BC 15-100

Form 9-1366
(Oct. 2005)

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

JOINT FUNDING AGREEMENT

Customer #:	6000000816
Agreement #:	14WSCA600081610
Project #:	
TIN #:	95-6002833
Fixed Cost Agreement	NO

FOR

WATER RESOURCES INVESTIGATIONS

THIS AGREEMENT is entered into as of the, 5th day of September, 2014 by the U.S. GEOLOGICAL SURVEY, UNITED STATES DEPARTMENT OF THE INTERIOR, party of the first part, and the SANTA BARBARA COUNTY WATER AGENCY (SBCWA),, party of the second part.

1. The parties hereto agree that subject to availability of appropriations and in accordance with their respective authorities there shall be maintained in cooperation the study "Geohydrology and Water Availability of the San Antonio Creek Valley, California" (Attachment A), incorporated into this agreement by reference, and herein called the program. The USGS legal authority is 43 USC 36C; 43 USC 50; and 43 USC 50b.

2. The following amounts shall be contributed to cover all of the cost of the necessary field and analytical work directly related to this program. 2(b) includes In-Kind Services in the amount of $0.00 .

   (a) by the party of the first part during the period

Amount	Date	to	Date
$104,978.00	November 1, 2014		October 31, 2019

   (b) by the party of the second part during the period

Amount	Date	to	Date
$673,950.00	November 1, 2014		October 31, 2019

   USGS DUNS is 1761-38857.

   (c) Additional or reduced amounts by each party during the above period or succeeding periods as may be determined by mutual agreement and set forth in an exchange of letters between the parties.

   (d) The performance period may be changed by mutual agreement and set forth in an exchange of letters between the parties.

3. The costs of this program may be paid by either party in conformity with the laws and regulations respectively governing each party.

4. The field and analytical work pertaining to this program shall be under the direction of or subject to periodic review by an authorized representative of the party of the first part.

5. The areas to be included in the program shall be determined by mutual agreement between the parties hereto or their authorized representatives. The methods employed in the field and office shall be those adopted by the party of the first part to insure the required standards of accuracy subject to modification by mutual agreement.

6. During the course of this program, all field and analytical work of either party pertaining to this program shall be open to the inspection of the other party, and if the work is not being carried on in a mutually satisfactory manner, either party may terminate this agreement upon 60 days written notice to the other party.

7. The original records resulting from this program will be deposited in the office of origin of those records. Upon request, copies of the original records will be provided to the office of the other party.

8. The maps, records, or reports resulting from this program shall be made available to the public as promptly as possible. The maps, records, or reports normally will be published by the party of the first part. However, the party of the second part reserves the right to publish the results of this program and, if already published by the party of the first part shall, upon request, be furnished by the party of the first part, at costs, impressions suitable for purposes of reproduction similar to that for which the original copy was prepared. The maps, records, or reports published by either party shall contain a statement of the cooperative relations between the parties.

9. USGS will issue billings utilizing Department of the Interior Bill for Collection (form DI-1040). Billing documents are to be rendered QUARTERLY. Payments of bills are due within 60 days after the billing date. If not paid by the due date, interest will be charged at the current Treasury rate for each 30 day period, or portion thereof, that the payment is delayed beyond the due date. (31 USC 3717; Comptroller General File B-212222, August 23, 1983).

U.S. Geological Survey United States Department of the Interior		Santa Barbara County Water Agency	
USGS Point of Contact		**Customer Point of Contact**	
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Signatures and Date

Signature:	[signature]	Date: 9-10-14	Signature:	See page 3	Date:
Name:	Eric G. Reichard		Name:		
Title:	Director, California Water Science Center		Title:		

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TIN #: 95-6002833

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SANTA BARBARA COUNTY WATER AGENCY

By: ______________________
Chair, Board of Directors

Date: 11-4-14

ATTEST:
MONA MIYASATO
CLERK OF THE BOARD

BY: ______________________
Deputy

APPROVED AS TO FORM:
MICHAEL C. GHIZZONI
COUNTY COUNSEL

BY: ______________________
Deputy

APPROVE AS TO ACCOUNTING FORM:
ROBERT W. GEIS, CPA
AUDITOR-CONTROLLER

BY: ______________________
Deputy

APPROVE:
SCOTT D. MCGOLPIN
PUBLIC WORKS DIRECTOR

BY: ______________________

Geohydrology and Water Availability of the San Antonio Creek Valley, California

by
Claudia Faunt, Matthew Landon, Matthew Scrudato,
Jill Densmore, Donald Sweetkind, and Nicholas Teague
U.S. Geological Survey

Problem and Study Area

The San Antonio Creek Valley is located in western Santa Barbara County about 15 miles south of Santa Maria and 55 miles north of Santa Barbara (fig. 1). The valley is about 30 miles long and 7 miles wide and roughly parallels the drainage of San Antonio Creek. It lies between Santa Maria Valley to the north and the Santa Ynez Valley to the south. The valley is bounded on the north by the Casmalia Hills and the Solomon Hills, on the south by the Purisma Hills and Burton Mesa, and on the east and west by uplifted consolidated rocks. The surface-water drainage of the proposed study area encompasses 154 mi^2 of Santa Barbara County and the groundwater basin covers an area of about 128 square miles (mi^2). San Antonio Creek provides the main surface drainage for the area, flowing generally from east to west into the Pacific Ocean. At the western end of the ground-water basin, about 5 miles east of the Pacific Ocean, consolidated rocks form a barrier to the seaward flow of ground water. Upwelling of ground water east of the barrier has created a 660-acre marshland known as Barka Slough. This slough, one of the few pristine marshlands in southern California, is known or believed to be inhabited by at least nine threatened or endangered species of wildlife (Descheneaux, 1975).

Land in the San Antonio Creek valley is used primarily for agriculture. Historically, the upland parts of the valley have been used for dry farming or pastureland and the flatlands along the streams for irrigated farming. Since 1980, however, large sections of formerly non-irrigated pastureland in the upland parts of the valley have been converted to irrigated vineyards. The western quarter of the valley is owned by Vandenberg Air Force Base (VAFB), and the remainder of the valley is privately owned. Los Alamos, a census-designated place (CDP) in Santa Barbara County, covers about 3.9 mi^2 in the east-central part of the valley and had a population of 1,890 at the 2010 census, up from 1,372 at the 2000 census.

Currently, groundwater is the sole source of water supply in the San Antonio Creek Valley. Groundwater withdrawals, mainly for the irrigation of agricultural crops, have resulted in water-level declines in some areas of more than 100 ft since the 1950s (fig. 2). Demand for ground water in the predominantly rural San Antonio Creek valley has increased significantly since 1978 because of the establishment of extensive irrigated vineyards on formerly non-irrigated pastureland and pumpage from the valley and by VAFB (Martin, 1985). An evaluation of groundwater conditions in the San Antonio Creek groundwater basin by the USGS indicated that at that time there was an average groundwater overdraft (loss in groundwater storage) of 6,390 acre-ft/yr during 1982 (Martin, 1985). In addition to loss of groundwater in storage, the pumpage demand was met by a reduction of groundwater discharge (base flow) to San Antonio Creek and Barka Slough and reduced evapotranspiration from native riparian vegetation habitat at Barka Slough.

Future transfer of pastureland to irrigated vineyards will further increase the demand for water in the valley. Previous studies (Muir, 1964; Hutchinson, 1980; Martin, 1985) have indicated that pumpage in the valley by the 1980s was already greater than perennial base flow in San Antonio Creek prior to 1978. To plan for anticipated growth in the San Antonio Creek valley, there is a need to develop methods to evaluate and predict changing ground-water conditions resulting from current and proposed pumpage in the valley.

There is concern by many residents and water managers that if the basin has overdraft conditions, groundwater 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 alluvial aquifer deposits. The western end of the valley is an important source of water for VAFB. Hence, the overdraft may endanger VAFB's supplementary water source. Furthermore, there are concerns that increase withdrawals by VAFB and other users in the western end of the basin may affect the viability of several endangered species and their habitat.

