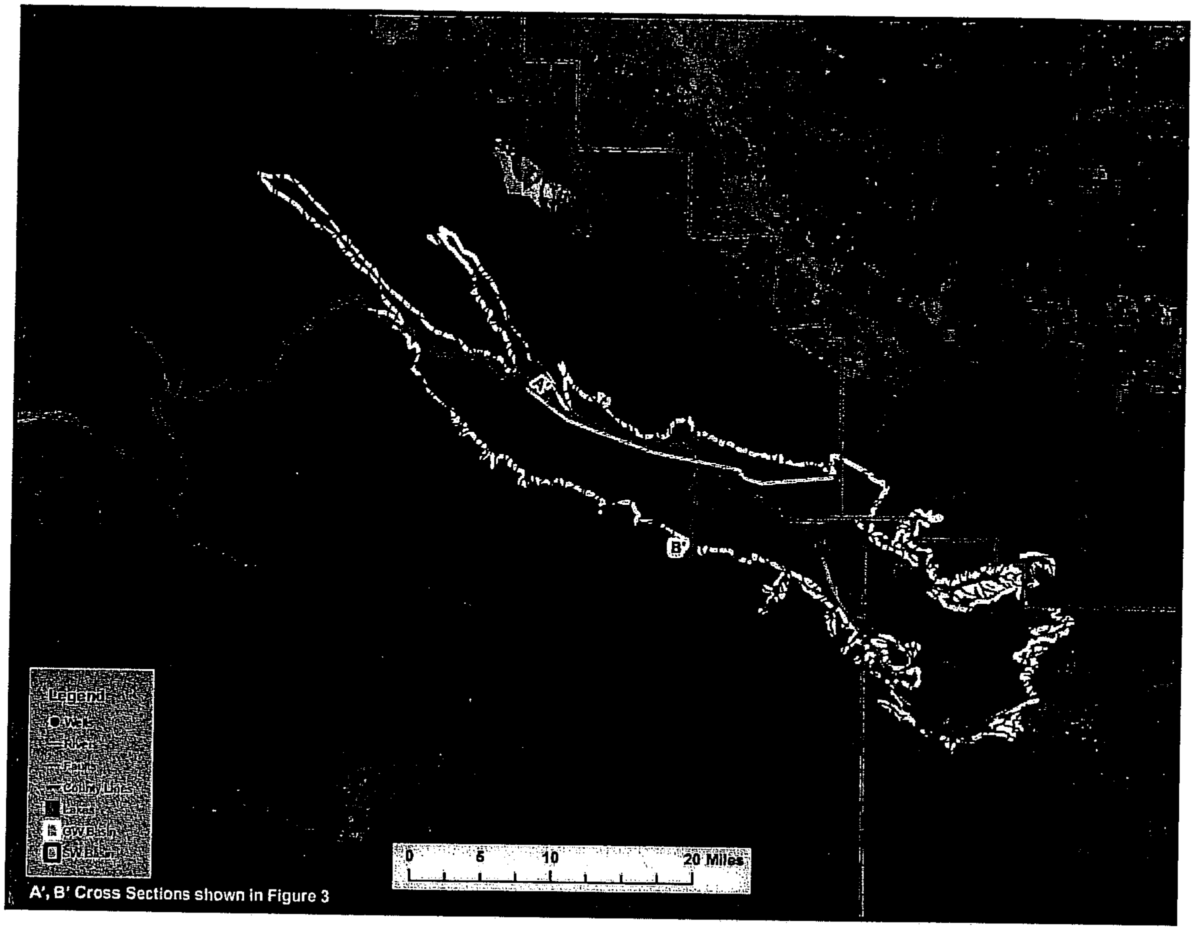
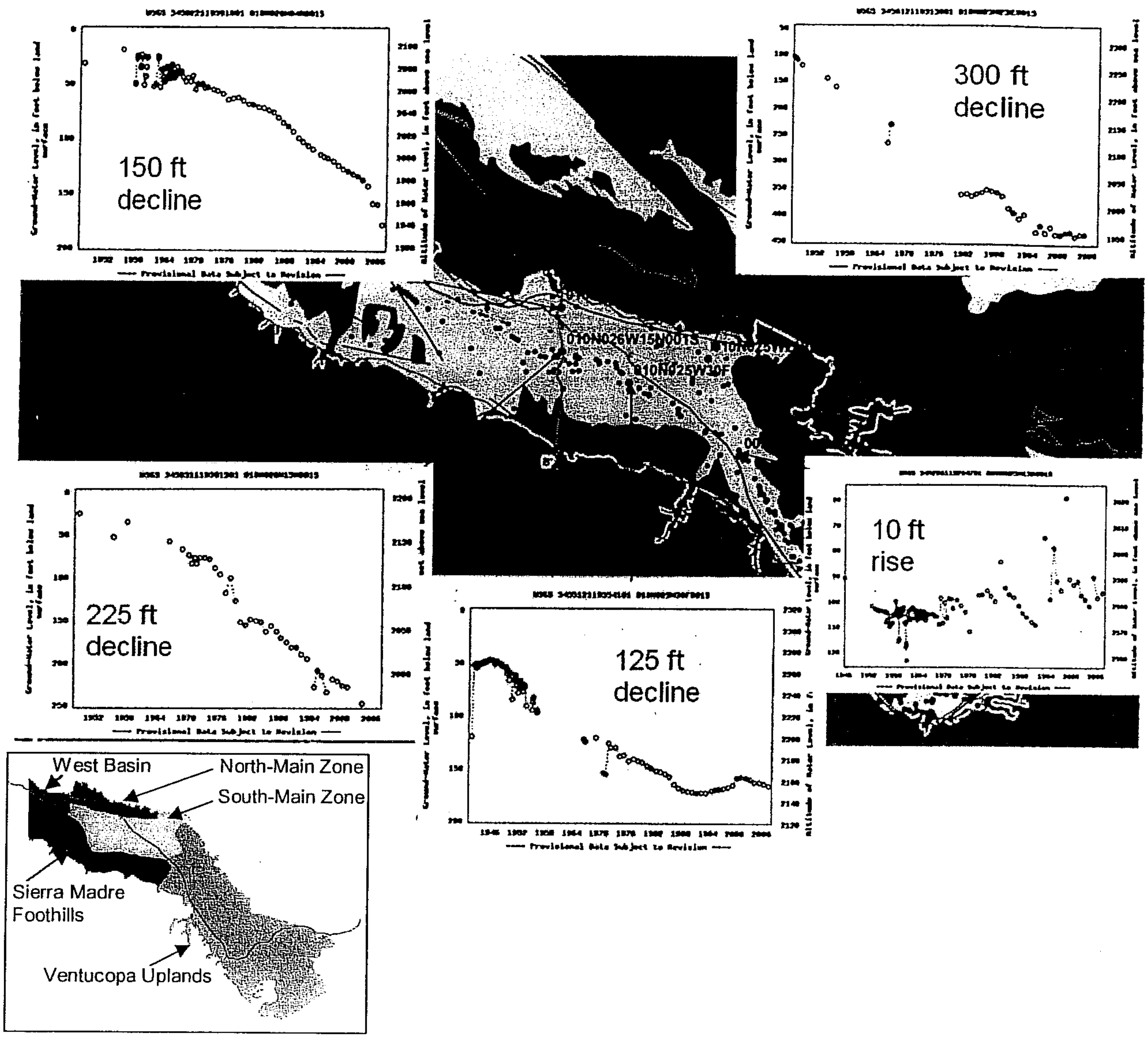


Figure 1. -- Map showing the Cuyama Valley, surface-water and ground-water basins, streams, and faults.

Figure 2. -- Map showing potential multiple-well monitoring sites, cross section profiles, related geologic structure, and hydrologic subregions.



