

Draft Work Plan for the Southwest Principal Aquifers Group beginning in FY06

December 27, 2005

Problem

Ground water is an important water supply for many cities and agricultural communities in the basins of the arid and semiarid southwestern United States because of limited water resources. Ground-water management plans have been established for several basins based on estimated average annual natural recharge to the aquifer system. Ground-water resources are fully appropriated in many of these basins, often at quantities much larger than the actual annual recharge amount. While water availability is a primary concern for municipal planners and managers, the quality of ground water now and in the future is also of concern. Stresses such as withdrawals from wells and artificial recharge imposed on a ground-water system can result in water-quality changes. Reduction in the amount of ground water available for public supply due to water-quality impairment coupled with an increasing demand for water generally will result in fewer and more expensive alternatives for water managers.

The primary objectives of the USGS NAWQA program are to assess the status and trends in the quality of the nation's ground-water and surface-water resources and to link the status and trends with an understanding of the natural and human factors that affect water quality (Gilliom and others, 1995). NAWQA has studied the water quality of selected basin-fill aquifers in the Southwest and has done several detailed studies to determine how land use has affected shallow water quality. A better understanding is needed of the factors that affect water quality in the deeper parts of aquifers across the region, and in particular, what factors result in the transport of constituents from the shallow to deeper parts of aquifers that are commonly used for drinking-water supply.

Southwest Principal Aquifers Study Goals

1. Determine the susceptibility and vulnerability factors that affect ground-water quality of the deeper parts of basin-fill aquifers, which are commonly used for drinking-water supply. Focus on key constituents such as dissolved solids, nitrate, arsenic, uranium, and the anthropogenic compounds pesticides and VOCs.
2. Extrapolate information gained above at the basin scale to other basins in the Southwest with similar environmental settings. Develop and test hypotheses on what factors affect water quality across the region. This will allow water managers in other areas of the Southwest to be able to focus data collection efforts and resources on factors that have the greatest impact on water quality in their area.

Purpose and Scope

This study will provide a better understanding of how water quality is affected by various processes and factors in areas that have been studied and will provide a basis for extrapolation to areas with similar characteristics but less water-quality data or hydrogeologic information available. Information will be synthesized regionally from many sources so that it can be used to understand the relation between ground-water quality and susceptibility/vulnerability explanatory factors.



The extent of the Southwest Principal Aquifers study area is based on major surface-water drainages and the border between the United States and Mexico (red or bold line). Principal aquifers included in the regional analysis are the Basin and Range basin-fill aquifers in Nevada (NVBR study unit), Utah (GRSL study unit), and Arizona (CAZB study unit); the Rio Grande aquifer system in New Mexico and Colorado (RIOG study unit); and the Coastal Basin (SOCA study unit) and Central Valley (SACR and SANJ study units) aquifer systems in California. These principal aquifers consist primarily of unconsolidated to semi-consolidated basin-fill deposits, have similar land-use and water-use practices, and face many of the same water-quality issues.

Fresh ground-water withdrawals for irrigation, public-supply, and self-supplied industrial water uses in the year 2000 from 66 principal aquifers in the United States were estimated at 76,500 million gallons per day (Maupin and Barber, 2005). The 4 principal aquifers included in the Southwest Principal Aquifers Group accounted for 26 percent of this total. The Central Valley aquifer system had the second highest water use of the 66 principal aquifers, while the Basin and Range basin-fill aquifers was ranked fourth, the California Coastal Basin aquifers seventh, and the Rio Grande aquifer system eleventh.