Previous studies of the San Antonio Creek Valley (Hutchinson, 1980; Martin, 1985; VAFB) documented the hydrogeologic conditions of the area, summarized water-level fluctuations, pumpage, natural discharge, water quality, delineated aquifers and estimated recharge, natural discharge, pumpage, and storage changes. Since these studies were completed, water levels have declined into the deeper alluvium that was not previously investigated in detail. Because the San Antonio Creek Valley is dominantly supplied by this local aquifer, it will be important to define the water-bearing and water-quality properties of the deeper stratigraphic sections of the groundwater basin. Moreover, it is important to determine the effects of changes in the basin on the hydrology and water quality of Barka Slough and perennial reaches of San Antonio Creek, which provides habitat to several sensitive wildlife species, including the California red-legged frog, Southwestern Pond Turtle, and endangered tidewater goby, three-spine stickleback, and California tiger Salamander. To plan for future use, it will be important to define the quantity and quality of the groundwater supply and establish tools to allow users to efficiently utilize the available groundwater resources.

Objectives

The objectives of this study are to: (1) refine the hydrogeologic framework of the San Antonio Creek Valley, (2) quantify the hydrologic budget of the valley, (3) develop hydrologic modeling tools to evaluate and manage the groundwater resources, (4) compile data and provide analysis that is consistent with the terminology of California state laws and regulations, including recently enacted SB 1168, SB 1319, and AB 1739. These objectives will be reviewed annually; if the State enacts new statutes or adopts new regulations that warrant changing the Project's current scope of work, the project scope and budget may be revised to reflect increased levels of cost or resources. The study will develop a greater understanding of the geohydrology of the San Antonio Creek Valley and help develop a management and monitoring plan to evaluate the potential hydrologic effects of future groundwater development on different parts of the valley. An additional objective is to refine understanding of the hydrology, water quality, and groundwater/surface-water interactions of Barka Slough, located within VAFB at the western end of the San Antonio Creek groundwater basin, which is critical wetland habitat for several endangered and threatened species of wildlife.

Study Area

Climate

The San Antonio Creek Valley is located within the Coast Ranges and has many of the climatic features of the region. The valley is characterized by dry summers and cool winters. Rainfall averages 15 inches per year (Hutchinson, 1980, p. 6).

Geology

The groundwater basin is underlain by consolidated rocks of the Miocene through Pliocene Monterey and Sisquoc Formations and Foxen Mudstone; poorly consolidated to unconsolidated basin-filling deposits include, from deep to shallow, the Pliocene Careaga Sandstone, the Paso Robles Formation, the Pleistocene Orcutt Sand, and Pleistocene to recent terrace and alluvial deposits (Woodring and Bramlette, 1950). Well data have shown that the basin fill is more than 3,000 feet thick in the center of the basin and rapidly decreases in the thickness near the basin margins (Hutchinson, 1980). The structure of the area is a syncline that is bounded between the thrust-bounded uplift of the Purisima Hills to the south and the Camalia/Orcutt anticline to the north. No major structures are known to cut transverse across the basin, although a number of minor folds have axes that are transverse to the main valley. The deep consolidated-rock section is upfolded or faulted at the west edge of the groundwater basin near the east edge of Burton Mesa and forms an impediment to subsurface flow, forcing groundwater discharge at Barka Slough.

Aquifer System

Muir (1964) identified the main water-bearing units to be the up to 2,000-ft thick unconsolidated gravel, sand, silt, and clay of the Paso Robles Formation and young alluvium that is up to about 100 feet in thickness. Other formations, such as the deeper Careaga Sands, may yield significant amounts of groundwater and are potentially exploitable as a viable deep resource.

Figure 1 shows the study extent as the California Department Water Resource's basin boundary. Based on results of this study, the current applicability of this basin boundary will be discussed. For example, there are historic wells west of this boundary.

However, recent monitoring attempts have not been successful in finding existing groundwater resources (wells to monitor) west of the slough.

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 groundwater overdraft. In particular, Santa Barbara County will benefit from a more thorough understanding of the water resources in an important local agricultural area. The study will benefit VAFB, which manages Barka Slough, by providing improved understanding of the sensitivity of the endangered species habitat in the wetland to basin-wide hydrologic, climatic, and water-quality conditions. Benefits to the nation include quantifying the resources of a local 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 provide complete coupled hydrologic simulation of the valley. 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. Santa Barbara County will be instrumental in the success of these tasks, particularly data acquisition.

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. The GIS data system for San Antonio Creek 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 basin-wide synthesis of water resources. Ground-water-level maps will be prepared showing water levels and the direction of groundwater flow for selected periods. In addition, water-level change maps and water-level hydrographs will be prepared to show the long-term change in groundwater 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 groundwater quality.

Task 2: New Data Acquisition

Refining the hydrogeologic framework of the valley, as well as developing new geologic and hydrologic models, will require the collection of depth-dependent or aquifer dependent hydrogeologic 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. New data will be collected to better quantify groundwater/surface-water interactions.

Santa Barbara County personnel will be instrumental in talking with San Antonio Creek Valley residents and discussing the benefits of the study. These interactions will be necessary for access to existing well sites and potential drilling sites. Furthermore, Santa Barbara County personnel will be invaluable for canvasing well existing well sites and determining and gaining access to county right of way

Task 2A. Drilling and Well Installation

All drilling and well installation will be completed by the USGS Research Drilling Program. All wells will be developed to obtain representative measurements of aquifer conditions and will subsequently be used for additional data collection as specified in tasks 2B, 2D, 2E, and 2F.

i. Multiple-Well Monitoring Sites

Up to two new multiple-well monitoring sites will be constructed for this study. The completion of new multiple well monitoring sites will provide original 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). Conceptually, it is expected that one multiple-well monitoring site (site 1) will be installed along the main east-west axis of the San Antonio Creek Valley where basin sediments are thickest. The target depth for the bottom of site 1 is about 1,000 ft below land surface. The other multiple-well monitoring site (site 2) will likely be installed north or south of the main axis of the valley, where existing hydrologic data are sparse. Because the basin sediments thin away from the axis of the valley, a target depth of 600 ft is planned for site 2. Mud-rotary drilling techniques will be used for the test drilling at the multiple-well monitoring sites; geologic samples will be collected throughout the drilling and will be described and archived following standard operating procedures (Hanson, 2001; Hanson and others, 2002; Everett and others, 2011). Geophysical logs will be collected and used to select depths for monitoring well installation. Each of the monitoring sites will include approximately four wells in a single borehole that will allow for the monitoring of water levels and groundwater chemistry at specific depths (fig. 4). The depth of these monitoring sites will vary but should include wells completed in the unconsolidated to semi-consolidated basin-fill sediments. However, at site 2, it is planned that drilling will continue up to 100 ft into the underlying bedrock, probably Miocene through Pliocene Monterey or Sisquoc Formations, and that the deepest monitoring well will be installed in a permeable layer within the predominantly low permeability shale. The purpose of the monitoring well in the underlying bedrock is to obtain water level and water chemistry data to help characterize interactions with the underlying bedrock as a source of salinity and trace elements of concern to the overlying aquifer.

These multiple-well monitoring sites provide geologic, hydrologic, geochemical, and water-quality data (ex. Hanson, 2001; Hanson and others, 2002). Additional sites can be added if additional resources become available.

ii. Shallow Wells at Multiple Locations

Up to 7 shallow monitoring wells, one per test hole, will be installed at selected locations in the shallow portion of the aquifer system. Access to sites for this drilling may be problematic. Contacts developed by Santa Barbara County personnel will be necessary to make this task viable. Ideally, the shallow wells will be located relatively close to selected existing production or other wells in which water levels are currently monitored annually by USGS. Wells currently monitored for water levels are typically 250 to 650 ft deep but the depth to water is 100 ft or less at many of these sites. The purpose of installing the shallow water table wells is to quantify vertical changes in water levels and water quality in the upper portion of the aquifer system between the newly installed shallow wells and the existing wells. The upper part of the aquifer system may be experiencing the most rapid changes in groundwater velocities and water quality as a result of proximity to modern land use, and effects of increased pumping and recharge, which cause increased vertical flow components. Because the shallow wells will typically be less than 150 ft deep, they can be drilled using an auger rig, which is a less expensive method for drilling than the mud-rotary method used for drilling deeper multiple-well monitoring sites; thus, shallow wells can be cost-effectively installed at multiple locations. These wells will be located along the main axis of the valley where most wells monitored for water levels are located and where depths to water are usually less than 100 ft. Of the planned 7 shallow wells, two are planned to be installed in close proximity to stream gages discussed in task 2C, unless existing wells are found to be suitable. These wells will be used as part of an effort to quantify groundwater recharge from surface water using temperature and hydrologic data (see task 2D).

