GCASE

Groundwater, Climate and Stakeholder Engagement

A Framework for Informing Groundwater Management

Introduction

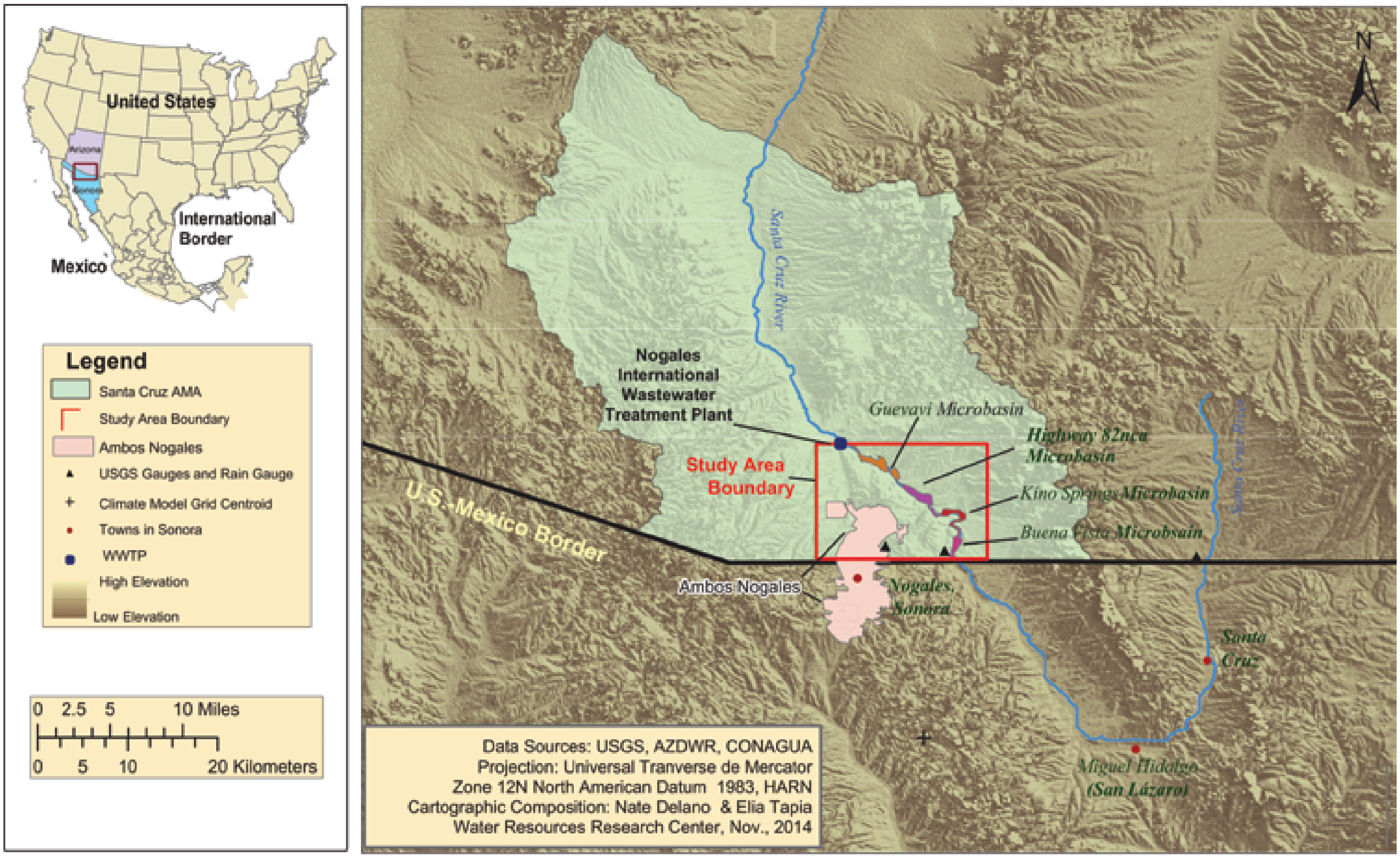
Uncertainty over future climate is increasing groundwater management challenges for communities in arid and semi-arid regions where local climate has a significant influence on water supplies.

The University of Arizona (UA) Water Resources Research Center (WRRC) and the Hydrologic Research Center (HRC) of San Diego conducted research designed to help water managers deal with climate change uncertainties. The two-year project was funded by the National Oceanic and Atmospheric Administration (NOAA) Climate and Societal Interactions Sectoral Applications Research Program. Initiated in August 2012, Incorporating Climate Information and Stakeholder Engagement in Groundwater Resources Planning and Management, combines an innovative modeling framework with extensive stakeholder engagement. It was given the acronym GCASE, which stands for Groundwater, Climate And Stakeholder Engagement.