General Approach of Proposed Work for the Southwest Principal Aquifers Group beginning in FY06

The major components of work described in this plan are:

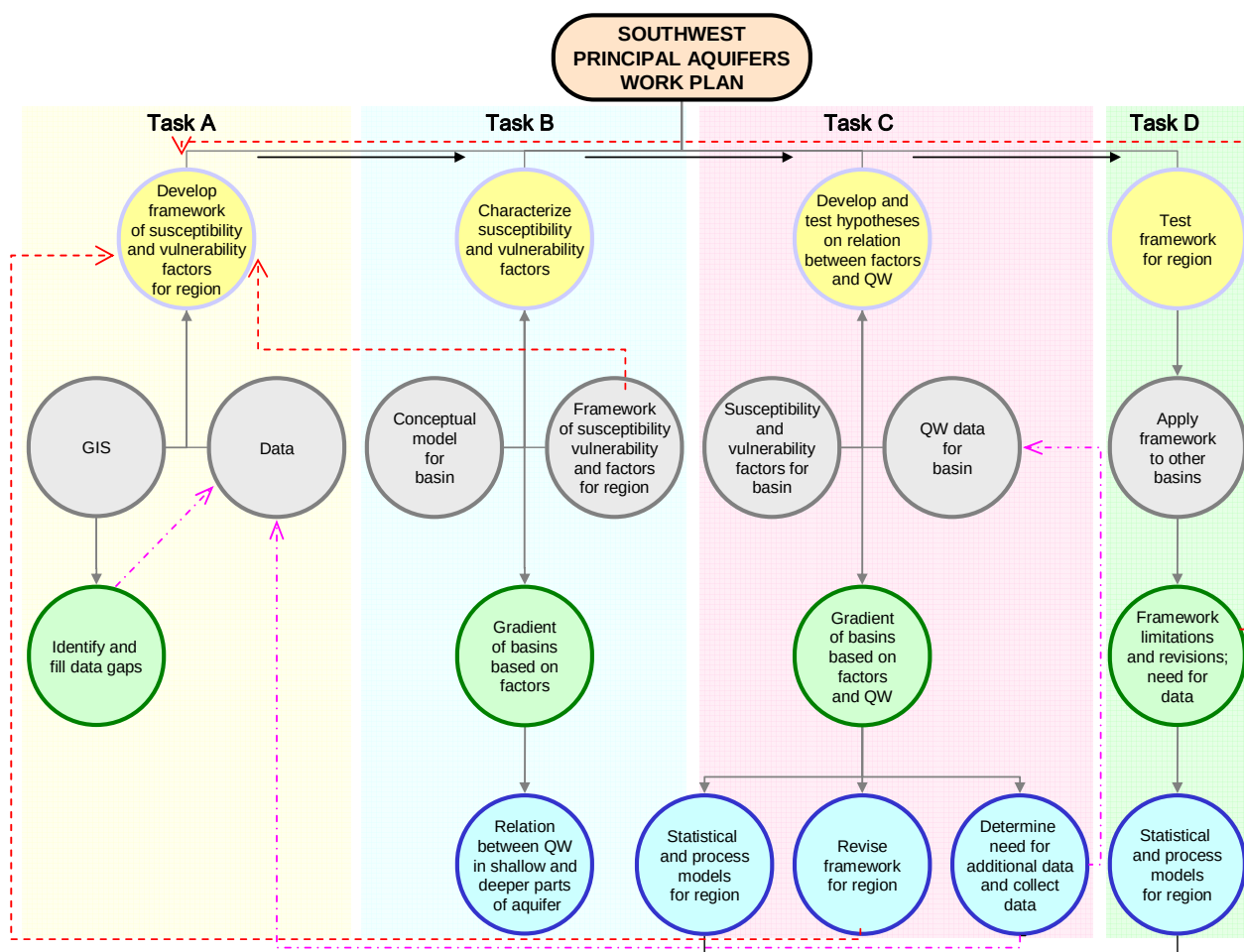
Task A – Develop framework of susceptibility and vulnerability factors that affect ground-water quality

Task B – Characterize susceptibility and vulnerability factors for selected basins

Task C – Relate selected water-quality constituents to susceptibility and vulnerability factors

Task D – Test framework on selected constituents in other basin-fill aquifers in the Southwest

The period covered by this work plan is for fiscal year 2006 through 2011, and possibly beyond. The major components of work can result in separate stand-alone reports or products; however, the components can be worked on concurrently; each subsequent component is dependent on results from the previous one; and each component will provide additional or modified information with which to revise previous components. This work plan and task timeline (see spreadsheet) are planning documents that must be flexible to incorporate findings as the study progresses.