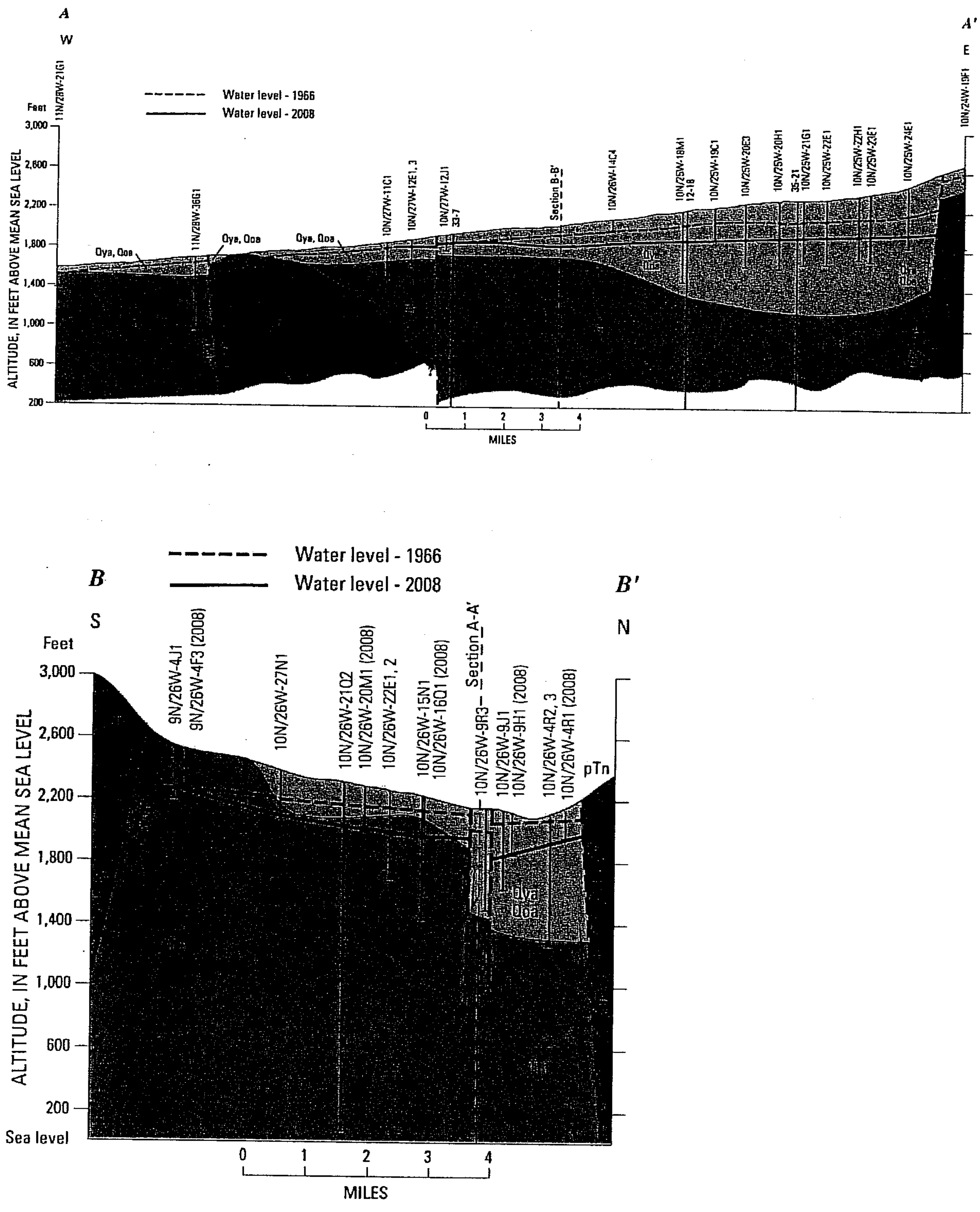


Figure 3. -- Sections showing preliminary geology, structure, and water-level surfaces for 1966 and 2008.