Task 2B. Groundwater Levels

Under contract with Santa Barbara County, the USGS currently measures water levels annually in approximately 30 wells within or immediately adjacent to the San Antonio Creek groundwater basin. During this study, the number of existing wells measured and the frequency of measurements will be increased. In addition, new wells will be installed and added to the measurement network. Selected wells will be instrumented with pressure transducers to record hourly water levels.

i. Well Canvassing

At the beginning of the study, an inventory of wells in the basin will be compiled and reviewed in cooperation with Santa Barbara County. Priority areas for additional water-level monitoring to fill spatial gaps will be identified. Well owners will be contacted and site visits conducted to add approximately 15 existing wells to the monitoring network.

ii. Expanded Periodic Measurements

In addition to continued monitoring in approximately 30 wells already measured, approximately 15 existing wells identified during well canvassing and about 15 newly installed monitoring wells (task 2A) will be added to the groundwater-level monitoring network. For all wells for which recorders are not installed, water levels will be measured approximately quarterly during FY2014-FY2016. The expanded network will fill critical horizontal and vertical gaps in water-level data and the increased frequency will be necessary to identify the sensitivity of the aquifer system to seasonal changes in climatic and pumping conditions.

iii. Groundwater Level Recorders

Selected monitoring wells at the two newly installed multiple-well sites, the existing multiple well site near Barka Slough, and shallow wells near stream-gaging stations will be equipped with pressure transducers for recording hourly water levels. The existing multiple well site near Barka Slough has already been instrumented with pressure transducers by Santa Barbara County and these sites will be included in those for which records are managed, quality-assured, and made available to the public through the USGS National Water Information System (NWIS). Similarly, pressure transducers will be installed in some wells at the new multiple-well monitoring sites. Pressure transducers for measuring water level and temperature will be installed in newly drilled or existing wells located in close proximity to the existing stream-gaging station of San Antonio Creek above Los Alamos and a station installed for this study on a tributary to San Antonio Creek (see Task 2C). In addition, a recorder will be installed in an existing shallow well in or on the edge of Barka Slough. The hourly water-level and temperature data from the shallow groundwater wells and surface-water sites will be used in modeling to calculate surface-water/groundwater fluxes (task 2D).

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.

iv. Measuring Point Elevations

A high precision Global Positioning System (GPS) will be used to determine the elevations of measuring points of all wells and surface-water sites in the monitoring network.

Task 2C. Streamflow Gaging

In addition to continued operation of an existing streamflow gage, San Antonio Creek at Los Alamos (11135800), two new streamflow stations will be added as part of the study and will be operated during FY2014-FY2016. A previously operated gage at San Antonio Creek near Casmalia (11136100), which is slightly downstream of the San Antonio groundwater basin and represents the outflow from the basin, will be reinstalled and operated during the study. This station was operated from 1955-2003 and will be essential for comparing current basin outflows to historical data. A new station will be installed on a tributary to San Antonio Creek. The site will be selected based on expected measureable flows, the representativeness with respect to tributaries in the basin, and access for a gaging station. A tributary station will be valuable for providing measured streamflow data to constrain watershed runoff simulations (task 3) and for estimating groundwater/surface-water interactions (task 2D) along a tributary.

Task 2D. Groundwater/Surface-Water Interaction

Historical water budgets (Hutchinson, 1980; Martin, 1985; Santa Barbara County, 2003; 2012) have indicated that infiltration from streamflow during ephemeral winter runoff events is a major source of recharge to the groundwater system. Similarly, groundwater discharge to Barka Slough is the major natural discharge from the basin and is critical for maintaining riparian wetland habitat supporting endangered species. For these reasons, as part of a comprehensive hydrologic investigation, it is important to make field measurements that can be used to determine independent estimates of groundwater/surface-water interactions that can be used to compare to and constrain estimates from hydrologic models. Three sets of analyses of groundwater/surface-water iterations are proposed, as described below.

i. Groundwater/surface-water fluxes from temperature

Temperature is a naturally occurring tracer that can be used to calculate fluxes of water between surface water and groundwater (Constanz and Stonestrom, 2003). There are a number of methods for calculating water fluxes based on temperature contrasts and propagation of the amplitude and timing of temperature signals with depth in the sediments beneath a surface-water body (Constanz and Stonestrom, 2003; Hatch and others, 2006). For this study, up to five temperature recorders will be installed at different depths in a piezometer pounded into the upper meter of the streambed at three locations in the San Antonio Creek valley. One profile each will be installed: near the gage at San Antonio Creek above Los Alamos, near the gage on the tributary to San Antonio Creek, and in Barka Slough. At the first two locations, streamflow will be ephemeral, and downward fluxes from the stream are expected; stream stage data from the gage and groundwater level and temperature in a nearby shallow well will also be measured. In Barka Slough, the an upward flux of water from groundwater to surface water is expected; pressure transducers that record temperature and water level will be installed in a shallow well and in surface water. Fluxes of water between surface water and groundwater using temperature signals in the streambed will be estimated using a onedimensional numerical modeling approach described by Voytek and others (2013). In addition, temperature and head differences between surface water and shallow wells will be modeling using methods described by Constanz and Stonestrom (2003). The outcome of these analyses will be quantification of fluxes of water between surface water and groundwater as a function of hydrologic conditions at a few representative locations. These independent estimates will be valuable for comparison with and constraining groundwater/surface-water fluxes estimated by hydrologic models of the basin.

ii. Streamflow duration and location

Electrical resistance (ER) sensors installed in streambeds represent a relatively new technique for evaluating the presence of water in a stream (Blasch and others, 2002; Jaeger and others, 2012). The ER sensors record a low resistance (high conductivity) in an electrical circuit when water is present to close the circuit and high resistance (low conductivity) when water is absent. The ER sensors are relatively simple to construct by modifying commercially available temperature sensors (Blasch and others, 2002). Because the ER sensors simply record high or low conductance, and the presence of water saturated conditions is the variable determining the difference in signal, the record requires little processing. The ER sensors are anchored to the streambed and downloaded once or twice a year.

The ER records, recorded at approximately hourly or more frequent time periods, will indicate the location and timing of streamflow. In San Antonio Creek, a network of about 25 ER sensors is planned, including approximately 5 in Barka Slough, 5 along a tributary, and 15 along the length of San Antonio Creek from the headwaters to Barka Slough. In the predominantly ephemeral stream network of San Antonio Creek, the data will be used to better quantify the timing of ephemeral runoff events and the propagation of ephemeral runoff through the network; this information will be used to refine estimates of the duration and location of groundwater recharge from ephemeral streamflow. In Barka Slough, placement of ER sensors in different portions of the wetland will be used to better quantify the timing of standing water (hydroperiod) as a function of elevation and regional hydrologic conditions. This data will be useful for indicating the sensitivity of standing water in the wetland to regional hydrologic and climatic conditions in San Antonio Creek, which could be relevant to understanding temporal fluctuations in wetland habitat conditions for endangered species such as the unarmored threespine stickleback (U.S. Fish and Wildlife Service, 2009).

iii. Streambed Infiltration Tests

Streambed infiltration tests at selected locations will be conducted to quantify infiltration rates under controlled conditions. A double-ring infiltrometer method will be used for these tests (Youngs, 1991). At selected sites, a 4-foot diameter double-ring infiltrometer, having an inner-ring with a diameter of 2 feet is driven a few inches into undisturbed surficial material and where necessary, soil is mounded around the outside of the infiltrometer to prevent leaking. The flow of water from calibrated containers into the two individual infiltrometer rings is regulated to maintain a constant head within the rings. The slope of the best-fit line through cumulative infiltration volume (the volume of water lost from the calibrated containers) versus time represents the ponded infiltration rate. The numerical modeling program VS2D can be used to estimate hydraulic conductivity and detect the possibility of low permeability layers by matching modeled infiltration rate curves to the measured data (Healy and Ronan, 1996). These infiltration rates can be combined with information on streamflow duration and location and stream stage, to estimate fluxes from ephemeral streams to groundwater. These independent estimates can then be compared to stream infiltration simulated in hydrologic models to constrain model estimates.