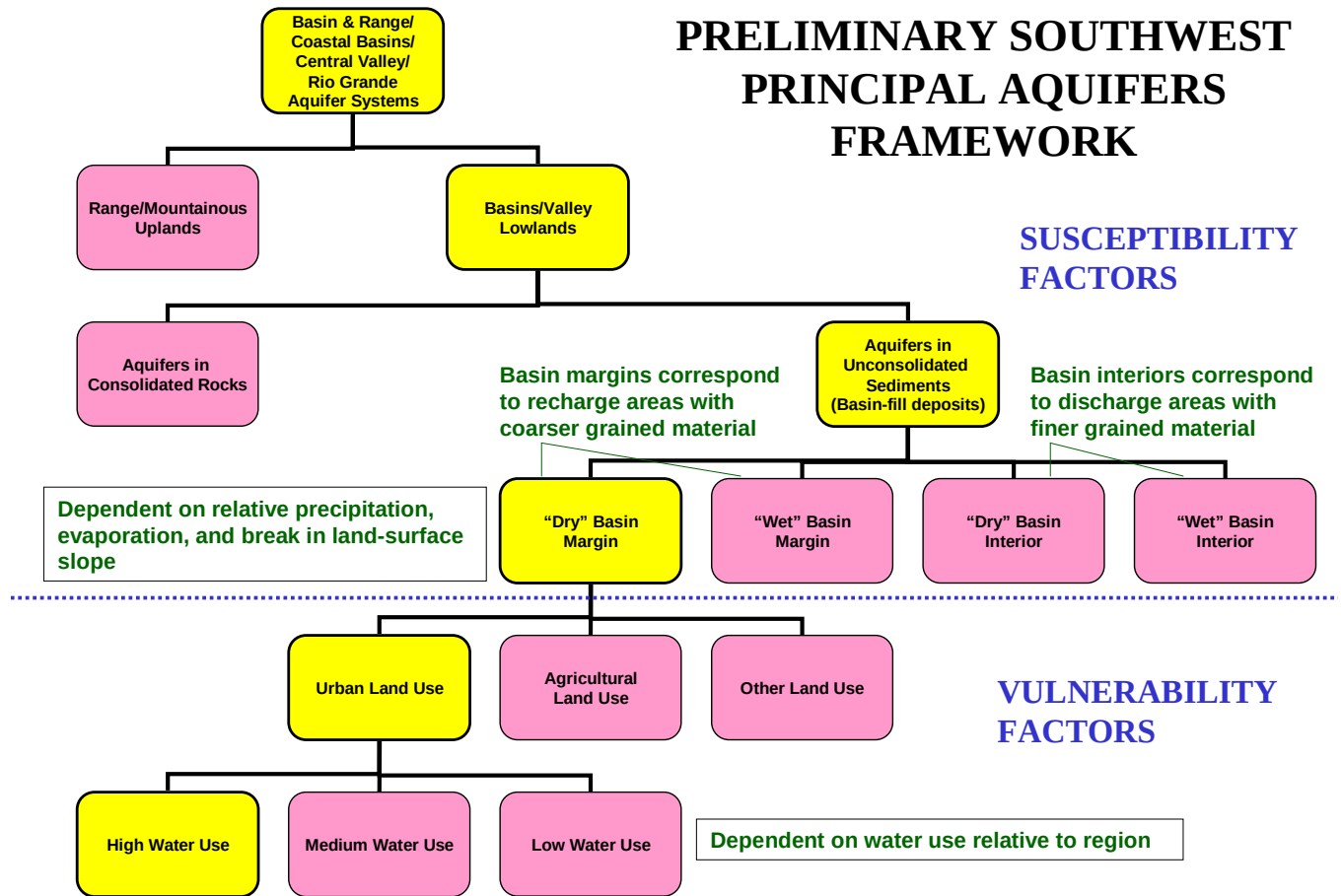


Task A. Develop a preliminary framework of susceptibility and vulnerability factors that likely affect ground-water quality in the deeper parts of basin-fill aquifers of the southwestern United States.