The GCASE project had three primary goals:

- Apply an innovative modeling framework to address water resources management issues in light of a projected increase in climate uncertainties;
- Increase stakeholders' capacity to adapt water planning and management to future climate uncertainties;
- Establish transferability of the modeling approach and stakeholder engagement.

To accomplish these goals, the project team focused on a case study area located within the Santa Cruz Active Management Area (SCAMA), which lies in south-central Arizona (AZ), and shares a border with Sonora, Mexico. It includes the City of Nogales AZ, which relies on water resources from a series of relatively shallow, small aquifers (the

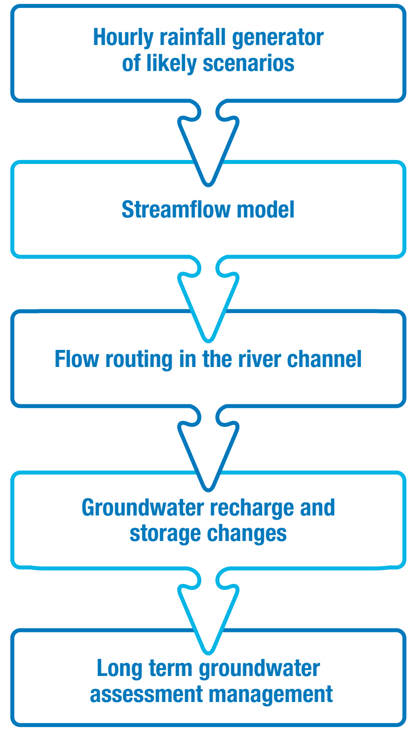


Location of Study Area

“microbasins”) for about half its water supply. The water derived from these microbasins is the least costly and highest quality supply available to the City. Highly variable seasonal flow events on the Upper Santa Cruz River are the main source of recharge to these aquifers. A tightly linked relationship exists among regional climate patterns, streamflow variability, and localized aquifer conditions.

The SCAMA exists as a discrete area as a result of Arizona’s landmark 1980 Groundwater Management Act (GMA or Act). The GMA set a water management and policy framework to control severe overdraft of groundwater, promote effective allocation of groundwater resources, and improve groundwater management through water planning, conservation, and augmentation. The Arizona Department of Water Resources (ADWR) is responsible for administrating the GMA provisions. The Act established Active Management Areas (AMAs) and specified water management goals for each. The SCAMA was established in 1994 from the Tucson AMA, with the statutory water management goal “to maintain a safe-yield condition in the active management area and to prevent local water tables from experiencing long term declines.” (A.R.S.45-562C at www.azleg.gov) The safe yield goal, “...which attempts to achieve and thereafter maintain a long-term balance between the annual amount of groundwater withdrawn and the annual amount of natural and artificial recharge....” (A.R.S. 45-562A), is a goal in three out of the five AMAs. The second half of the SCAMA’s management goal is unique in Arizona. Although the statute does not explicitly mention conjunctive management of surface water and groundwater, the tight linkage between streamflow in the Upper Santa Cruz River and groundwater recharge means that surface flows are relevant to any long-term groundwater management scheme.

Unlike the three largest AMAs, there is no direct access to imported surface water in the SCAMA, and the storage capacity of the groundwater reservoirs is relatively small. Climatic change is projected to have an adverse effect on the regional hydrologic regime. The GCASE project aimed to support efforts to develop a management framework that appropriately addresses the SCAMA’s unique combination of specific conditions.



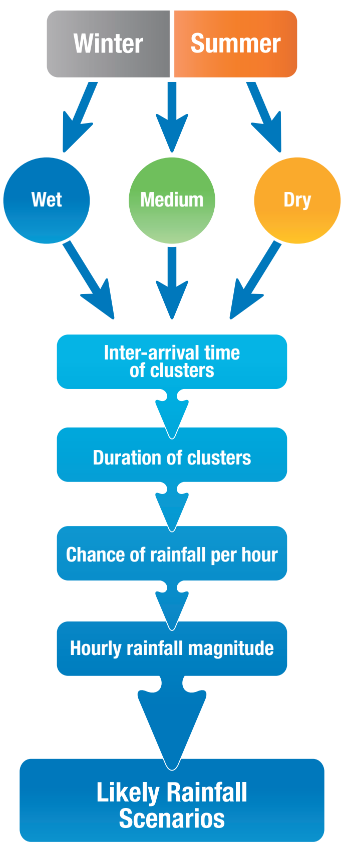
Modeling Framework

The modeling framework

ADWR created a model depicting localized and regional hydrologic conditions and interactions between surface flows and aquifers to further its understanding of regional aquifer conditions. The GCASE modeling framework is based on this model. HRC’s prior work with ADWR focused on the region’s highly variable precipitation and the groundwater response to surface water flows. A framework component representing various climatological features of precipitation generates an ensemble of likely scenarios of hourly precipitation based historic gauge data. This capability makes it possible to use probabilistic analysis rather than relying on traditional deterministic simulations. As a result, the rainfall generator can better characterize the uncertainty of the natural system.