Task 2E. Water Quality

The existing water-quality data will be supplemented with groundwater chemistry data collected during this study from the newly installed multiple-well monitoring sites and shallow wells (approximately 15 wells), and selected existing production wells (approximately 15). These data will be used to define the source, movement, and age of water from wells in relation to priority water-quality concerns, including salinity, nitrate, arsenic, iron, manganese, molybdenum, and combustible gases from petroleum sources. Samples will be analyzed for major ions, nutrients, trace elements, by the U.S. Geological Survey National Water Quality Laboratory (NWQL) in Denver, CO; the major ion and trace element data include numerous constituents that can be used to analyze the sources of salinity in the aquifer system. Stable isotopes of oxygen and hydrogen inwater, which serve as a tracer of water source, will be analyzed by the USGS Reston Stable Isotopic Laboratory (RSIL) in Reston, VA. Samples will be analyzed for additional solute isotopes, including sulfur and oxygen isotopes of sulfate (RSIL) and strontium isotopic ratios at the USGS Menlo Park Trace Metal Laboratory; these isotopic values can be used to understand the sources of and processes affecting solutes. Samples will be analyzed for tritium to determine presence of water that has recharged the aquifer since about 1950 (less than about 60 years old); these samples will be analyzed at the USGS Menlo Park Tritium Laboratory. Samples will be analyzed for carbon-14 and carbon-13 to determine the age of older (greater than 100 years) groundwater that does not contain tritium;

laboratories under contract with the U.S. Geological Survey will analyze samples for carbon isotopes.

Samples collected for analysis of dissolved gases (nitrogen, argon, methane) will be analyzed at the USGS Dissolved Gas Laboratory in Reston, Virginia. Methane data will be used to assess geochemical conditions in the aquifer and to evaluate if gases from underlying formations or petroleum extraction are influencing water chemistry in the basin.

Quality assurance for the analytical data will be provided through the use of blank and replicate samples collected as part of the study. Many of the analytes are in common with a recent study by the California Groundwater Ambient Monitoring and Assessment (GAMA) Program in which samples were collected from 11 wells in the San Antonio Creek Basin in 2008 (Mathany and others, 2010; Burton and others, in press). Data from this recent study will be included with data collected for this study.

Because surface-water infiltration is a major source of groundwater recharge, surface-water samples will be collected and analyzed for most of the constituents as groundwater samples. Samples will be collected twice during the winter, once early in the season, and once late in the season, during runoff events from all three surface-water gaging sites. An additional sample will be collected during summer baseflow conditions from San Antonio Creek at Casmalia, which is perennial; the other two stations are ephemeral and can only be sampled after runoff events.

Task 2F. Aquifer Properties Data

i. Slug Tests in New Monitoring Wells

Slug tests will be performed on all monitoring wells installed for the study. Approximately 8 of these new monitoring wells will be at different depths in multiple-well monitoring sites and approximately 7 will be relatively shallow wells. These data will help define the properties of the aquifer system in three-dimensions and provide valuable information for development of the hydrologic models.

ii. Temporal Geophysical and Temperature Logging

At three multiple well monitoring sites, resistivity and temperature logs will be collected from the full depth of the deepest monitoring well at each site at different times of the year to identify seasonal changes in water quality and groundwater flow patterns. Two of the deep monitoring wells will be installed as part of this study and the third is an existing multiple-well monitoring site installed in the 1980s near Barka Slough. Sequential electromagnetic (EM) resistivity logging is useful for identifying changes in groundwater quality through polyvinyl chloride-cased wells in intervals not screened by wells (Metzger and Izbicki, 2013). Perturbations in vertical temperature gradients revealed in temperature logs can provide information on horizontal and vertical groundwater flow patterns (Ingebritsen and Sanford, 1998; Everett and others, in review); collection of temperature logs at different times seasonally could reveal the sensitivity of groundwater flow patterns to seasonal changes in pumping. At each of the three sites, temperature and EM resistivity logs will be collected three times over an approximately 1 year period to identify changes in temperature gradient and resistivity profiles through time as function of hydrologic conditions.

Task 3: Model Development

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

Hydrogeologic Framework Model

The subsurface configuration of aquifers and confining units and their sediment textural and hydraulic properties will be interpreted from surface geologic mapping, borehole geologic and hydrologic information, and geophysical data. Analysis will involve such elements as defining basin stratigraphy and structure, developing 3D distribution of permeabilities and other properties, predicting the location and hydrologic influence of structures, and evaluating basin evolution within the overall tectonic framework of the region. Previous descriptions of the basin shape and geometry (Muir, 1964; Hutchinson, 1980) have relied on a limited number of boreholes and have been relatively poorly documented in be based on abundant well-documented well data (e.g., Sweetkind and others, 2010) to develop a fuller, better documented 3D portrayal of the basin and component aquifer units.

Work will be conducted in three areas;

(1) Construction of 3D hydrogeologic framework

A digital 3D hydrogeologic framework model will be created from existing data that will show, at a minimum (a) the thickness of unconsolidated fill in the study area; (b) the extent, elevation, and estimated thickness of principal aquifers, and (c) the location of underlying impermeable rocks. Hydrogeologic framework will be constructed at a level of detail sufficient for numerical groundwater flow modeling of the basin. 3D hydrogeologic model will be based on interpretation of stratigraphic data from oil wells (Sweetkind and others, 2012), water wells, surface geologic maps (Tennyson and others, 1995), and existing geophysical data.

The basin boundary with Santa Maria basin to the north and the Santa Ynez uplands to the southwest is in places defined by the topographic divide and not by subsurface geology (Hutchinson, 1980). Aquifer materials are continuous in these areas, leading to the possibility that there could be some underflow or groundwater connection between these adjacent basins. A full 3D portrayal of the groundwater basin and surrounding areas would help define the nature of the subsurface geology at the boundary of the basin which would aid in an assessment of potential inflows and outflows

(2) Definition of textural variations in principal aquifers.

Previous reports lacked specifics in defining the aquifer characteristics of each unit and in defining what unit each well was drawing from. This lack of specificity creates some confusion in the basin descriptions, for instance, where alluvium is described as saturated but the underlying Orcutt sands are described as unsaturated. A more careful description of the extent and thickness of all units will better define which aquifers are important in what part of the basin. Likewise, previous reports did not deal all that well with internal variability of units, including the alluvium, the Orcutt Sand and the Paso Robles Formation, even though the Paso Robles is described as having channels of coarse materials. Hutchinson (1980) describes well yields from alluvium as being lower in the center of the basin, which does not make much sense because that is where the alluvial channel is.

3-D lithologic models will be constructed depicting major textural (grain size) variations within each aquifer hydrogeologic unit, both in map view and in the vertical sense. Textural variations will be derived from water well driller's lithologic descriptions and interpretation of borehole electric logs. Textural analysis will seek to identify significant within-unit grain-size variations including the presence of coarse-grained channels or persistent clay layers. Results are intended to inform assignment of horizontal hydraulic conductivity to aquifer units during numerical flow modeling.

(3) Aquifer hydraulic properties

Test data from water wells, including discharge rate, water-level drawdown, and the length of pump test will be used to calculate specific capacity, a measure of well productivity. Where possible, discrete water-bearing zones will be identified in each borehole such that the specific capacity data may be tied to a lithologic or hydrogeologic unit. For wells that lack information regarding water-bearing zones, the unit elevations from the 3D hydrogeologic model will be used to infer which units are likely present down hole.

Hydrologic Models

Recharge Model-- Groundwater recharge is one of the largest unknowns in the hydrologic budget of the San Antonio Creek Valley. Many methods have been developed and used over the years to quantify these rates throughout various portions of the San

Antonio Creek Valley. The San Antonio Creek 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. Therefore, several methods will be examined to help quantify the uncertainty in the recharge component of the water budget.

In order to calculate the recharge to the groundwater system, a variety of methods will be examined. In some cases, new analyses will be performed. The existing recharge estimates will be compiled, including previous modeling investigations. Possible recharge estimation methods include:

1) Watershed models
   a. Precipitation Runoff Modeling System (PRMS) (Leavesly and others, 1983)
   b. INFIL (Hevesi and others, 2002; Hevesi and others, 2003)
   c. Basin Characteristics Model (BCM) (Flint and Flint, 2007a; Flint and Flint, 2007b)
   d. Variable Infiltration Capacity Model (VIC) (Liang and others, 1994)
   e. Soil Water Balance Model (SWB) (Westenbroek and others, 2010)
2) Analytical and empirical methods
   a. Channel geometry
   b. Others (?)
3) Chemical methods
   a. Chloride pulse
   b. Stable isotopes and anomalous water samples from precipitation, springs, and wells (recent sampling (GAMA))
4) Field data

Estimation of recharge from losing stream reaches will be compiled and data gathered through the course of this study. Recharge in these areas will be estimated from different sources of information such as published recharge estimates (for example, numerical modeling studies), published streamflow data, and data acquired as part of this study. Where significant, streamflow data will be examined to identify and quantify streamflow losses within individual stream reaches.