1. Define a preliminary framework on the basis of expert knowledge from study unit personnel (see framework schematic). This framework represents a set of natural and human affected characteristics that geographically describe the physical factors affecting flow of water to, and through, the ground-water system (susceptibility factors) as well as the locations and types of naturally occurring and anthropogenic contamination and the fate and transport of contaminants (vulnerability factors).
2. Compile regionally available information on susceptibility and vulnerability factors for the southwestern United States (geology, altitude, land-surface slope, climate, precipitation, evaporation, land use, water use, soil properties, population density, ground-water recharge from net infiltration model, others?). These data will be derived from existing GIS data sets and will cover the mountain and basin areas of the Southwest, including the area outside of the NAWQA study units. Rob Baskin and Tim McKinney with the GRSL are currently working on this component.
3. Use framework and compiled data to classify geographic areas across the Southwest based on susceptibility and vulnerability factors (use GIS to map framework). This will result in maps showing the grouped conditions described by the individual framework schematic bins throughout the southwestern United States.
4. Determine which framework bins have relatively high water use or population (high vulnerability factors) that have not been studied by NAWQA. Areas with these conditions have a high priority for future Major Aquifer Studies that will be used to better understand the principal aquifers in the Southwest.

Possible products from this component of work are interactive maps showing the framework factors presented in an online report or in a web page describing the framework.

PRELIMINARY SOUTHWEST PRINCIPAL AQUIFERS FRAMEWORK



This schematic of the preliminary framework only shows the subdivisions for a set of selected bins (yellow or light boxes). Each pink (dark) box would have the same subdivisions as those shown for the yellow box on the same level, although some bins may have limited or no aerial extent.

Task B. Characterize the susceptibility and vulnerability factors for the used, deeper basin-fill aquifer of selected NAWQA studied basins

Basins or parts of basins studied as part of a SUS, MAS, and/or SWQA-TANC with an existing conceptual model of the ground-water flow system that could be included in the characterization are:

Coastal Basin, SOCA, California Coastal Basins Aquifers
Inland Basin, SOCA, California Coastal Basins Aquifers
San Jacinto Basin, SOCA, California Coastal Basins Aquifers
Eastern part of San Joaquin Valley, SANJ, Central Valley Aquifer System
Southeastern part of Sacramento Valley, SACR, Central Valley Aquifer System
Eagle Valley, NVBR, Basin and Range Basin-fill Aquifers
Spanish Springs Valley, NVBR, Basin and Range Basin-fill Aquifers
Truckee Meadows (Reno/Sparks area), NVBR, Basin and Range Basin-fill Aquifers
Carson Valley, NVBR, Basin and Range Basin-fill Aquifers
Las Vegas Valley, NVBR, Basin and Range Basin-fill Aquifers
Salt Lake Valley, GRSL, Basin and Range Basin-fill Aquifers
West Salt River Valley, CAZB, Basin and Range Basin-fill Aquifers
Upper Santa Cruz Basin, CAZB, Basin and Range Basin-fill Aquifers
Sierra Vista subbasin, CAZB, Basin and Range Basin-fill Aquifers
Middle Rio Grande Basin, RIOG, Rio Grande Aquifer System
San Luis Basin, RIOG, Rio Grande Aquifer System

The basins to be studied as part of this task will depend on how much information is available on the conceptual flow system and how the ground-water system has changed from predevelopment to current conditions and on the scope of work allowed by funding. The characterized basins will be referred to as type basins.

1. Describe the conceptual model for the natural ground-water flow system and the current ground-water flow system in the selected basin or part of basin. Include a generalized conceptual diagram of the flow system showing recharge and discharge areas, subsurface material and structure, and flow directions.
 - a. Climate
 - i) Precipitation
 - ii) Temperature
 - iii) Evaporation
 - b. Hydrogeology
 - i) Aquifer mineralogy
 - ii) Geochemical conditions (redox)
 - iii) Subsurface properties and confining layers
 - iv) Geometry of flow system
 - v) Recharge-discharge areas
 - vi) Shallow aquifer – occurrence, use, connection to deeper aquifer
 - c. Water budget – use existing studies, output from existing regional-scale numerical models, and limited additional data compilation to quantify components. This section

will be descriptive and can be summarized in a table for each basin. Spatial data will be stored in a GIS for use in Task C to determine the relation of factors with QW.