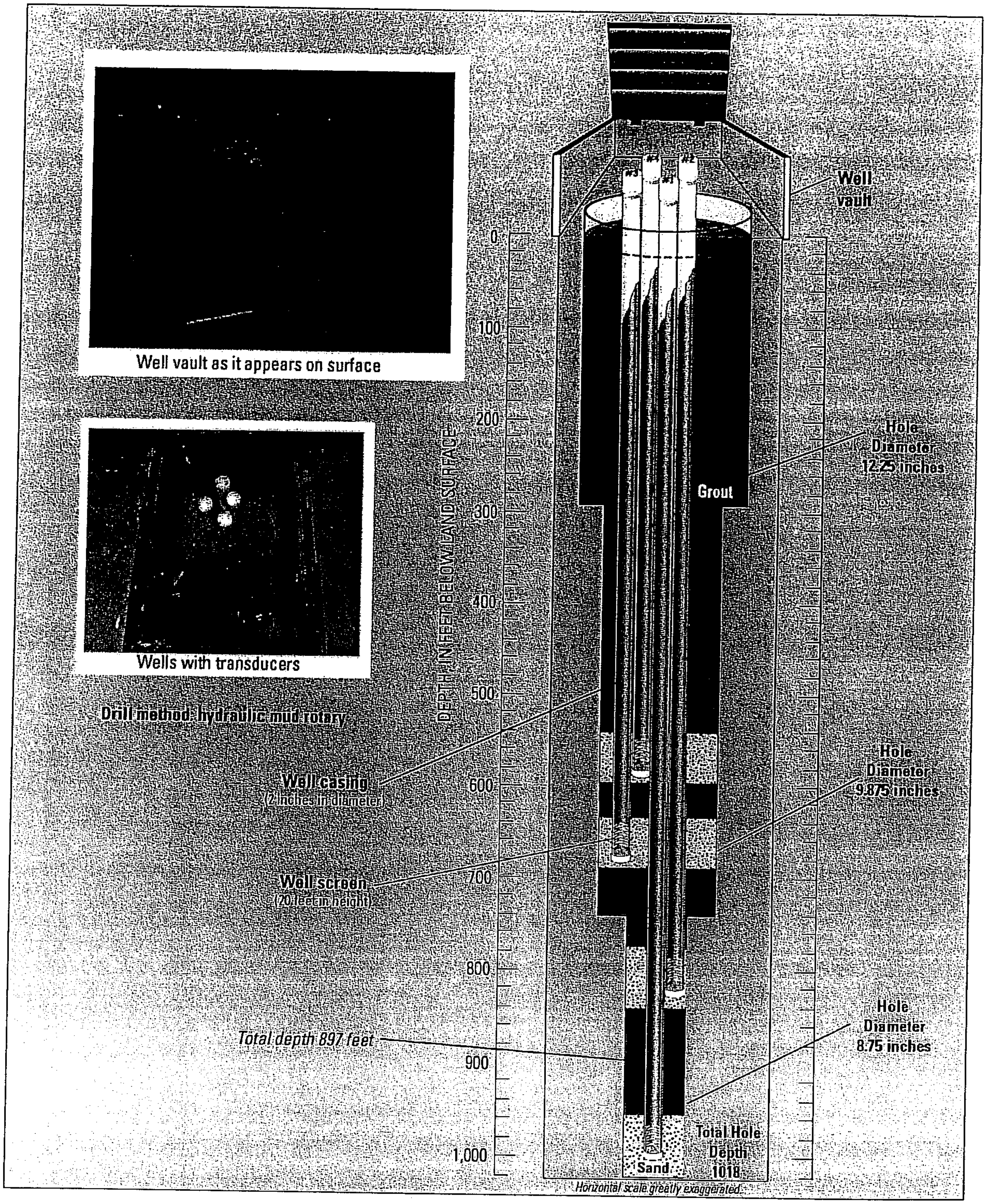


Figure 4. -- Diagram showing the typical construction of multiple-well monitoring sites.