Recharge will be estimated for a minimum 70-year record (e.g., 1940-2010) on a yearly time step. Several methods for estimating recharge will be examined initially, and several of these will be selected for application to our study area. A preliminary BCM has already been developed for the San Antonio Creek Valley study area and will be one of the selected methods (Flint and Flint, 2007a). Likewise, INFIL has been applied to nearby basins. The SWB model, which was recommended by Stanton and others (2011), is also a possibility. The SWB code uses commonly available GIS layers of soil and land use and datasets of temperature and precipitation to estimate the availability of water for recharge on a daily time step. The SWB model is designed for regional problems and is most reliable when averaged over time scales of months to years (Westenbroek and others, 2010). The soil moisture retention curve numbers in SWB were tested for humid climates in their development and may need to be modified for the study area. However, the SWB model was successfully used for a semi-arid climate to estimate recharge in the High Plains aquifer system groundwater availability study (Stanton and others, 2011).

Because it exists in the region and has been shown to be a robust method, the BCM (Flint and Flint, 2007a,b) will be used to estimate a time series of ungaged runoff from the mountains that surround San Antonio Creek Valley within the entire watershed. This model will be calibrated, in part, on the inflow and outflow stream gage data on the San Antonio Creek River Creek and its tributaries. 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 San Antonio Creek Valley recharge estimates will be compared to published recharge estimates and other simulation techniques and differences will be examined. Results of the selected recharge simulation models will be compared and contrasted. The statistical variability/uncertainty of these methods and how they compare and contrast as a whole and spatially will be examined. The pros and cons of the methods available will be identified and summarized. Finally, a precipitation-runoff model will be selected and integrated within a hydrologic flow model to simulate recharge and groundwater flow in the San Antonio Creek Valley.

Integrated Hydrologic Flow Model-- The hydrologic 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 non-steady 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 possibility of using GS-FLOW in the areas outside of agricultural pumping will also be examined (Markstrom and others, 2008). The hydrologic model will be constructed on the structure and layering delineated from the hydrogeologic model (Task 3) and calibrated to historical water-level and water-use data for the period of 1939-2015 (Task 1). The calibrated model will provide an analysis of the historical groundwater use and an analysis of future water availability under different water-use scenarios.

Task 4: Water Availability Analysis

The hydrologic model developed in Task 3 will be used to evaluate how selected water-use and climate scenarios affect the availability of groundwater in the San Antonio

Creek 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 groundwater flow and groundwater storage in different hydrologic regions of the San Antonio Creek Valley caused by current and projected groundwater use. The hydrogeologic 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 groundwater 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 deeper formations decreases with depth and/or water-quality is degraded with depth then the estimates of potable water in groundwater storage could be reduced significantly. The effect of poor water quality in the deeper units will be evaluated using a particle tracking analysis.

Task 5: Reporting

Quarterly reports will be produced summarizing the work completed during that quarter by task. These reports will accompany the quarterly billing.

The following meetings will be attended by at least one USGS representatives:

1. Kickoff
2. Four annual stakeholder meetings
3. Concluding stakeholder meeting
4. Concluding Board of Supervisors meeting

Three technical manuscripts, a fact sheet, and a web site reporting the results of the study are planned. The technical manuscripts include: (1) a USGS Scientific-Investigation Report (SIR) summarizing the hydrogeologic framework, including analysis of existing (task 1) and new (task 2) hydrologic data, (2) a journal article or short USGS SIR summarizing the results of analysis of groundwater and surface-water quality in the study area, (3) a USGS SIR describing model construction and calibration and water availability analysis. These reports will provide the technical information for stakeholders to pursue a basin wide groundwater management plan to protect water resources of the basin. A fact sheet will be developed as an executive summary of the results of the study. 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 San Antonio Creek Valley.

The USGS SIR describing the water availability will do the following:

1. Delineate the different zones or sub-areas of the aquifer, both spatially and with depth.
2. Describe the interaction and hydraulic continuity between these differing zones or

sub-areas, including whether declining water levels (increasing gradients) in one zone or sub area may affect an adjacent zone or sub-area.

3. Evaluate the overall hydrologic budget including the current status of each zone or sub-area in terms of surplus, equilibrium, or usage greater than replenishment and what can be expected under differing climatic and cultural scenarios. Include in these scenarios VAFB's possible maximum, median and minimum pumping patterns from their production field in the Barka Slough.
4. Calculate the "sustainable yields" per each zone, in order to avert further decline in water elevations.
5. Calculate the remaining "useable" or "available" storage; that is the amount of water currently in the whole aquifer that could be extracted from the level of the current deepest drilled water well.
6. Calculate the current "dewatered storage".
7. Identify if subsidence is occurring and if so calculate such. (Note: Preliminary estimates indicate very little subsidence and an extensive analysis of subsidence is not planned. Results of the preliminary analysis will be included; however, if new evidence of subsidence is uncovered, the parties will mutually agree on what to cut from the scope of work to fund the additional subsidence calculations).
8. Identify areas of potential future recharge projects where percolation to the main body of the aquifer can be realized.

Along with SIR report cataloguing results of the study, the USGS will provide a condensed "fact sheet" summarizing results.

Staffing

The project chiefs will be Claudia Faunt, Matthew Landon, and Matthew Scrudato and personnel will also include Jill Densmore, Lorrie Flint, Alan Flint, Donald Sweetkind, David O'Leary, and Peter Martin (if still available) as part of the team that will complete the project. Tasks 2B (groundwater levels) and 2C (stream gaging) will primarily be conducted by staff from the Santa Maria Field office. Staff from the Santa Maria Field office and project offices in San Diego and Sacramento will participate in task 2D (groundwater/surface-water interaction) and task 2E (water quality). Tasks 1 (existing information analysis), 2A (drilling and well installation), 2E (aquifer properties), 3 (model development), 4 (water availability analysis), and 5 (reporting) will primarily be conducted by project staff from San Diego or Sacramento.

Cooperators/Collaborators

The principal cooperating agency will be the Water Agency Division of the Santa Barbara County Public Works Department. In particular, Dennis Gibbs has taken the initiative to develop this study and address the water-resource issues in San Antonio Creek Valley even though no water management agency presently exists in San Antonio Creek Valley. The U.S. Air Force, Vandenberg Air Force Base (VAFB), will also be a cooperator for this study. The study will benefit from the activities of a separately-funded project within the USGS Geologic Discipline (Menlo Park and Denver) that will contribute to data collection, analysis, and assist with hydrogeologic 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 San Antonio Creek Valley as part of their ongoing statewide project on assessment of water quality for water supply (Belitz and others, 2003; Burton and others, in press). Although there are many cooperators on this study, the bulk of the funding for this project will be from the Water Agency Division of the Santa Barbara County Public Works Department

Budget

The budgets for the different study tasks are listed by Federal fiscal year (table 1). 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-15 through FFY-19 and include preliminary estimates of the maximum federal matching funds of 25 percent of 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 2014 through 2019. Estimated funds from VAFB were estimated from the fraction of each task and subtask being conducted within the area of VAFB. For example, for the analysis of groundwater/surface-water fluxes from temperature data, one of the three study locations was planned to be located in Barka Slough, within VAFB. Therefore, one third of the funding for this analysis was estimated to be needed from VAFB. For the stream duration and location analysis, one-fifth of the ER sensors are planned to be located in Barka Slough within VAFB, so one-fifth of the cost for that analysis is planned for VAFB. The proportions vary by task or subtask based on the fraction of activity occurring within the area of VAFB.

Work Plan

This proposed study will require parts of several Federal Fiscal Years (FY) to complete.

A generalized work plan (by quarter) is given in Table 2.