- i) Types, amounts, and sources of recharge
 - a) Natural (Alan Flint's net infiltration model for the region and existing conceptual models)
 - b) Modified/artificial-engineered
 - c) Modified/irrigation
 - ii) Types and amounts of discharge
 - a) Natural
 - b) Modified/well withdrawals
 - d. Ground-water movement
 - i) Direction
 - a) Vertical
 - b) Horizontal
 - ii) Thickness of unsaturated zone
 - iii) How fast
2. Describe how the water budget has changed from predevelopment (natural) to current conditions for each type basin. Information from previous steps.
- a. Recharge
 - b. Storage
 - c. Discharge
 - d. Effect on water levels and head gradients
3. List similarities and differences in susceptibility and vulnerability factors for the type basins
- a. Compare and contrast the conceptual ground-water flow systems including the period of development and the degree of hydrologic modification
 - b. Place basins on gradients of factors, such as climatic, water use, and hydrogeologic conditions
4. Evaluate the relation between QW in the shallow and deeper parts of the aquifer in each type basin
- a. Relate susceptibility and vulnerability factors that affect QW in shallow parts of aquifers to QW in deeper parts of aquifers
 - i) Compare the effects of land use on QW in the shallow aquifer in selected basins (from the 'Land-use effects on shallow ground water' regional study currently in progress and from published reports) to effects on QW in deeper parts of the aquifer
 - ii) Use occurrence/concentration of anthropogenic compounds in shallow and deeper parts of the aquifer to indicate connection
 - b. Use conceptual models of aquifer systems to better understand factors that allow the transport of constituents from the shallow to deeper parts of aquifers. For example:
 - i) Age of ground water in the deeper part of the aquifer from age-dating techniques, occurrence of anthropogenic compounds, type of and location in flow system (convergent-divergent, recharge-discharge area), presence or lack of confining layers, etc.
 - ii) Sources of ground water are important to occurrence of anthropogenic compounds (recharge occurring in the basin vs subsurface inflow from consolidated rocks)

5. Revise the framework of susceptibility and vulnerability factors that likely affect ground-water quality in the deeper parts of basin-fill aquifers in the Southwest based on information gathered as part of this task.

A report describing the conceptual ground-water flow systems of selected basins, the similarities and differences between them, how and where they fit on the gradient of susceptibility and vulnerability factors, and the relation between water quality in the shallow and deeper parts of basin-fill aquifers is a likely product from this component of work.

A preliminary product of this task could be similar to the first part of the USGS Circular on Land Subsidence in the United States (<http://water.usgs.gov/pubs/circ/circ1182/>), in which the conceptual hydrogeologic system for 5 aquifers is described in chapters along with the changes to the system caused by water use. This information is related to subsidence and provides a link to applicable scientific literature for the subject areas. We could do this relative to water quality, with the proposed report presenting some of the major findings from the NAWQA cycle I studies and their relation to hydrogeologic settings across the southwestern United States. Examples of NAWQA reports describing the water quality of deeper basin-fill aquifers in the region include:

Occurrence and Distribution of Volatile Organic Compounds and Pesticides in Ground Water in Relation to Hydrogeologic Characteristics and Land Use in the Santa Ana Basin, Southern California by Scott N. Hamlin, Kenneth Belitz, and Tyler Johnson
(<http://water.usgs.gov/pubs/sir/2005/5032/>)

Low-Level Volatile Organic Compounds in Active Public Supply Wells as Ground-Water Tracers in the Los Angeles Physiographic Basin, California, 2000 by Jennifer L. Shelton, Karen R. Burow, Kenneth Belitz, Neil M. Dubrovsky, Michael Land, and JoAnn Gronberg
(<http://ca.water.usgs.gov/archive/reports/wrir014188/>)

Stable Isotopes and Volatile Organic Compounds along Seven Ground-Water Flow Paths in Divergent and Convergent Flow Systems, Southern California, 2000 by Barbara J. Milby Dawson, Kenneth Belitz, Michael Land, and Wesley R. Danskin
(<http://water.usgs.gov/pubs/wri/wrir034059/>)