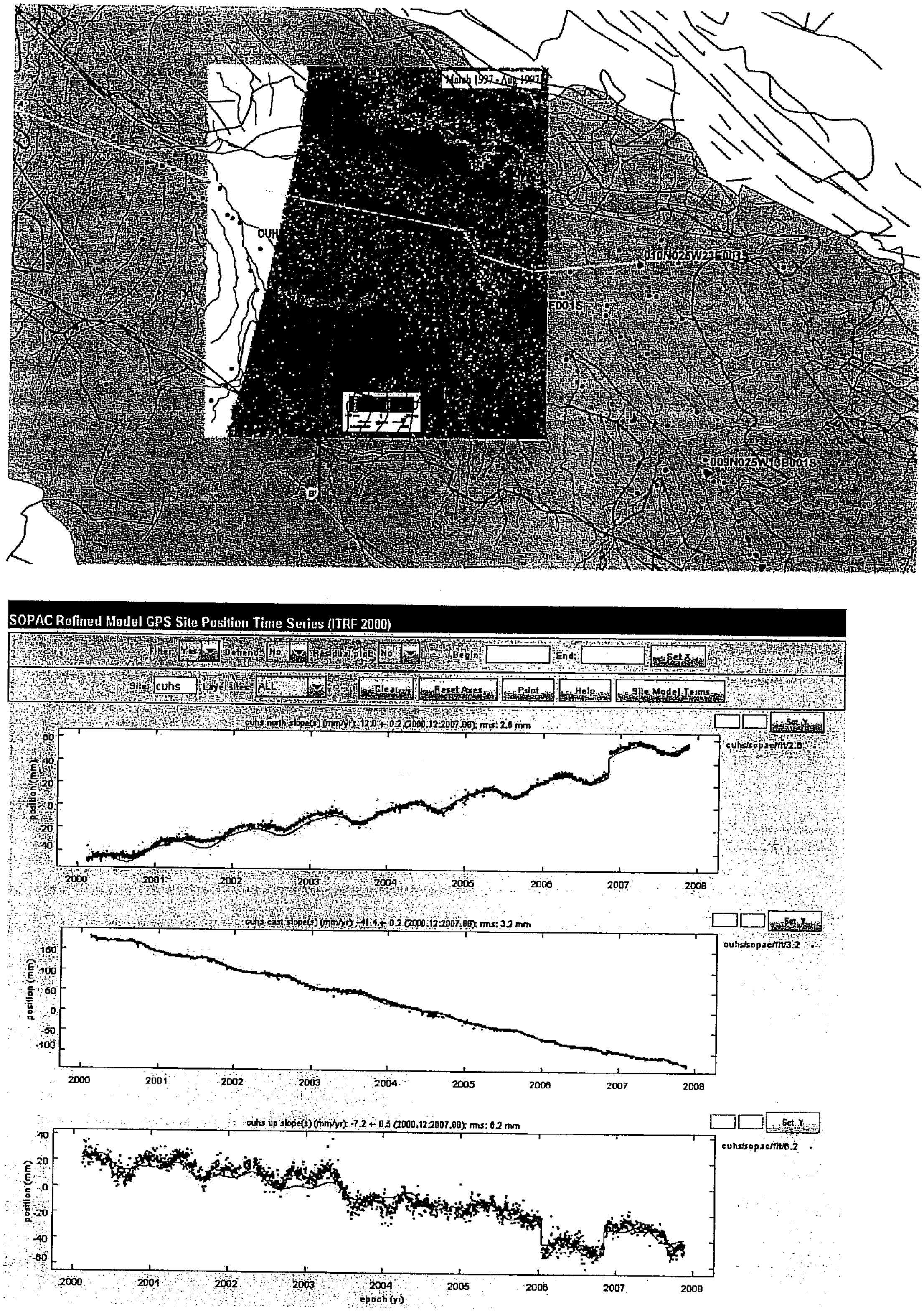


Figure 5. -- Map showing preliminary InSAR image of Cuyama Valley and related continuous GPS measurements at Cuyama Valley High School (CUHS) (from SOPAC data, http://pboweb.unavco.org/).