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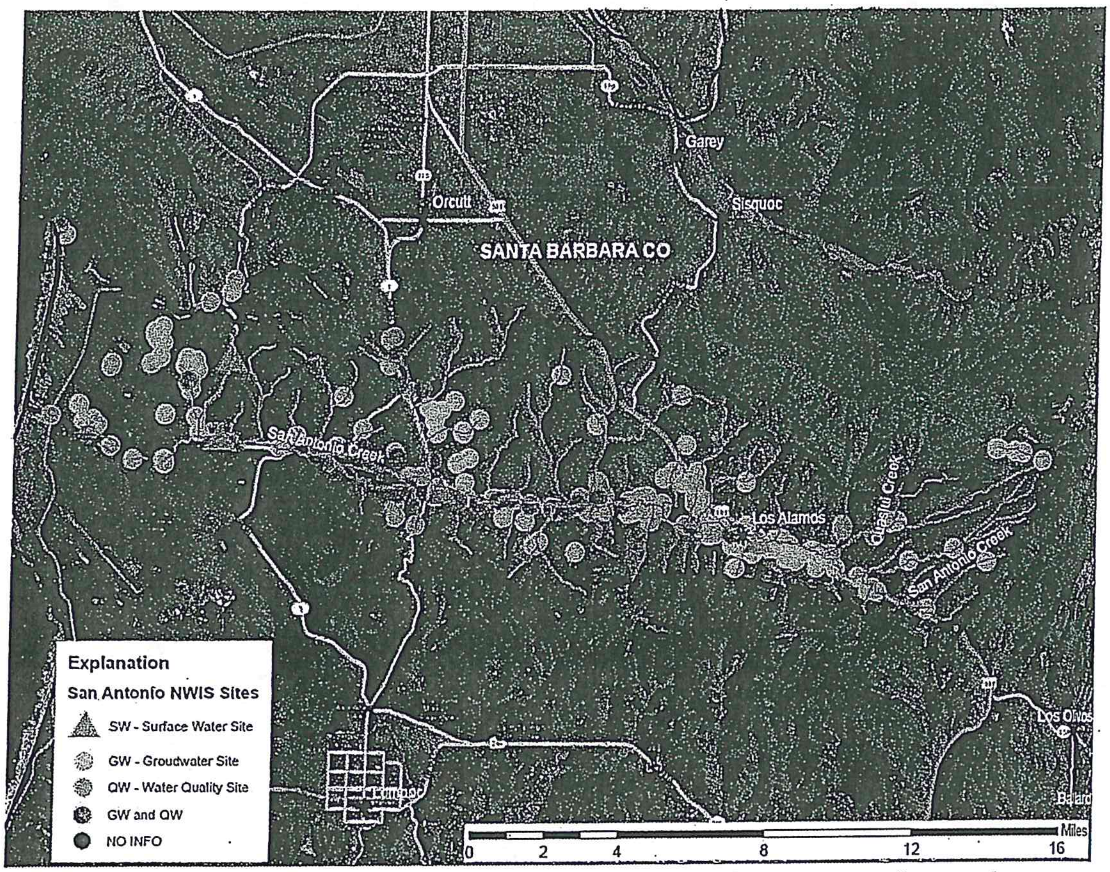

Figure 1. Map showing the San Antonio Creek Valley, surface-water and groundwater basins, streams, and faults.

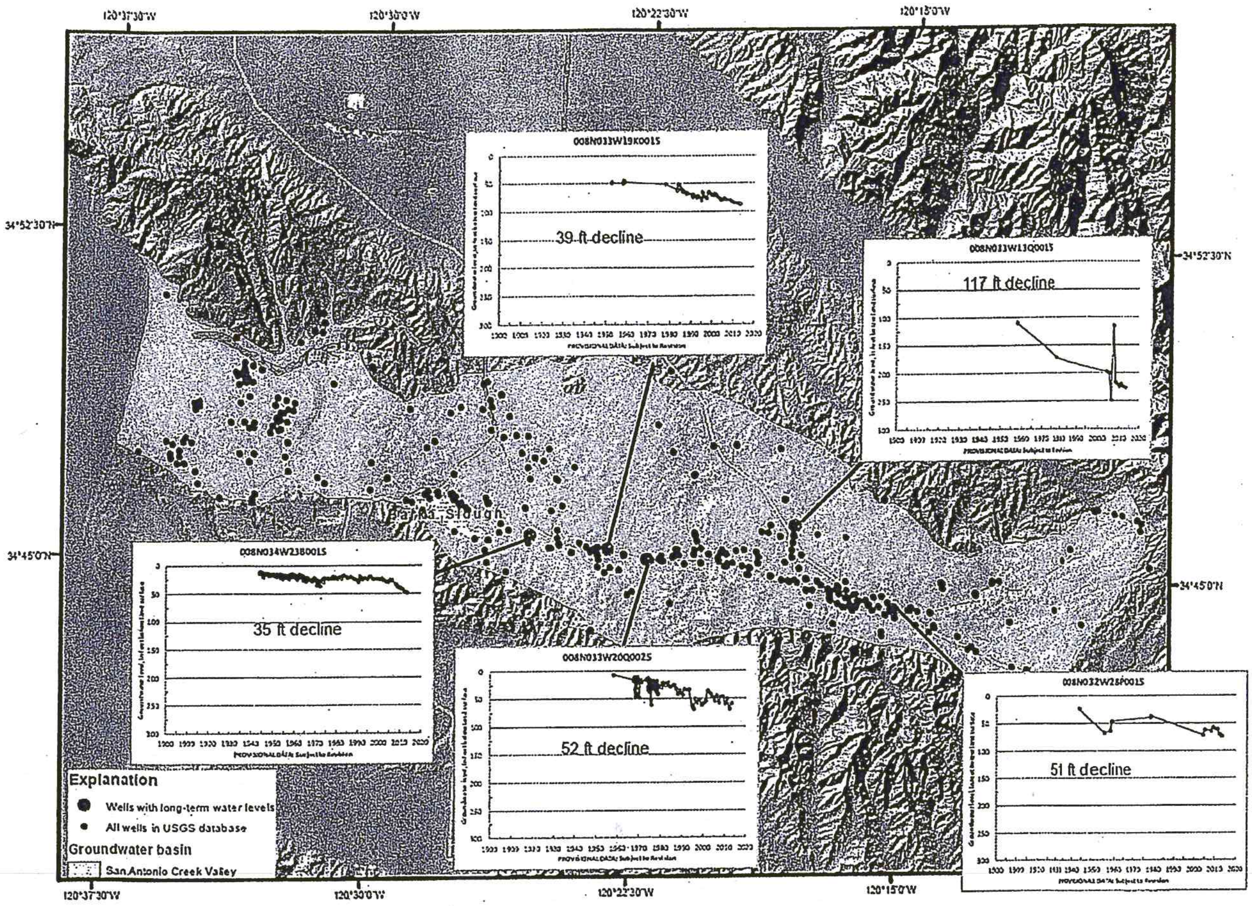

Figure 2. Map showing location of wells, generalized geology, and selected groundwater-level hydrographs from the San Antonio Creek Valley Basin, Santa Barbara County, California.