Quality and Sources of Ground Water Used for Public Supply in Salt Lake Valley, Salt Lake County, Utah, 2001 by Susan A. Thiros and Andrew H. Manning
(<http://pubs.usgs.gov/wri/wri034325/>)

Ground-Water Quality in the West Salt River Valley, Arizona 1996–98—Relations to Hydrogeology, Water Use, and Land Use by R.J. Edmonds and D.J. Gellenbeck
(<http://az.water.usgs.gov/pubs/01-4126intro.html>)

Ground-Water Quality in the Upper Santa Cruz Basin, Arizona, 1998 by A.L. Coes, D.J. Gellenbeck, D.C. Towne, and M.C. Freark (<http://az.water.usgs.gov/pubs/00-4117intro.html>)

Task C. Develop and test hypotheses that relate concentration or occurrence of selected constituents and/or constituent groups in water from deeper parts of basin-fill aquifers to susceptibility and vulnerability factors.

1. Select constituent/constituent group – probably limited to dissolved solids, arsenic, uranium, nitrate, and representative constituents from the VOC and pesticide groups that help characterize vulnerability factors
 - a. Compile concentration/occurrence data, including sources such as NWIS, state agencies, public suppliers. Ancillary data required for the water-quality data will likely include well depth, well location, date of sample, etc
2. Develop hypotheses about what factors and processes are important to selected constituent occurrence/concentration and distribution in the type basins
 - a. Assess factors and processes that affect water quality in the type basins and develop a conceptual model
 - i) Sources of constituent (natural-aquifer mineralogy, engineered recharge, land use, well withdrawal-screened interval, connection with shallow part of aquifer)
 - ii) Processes affecting presence or absence of constituent (geochemical reaction, confining layers, head gradients, flow velocity)
 - iii) Statistically relate concentration/occurrence data to factors and processes for the type basins
 - b. Develop statistical models based on the conceptual models
 - i) Determine dependent variable – concentration or probability of detection
 - ii) Determine numeric variable that can be used to represent each factor (independent variables)
 - iii) Develop simple statistical models such as Anova type tests to determine validity of factors
 - iv) Develop complex models such as regression (logistic, multiple, tree-based, other) to quantitatively determine the effects of each factor
3. Test hypothesis on other basins with QW data that are not among the type basins characterized in Task B
 - a. Use framework to select basins with similar characteristics as the type basins
 - b. Calibrate (build) model using QW data from some of the basins
 - c. Verify (check) model using QW data from other basins
4. Update or modify framework if factors and processes determined to affect water quality are not already incorporated into it
 - a. Use framework to identify basins most vulnerable to contamination

The relation between each constituent (or possibly, groups of constituents) and factors will likely be presented in separate reports.

Task D. Test the framework of susceptibility and vulnerability factors on the concentration or occurrence of selected constituents and/or constituent groups in other basin-fill aquifers of the Southwest.

1. Apply conceptual/process and statistical models that relate factors and QW developed in Task C to areas that are similar to the type basins, but have little QW data available.
2. Compare existing data on the occurrence or concentration of selected constituents available for the unstudied basins to what was expected based on relations derived from the studied basins (constituents will probably be limited to dissolved solids, arsenic, and nitrate because of availability of data).
3. Identify limitations and need for more information.
4. Use gradient of type basins and framework to predict potential constituent occurrence or concentration in similar basins under varying degrees of hydrologic modification.
5. Generate regional vulnerability, probability, or concentration maps based on the framework and statistical models developed for selected constituents.
6. Describe the application and use of the framework and models to water managers and others.

REFERENCES

Gilliom, R.J., Alley, W.M., and Gurtz, M.E., 1995, Design of the National Water-Quality Assessment Program--Occurrence and distribution of water-quality conditions: U.S. Geological Survey Circular 1112, 33 p.

Maupin, M.A., and Barber, N.L., 2005, Estimated withdrawals from principal aquifers in the United States, 2000: U.S. Geological Survey Circular 1279, 46 p.