The modeling framework incorporates a series of component models. The rainfall generator is the heart of the framework and its precipitation ensembles drive the analysis. A hydrologic model takes the hourly precipitation simulations to generate ensembles of mean hourly streamflow. The streamflow scenarios drive a simplified model, based on the ADWR groundwater model, which accounts for groundwater recharge and simulates aquifer response to streamflow. The groundwater model is also capable of evaluating the impact of pumping strategies on aquifer water levels. Although full integration with the ADWR model is possible, the simplified model provides an efficient and inexpensive alternative.

The rainfall generator produces ensembles of likely rainfall patterns based on the observed record and probabilities associated with various features, including seasonal, intra- and inter-annual variability, and low frequency cycles of wet and dry years. A key feature is wetness category; that is, whether a season is likely to be wet, intermediate or dry.



Rainfall Generator

Climate Change Projections

Global Climate Models capture general climatic patterns over ocean and land. They can project Pacific sea surface temperature and relations to Southwest climatology, trade wind, and atmospheric rivers and provide a general climatology of temperature and precipitation. Downscaling is needed for a more refined spatial distribution of climatological variables due to terrain and microclimate. Downscaled regional models can take account of special regional features and capture mesoscale phenomena such as summer rainfall and snow.

The existing modeling framework was enhanced with climate information produced from eight dynamically downscaled regional models, based on IPCC Global Circulation Models (GCMs). The North American Regional Climate Change

Assessment Program (NARCCAP) produced six simulations and the University of Arizona Atmospheric Sciences Department produced two additional simulations.

Analysis of projections from these eight dynamically downscaled models indicated that dry summers would occur more frequently and wet summers would occur less frequently. Projections suggest that the inter-annual variability of winter rainfall will increase, producing a higher frequency of both wet and dry winters. Other precipitation features (precipitation magnitude, number of storms, storm duration, etc.) exhibited no clear differences between historic and projected conditions.

The frequency of winter and summer wetness categories was compared for all eight downscaled RCM simulations in the periods 1971-2000 (historic) and 2041-2070 (future). The weather generation component of the modeling framework was modified to reflect this analysis.

Stakeholder engagement

Multiple modes of stakeholder communication were deployed. The primary mechanism was a series of workshops aimed at connecting use of the modeling framework with local groundwater management issues. Other mechanisms include a project web site (http://wrrc.arizona.edu/GCASE), project updates, and established points of contact for more traditional communications (e.g., telephone). The website hosts workshop materials, as well as other project materials and products.

Stakeholder Workshop

A Project Advisory Committee (PAC) consisted of the Deputy Director of ADWR, a Principal Analyst at Salt River Project, a senior Hydrologist with the U.S. Geological Survey (USGS) Arizona Water Science Center, and the Public Works Director of the City of Nogales, Arizona. They provided advice on translating between the technical-scientific perspective and the water management perspective. This advice was key to successful implementation the project. In addition, the PAC provided guidance on potential transferability of the project methodology to other regions in Arizona.

The series of workshops engaged stakeholders in enhancement and use of the modeling framework. Discussions aimed to establish the linkage of modeling assumptions and capabilities with water resource management objectives. Participants included individuals from State water management and regulatory agencies, federal partners, municipal and county water planners and managers, environmental non-governmental organizations (NGOs), and other active water planning organizations. The workshops described the project in detail as it developed, explaining the modeling framework and climate inputs. They provided essential background information on groundwater management in the SCAMA and gave stakeholders opportunities to question, comment, and air their major water management concerns. The workshop agendas and presentations are available on the GCASE website at http://wrrc.arizona.edu/GCASE/Workshops.

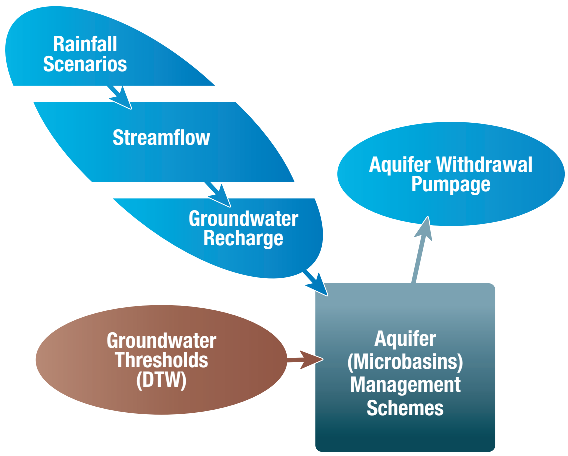
Workshop presentations were developed with close collaboration among UA and HRC team members and guidance from the Project Advisory Committee. The team went through a process of critique and revision of presentations to ensure that the material, which can be highly technical, was presented in a manner that is both comprehensible and meaningful to the stakeholders.