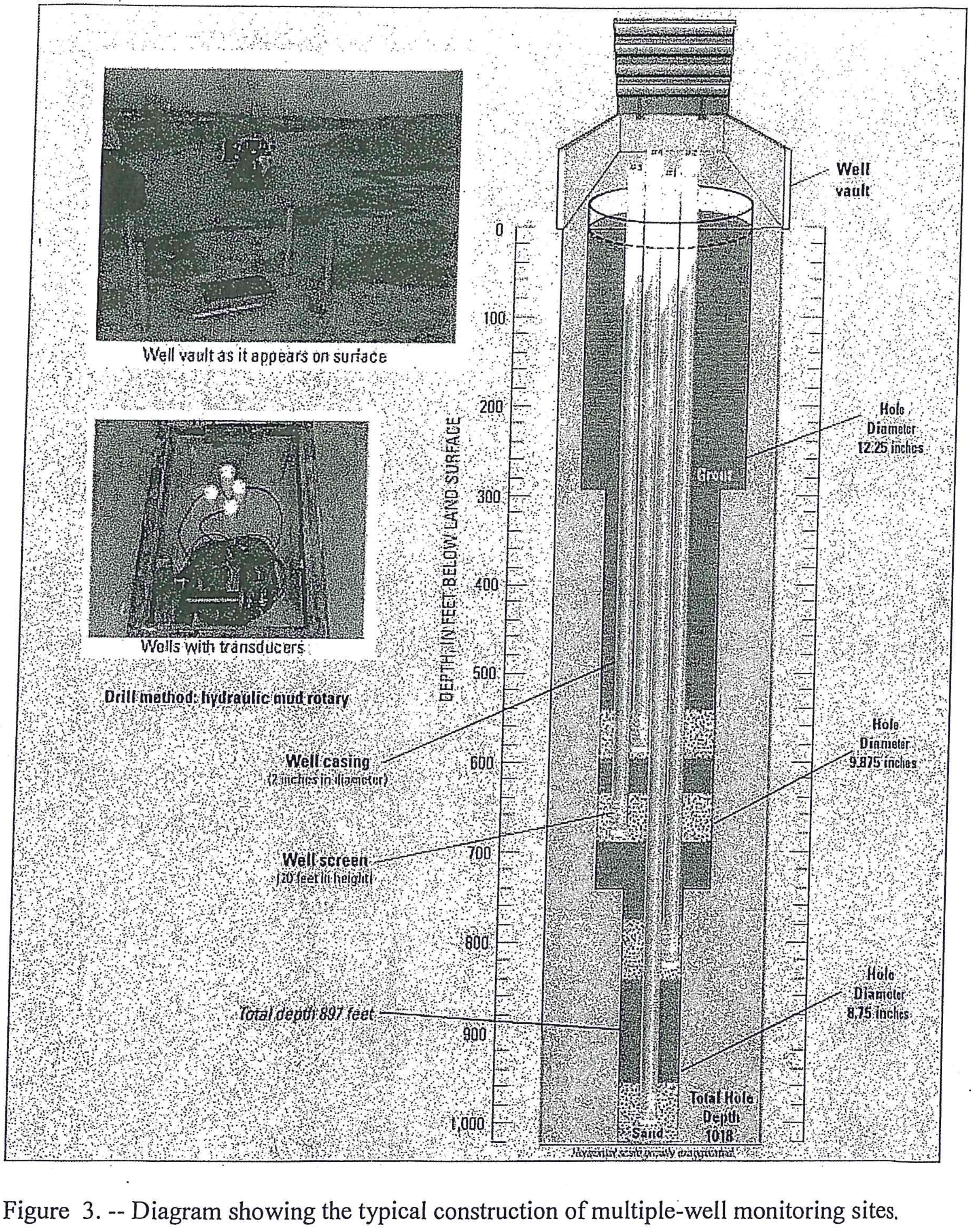

Figure 3. -- Diagram showing the typical construction of multiple-well monitoring sites.

Table 1. Budget for each task by county fiscal year (CY) and federal fiscal year (FY).

# Task	SB Co CY15	SB Co CY16	SB Co CY17	SB Co CY18	SB Co CY19	SB Co all
Start Date:	7/1/2014	7/1/2015	7/1/2016	7/1/2017	7/1/2018	
End Date:	6/30/2015	6/30/2016	6/30/2017	6/30/2018	6/30/2019	
1 Data Compilation	$0	$72,000	$0	$0	$0	$72,000
2 New Data Acquisition	$50,000	$552,160	$420,033	$22,621	$0	$1,044,814
A Drilling & well installation						
i Two multiple well monitoring sites	$0	$376,000	$0	$0	$0	$376,000
ii Auger drilling of shallow wells	$0	$0	$155,000	$0	$0	$155,000
B Groundwater levels						
i Well canvassing	$2,610	$0	$0	$0	$0	$2,610
ii Expanded GW level monitoring	$6,264	$12,241	$10,988	$2,767	$0	$32,260
iii GW level recorders	$3,560	$80,114	$28,031	$7,058	$0	$118,762
iv Measuring point elevations-GPS	$0	$0	$19,300	$0	$0	$19,300
C Streamflow gaging	$14,240	$11,131	$10,315	$2,597	$0	$38,282
D Groundwater/surface-water interaction						
i Temperature monitoring - GW/SW fluxes	$8,500	$37,500	$13,825	$3,275	$0	$63,100
ii Streamflow duration & location	$14,826	$35,174	$10,675	$2,225	$0	$62,900
iii Streambed infiltration tests	$0	$0	$8,200	$0	$0	$8,200
E Water-Quality sampling	$0	$0	$138,000	$0	$0	$138,000
Hydraulic properties & profiles data						
Collect new slug & aquifer tests	$0	$0	$21,000	$0	$0	$21,000
EM & temperature logging	$0	$0	$4,700	$4,700	$0	$9,400
3 Model Development (Geohydrologic and Integrated H	$0	$60,000	$50,000	$85,000	$0	$195,000
4 Water Availability Analysis	$0	$0	$0	$45,000	$0	$45,000
5 Reporting	$0	$15,840	$80,160	$88,213	$22,288	$206,500
Project Website	$0	$5,000	$5,000	$5,000	$2,500	$17,500
Water quality article	$0	$0	$9,550	$29,250	$0	$38,800
Hydrogeologic Setting SIR	$0	$8,340	$50,610	$27,713	$6,037.50	$92,700
Hydrologic modeling & water availability SIR and fact sheet	$0	$2,500	$15,000	$26,250	$13,750	$57,500
Sum:	$50,000	$700,000	$550,193	$240,834	$22,288	$1,563,314

# Task	SB Co FY15	USGS FY15	VAFB FY15	Total FY15	SB Co FY16	USGS FY16	VAFB FY16	Total FY16
Start Date:	10/1/2014	10/1/2014	10/1/2014	10/1/2014	10/1/2015	10/1/2015	10/1/2015	10/1/2015
End Date:	9/30/2015	9/30/2015	9/30/2015	9/30/2015	9/30/2016	9/30/2016	9/30/2016	9/30/2016
1 Data Compilation	$72,000	$14,000	$17,500	$103,500	$0	$0	$0	$0
2 New Data Acquisition	$541,950	$51,811	$112,613	$706,374	$358,479	$66,202	$117,927	$542,608
A Drilling & well installation								
i Two multiple well monitoring sites	$376,000	$18,000	$0	$394,000	$0	$0	$0	$0
ii Auger drilling of shallow wells	$0	$0	$0	$0	$155,000	$17,000	$0	$172,000
B Groundwater levels								
i Well canvassing	$2,610	$870	$0	$3,480	$0	$0	$0	$0
ii Expanded GW level monitoring	$10,440	$3,480	$3,480	$17,400	$10,753	$3,584	$3,584	$17,922
iii GW level recorders	$63,100	$7,011	$34,533	$104,644	$27,431	$9,144	$18,015	$54,590
iv Measuring point elevations-GPS	$0	$0	$0	$0	$19,300	$5,600	$8,300	$33,200
C Streamflow gaging	$17,800	$4,450	$42,600	$64,850	$10,094	$2,524	$23,278	$35,896
D Groundwater/surface-water interaction								
i Temperature monitoring - GW/SW fluxes	$34,000	$8,000	$20,000	$62,000	$16,000	$5,000	$10,000	$31,000
ii Streamflow duration & location	$38,000	$10,000	$12,000	$60,000	$16,000	$4,000	$5,000	$25,000
iii Streambed infiltration tests	$0	$0	$0	$0	$8,200	$2,700	$5,100	$16,000
E Water-Quality sampling	$0	$0	$0	$0	$70,000	$10,000	$39,000	$119,000
Hydraulic properties & profiles data								
Collect new slug & aquifer tests	$0	$0	$0	$0	$21,000	$6,000	$3,000	$30,000
EM & temperature logging	$0	$0	$0	$0	$4,700	$650	$2,650	$8,000
3 Model Development (Geohydrologic and Integrated H	$60,000	$26,667	$20,000	$106,667	$50,000	$33,333	$25,000	$108,333
4 Water Availability Analysis	$0	$0	$0	$0	$0	$0	$0	$0
5 Reporting	$0	$12,500	$0	$12,500	$54,000	$23,000	$24,800	$101,800
Project Website	$0	$12,500	$0	$0	$5,000	$3,333	$2,500	$10,833
Water quality article	$0	$0	$0	$0	$0	$0	$0	$0
Hydrogeologic Setting SIR	$0	$0	$0	$0	$39,000	$13,000	$17,300	$69,300
Hydrologic modeling & water availability SIR and fact sheet	$0	$0	$0	$0	$10,000	$6,667	$5,000	$21,667
Sum:	$673,950	$104,978	$150,113	$929,041	$462,479	$122,535	$167,727	$752,741

# Task	SB Co FY17	USGS FY17	VAFB FY17	Total FY17	SB Co FY18	USGS FY18	VAFB FY18	Total FY18
Start Date:	10/1/2016	10/1/2016	10/1/2016	10/1/2016	10/1/2017	10/1/2017	10/1/2017	10/1/2017
End Date:	9/30/2017	9/30/2017	9/30/2017	9/30/2017	9/30/2018	9/30/2018	9/30/2018	9/30/2018
1 Data Compilation	$0	$0	$0	$0	$0	$0	$0	$0
2 New Data Acquisition	$144,385	$33,346	$79,134	$256,865	$0	$0	$0	$0
A Drilling & well installation								
i Two multiple well monitoring sites	$0	$0	$0	$0	$0	$0	$0	$0
ii Auger drilling of shallow wells	$0	$0	$0	$0	$0	$0	$0	$0
B Groundwater levels								
i Well canvassing	$0	$0	$0	$0	$0	$0	$0	$0
ii Expanded GW level monitoring	$11,066	$3,689	$3,689	$18,444	$0	$0	$0	$0
iii GW level recorders	$28,230	$9,410	$18,539	$56,180	$0	$0	$0	$0
iv Measuring point elevations-GPS	$0	$0	$0	$0	$0	$0	$0	$0
C Streamflow gaging	$10,388	$2,597	$23,956	$36,941	$0	$0	$0	$0
D Groundwater/surface-water interaction								
i Temperature monitoring - GW/SW fluxes	$13,100	$4,100	$8,300	$25,500	$0	$0	$0	$0
ii Streamflow duration & location	$8,900	$2,900	$3,000	$14,800	$0	$0	$0	$0
iii Streambed infiltration tests	$0	$0	$0	$0	$0	$0	$0	$0
E Water-Quality sampling	$68,000	$10,000	$19,000	$97,000	$0	$0	$0	$0
Hydraulic properties & profiles data								
Collect new slug & aquifer tests	$0	$0	$0	$0	$0	$0	$0	$0
EM & temperature logging	$4,700	$650	$2,650	$8,000	$0	$0	$0	$0
3 Model Development (Geohydrologic and Integrated H	$80,000	$53,333	$40,000	$173,333	$5,000	$3,333	$2,500	$10,833
4 Water Availability Analysis	$15,000	$10,000	$7,500	$32,500	$30,000	$20,000	$15,000	$65,000
5 Reporting	$79,000	$33,033	$36,300	$148,333	$60,050	$29,950	$28,375	$118,375
Project Website	$5,000	$3,333	$2,500	$10,833	$5,000	$3,333	$2,500	$10,833
Water quality article	$19,100	$6,400	$8,500	$34,000	$19,700	$6,500	$8,800	$35,000
Hydrogeologic Setting SIR	$39,900	$13,300	$17,800	$71,000	$10,350	$3,450	$4,575	$18,375
Hydrologic modeling & water availability SIR and fact sheet	$15,000	$10,000	$7,500	$32,500	$25,000	$16,667	$12,500	$54,167
Sum:	$318,385	$129,713	$162,934	$611,032	$95,050	$53,283	$45,875	$194,208

# Task	SB Co FY19	USGS FY19	VAFB FY19	Total FY19	SB Co All	USGS All	VAFB All	Total All
Start Date:	10/1/2018	10/1/2018	10/1/2018	10/1/2018				
End Date:	9/30/2019	9/30/2019	9/30/2019	9/30/2019				
1 Data Compilation	$0	$0	$0	$0	$72,000	$14,000	$17,500	$103,500
2 New Data Acquisition	$0	$0	$0	$0	$1,044,814	$151,359	$309,674	$1,505,847
A Drilling & well installation								
i Two multiple well monitoring sites	$0	$0	$0	$0	$376,000	$18,000	$0	$394,000
ii Auger drilling of shallow wells	$0	$0	$0	$0	$155,000	$17,000	$0	$172,000
B Groundwater levels								
i Well canvassing	$0	$0	$0	$0	$2,610	$870	$0	$3,480
ii Expanded GW level monitoring	$0	$0	$0	$0	$32,260	$10,753	$10,753	$53,766
iii GW level recorders	$0	$0	$0	$0	$118,762	$25,565	$71,087	$215,414
iv Measuring point elevations-GPS	$0	$0	$0	$0	$19,300	$5,600	$8,300	$33,200
C Streamflow gaging	$0	$0	$0	$0	$38,282	$9,571	$89,834	$137,687
D Groundwater/surface-water interaction								
i Temperature monitoring - GW/SW fluxes	$0	$0	$0	$0	$63,100	$17,100	$38,300	$118,500
ii Streamflow duration & location	$0	$0	$0	$0	$62,900	$16,900	$20,000	$99,800
iii Streambed infiltration tests	$0	$0	$0	$0	$8,200	$2,700	$5,100	$16,000
E Water-Quality sampling	$0	$0	$0	$0	$138,000	$20,000	$58,000	$216,000
Hydraulic properties & profiles data								
Collect new slug & aquifer tests	$0	$0	$0	$0	$21,000	$6,000	$3,000	$30,000
EM & temperature logging	$0	$0	$0	$0	$9,400	$1,300	$5,300	$16,000
3 Model Development (Geohydrologic and Integrated H	$0	$0	$0	$0	$195,000	$116,667	$87,500	$399,167
4 Water Availability Analysis	$0	$0	$0	$0	$45,000	$30,000	$22,500	$97,500
5 Reporting	$13,450	$7,817	$6,525	$27,792	$206,500	$106,300	$96,000	$408,800
Project Website	$2,500	$1,667	$1,250	$5,417	$17,500	$24,167	$8,750	$37,917
Water quality article	$0	$0	$0	$0	$38,800	$12,900	$17,300	$69,000
Hydrogeologic Setting SIR	$3,450	$1,150	$1,525	$6,125	$92,700	$30,900	$41,200	$164,800
Hydrologic modeling & water availability SIR and fact sheet	$7,500	$5,000	$3,750	$16,250	$57,500	$38,333	$28,750	$124,583
Sum:	$13,450	$7,817	$6,525	$27,792	$1,563,314	$418,325	$533,174	$2,514,813

Table 2. Workplan of San Antonio Creek Hydrologic Study

	Calendar Year:				2015				2016				2017				2018				2019	
	County Fiscal Years (CY):		CY14				CY15				CY16				CY17				CY18			
	Quarters:	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
	Federal Fiscal Years (FY):	FY14	FY15				FY16				FY17				FY18				FY19			
Task #	Task Description	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	1 Data compilation/analysis																					
	Water-Quality					X																
	Precipitation					X																
	Groundwater levels		X	X	X	X																
	Streamflow					X																
	Evapotranspiration					X																
	Compile and analyze logs		X	X	X	X																
	Aquifer properties					X																
	GIS - land use, remote sensing, INSAR		X	X	X	X	X		X		X		X		X			X				
	2 New data collection																					
A	Drilling and well installation																					
i	Two multiple well monitoring sites					X																
ii	Auger drilling of shallow wells									X												
B	Groundwater level data																					
i	Well Canvassing		X																			
ii	Expanded groundwater level monitoring		X	X	X	X	X	X	X	X	X	X	X	X								
iii	Collection of recorder data		X	X	X	X	X	X	X	X	X	X	X	X								
iv	Measuring point elevation survey - high precision GPS									X												
C	Streamflow gaging																					
i	Installation of two new stations		X																			
ii	Operation		X	X	X	X	X	X	X	X	X	X	X	X								
D	Groundwater/surface-water interaction																					
i	Temperature monitoring for GW/SW fluxes		X	X	X	X	X	X	X	X	X	X	X	X								
ii	Streamflow duration & location		X	X	X	X	X	X	X	X	X	X										
	Streambed infiltration tests									X												
	Water-Quality sampling																					
i	Groundwater									X	X											
ii	Surface water									X	X	X										
F	Hydraulic properties & profiles data																					
i	Collect new slug & aquifer test data									X												
ii	EM & temperature logging - seasonal changes in WQ & flow									X		X										
	3 Model development					X	X	X	X	X	X	X										
A	Hydrogeologic Framework					X	X	X			X											
i	Construction of 3D hydrogeologic framework					X	X	X			X											
ii	Definition of textural variations in principal aquifers					X	X	X			X											
iii	Aquifer hydraulic properties					X	X	X			X											
B	Hydrologic Model					X	X	X	X	X	X	X	X	X	X							
i	Recharge Model					X	X	X	X	X												
	Recharge Analysis					X	X	X	X	X	X	X										
	Precipitation/Runoff - Surface Water Model						X	X	X	X												
ii	Hydrologic Flow Model						X	X	X	X	X	X	X	X	X	X	X					
	Groundwater Model							X	X	X	X											
	Linked Model										X	X	X	X	X	X	X					
	4 Water availability analysis													X	X	X	X					
	5 Products																					
a	Project Website		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
b	Water quality journal article																					
	Preparation											X	X	X	X							
	Review and Publication														X	X	X					
c	Hydrogeologic Setting - new & existing information (SIR)																					
	Preparation								X	X	X	X	X	X	X							
	Review and Publication														X	X	X	X	X	X	X	
d	Hydrologic modeling & summary (SIR and Fact sheet)																					
	Preparation								X	X	X	X	X	X	X							
	Review and Publication														X	X	X	X	X	X	X	