Case study

The case study examined the behavior of a series of shallow aquifers along the channel of the Upper Santa Cruz River east of Nogales, Arizona, flowing north from the Arizona-Mexico border to the International Wastewater Treatment Plant

Dry Microbasin Recharge Condition

Wet Microbasin Recharge Condition



Case Study Schematic

near Rio Rico, Arizona. These aquifers are primarily recharged by intermittent streamflow in the river derived from precipitation on the watershed, largely originating in Mexico.

Precipitation data were collected from weather stations operated by CONAGUA (the Mexican national water resources department) in Mexico and the National Weather Service in the US. The US Geological Survey gauges supplied stream flow records, principally from the gauge at the international border. These data were used to produce likely scenarios based on observed climatological conditions, which were then compared with likely future scenarios framed by climate projections.

To test the modeling framework, water management strategies were defined by the annual rate of withdrawal from the microbasin aquifers and the threshold depth to water (DTW) below which no pumping would be allowable. In the model, simulated pumping at defined rates was stopped when a DTW threshold was reached. Realistic annual pumping rates were estimated from ADWR water demands data and future population projections. Thresholds were based on the water requirements of local riparian vegetation.

A series of 90 scenarios were tested by varying the pumping rates, thresholds, and anticipated future climatic conditions. Nine scenarios represented historic climate conditions at pumping rates or goals of 2,000, 3,000, and 5,000 acre-feet per year and thresholds of 10, 20, and 30 feet below land surface. Eight regional climate model projections were also used with the three pumping rates and three thresholds to produce 72 scenarios. Finally, an average of the climate model projections was used to create nine more scenarios.

Results clearly show greater uncertainty in projections of future water resource conditions. Given any specific management strategy of pumping rate and threshold, water supply reliability will be more challenging in the future. In addition, groundwater deficits increase and recharge decreases. However, some strategies provide enhanced reliability, lower deficits, and greater recharge rates than others. In general, the greater the pumping rate and the deeper the threshold, the more recharge the micro-basin aquifers experience. A strategy of high pumping rates and deep thresholds may be indicated; however, the implications of this strategy must be carefully considered in the context of the SCAMA management goals.

Transferability

The project team organized five Transferability Workshops in locations with potential for application of the project methodology to water resource management issues. Four focused on Arizona and one specifically addressed the applicability of the methodology in Mexico. The team engaged organizations in each of the transferability workshop locations to co-host the workshop and leveraged their connections to reach local stakeholders.

The transferability workshops employed similar formats: presentations and discussion. The first section was devoted to presenting a description of the case study and its results. Questions of clarification were answered at that time, often leading to discussion of the modeling framework and climate projections. The presentation was revised following each workshop based on the participants' questions and comments. The final presentation is posted on the project web site at http://wrrc.arizona.edu/GCASE/Workshops. To prime the discussion, transferability criteria were presented along with a preliminary introduction to some relevant local factors.

Criteria, as presented in the four transferability workshops were;

1. Local climate is a major factor in the function of the local water resource system;
2. Rainfall and streamflow are highly variable and difficult to predict;
3. Future climate projections indicate increase variability and uncertainty;
4. Informative datasets are available for the region;
5. Local agencies and stakeholders are willing collaborators.

A discussion of potential uses of the methodology followed. Discussion elicited several suggestions of locations where the methodology might apply and the nature of the questions that might be answered. These included 1) projecting natural groundwater recharge where it has a significant impact; 2) investigating the impact of development on stream and wetland baseflow, 3) assessing the impact of watershed recharge on groundwater and surface streams, 4) identifying a management strategy to achieve groundwater balance in a connected surface water-groundwater system; 5) assessing the impacts on riparian ecosystems under various scenarios of wastewater discharge into an otherwise normally dry river channel.

These suggestions demonstrate stakeholder understanding of the flexibility of the project methodology to illuminate multiple questions in situations where climate, streamflow, groundwater, and management actions are closely linked.

More in depth information about the project can be found in "Climate change and water resources management in the Upper Santa Cruz River, Arizona," Shamir, et al, in the on-line *Journal of Hydrology, Vol.521, Feb. 2015*.

WRRC WATER RESOURCES RESEARCH CENTER

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