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I. GENERAL INFORMATION

1a. Lead University and Participating Institutions

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<tr>
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<th>9/5/03</th>
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<tr>
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<tr>
<td>Name of the Center</td>
<td>Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA)</td>
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</table>
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| Role of Institution at Center | Partner in scientific research and education |
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New Mexico Institute of Mining and Technology  
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<thead>
<tr>
<th>Institution</th>
<th>Address</th>
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<tbody>
<tr>
<td>Institution 4</td>
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<tr>
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<td>Institution</td>
<td>Address</td>
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<td>Role of Institution at Center</td>
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<tr>
<td>Institution 10</td>
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<tr>
<td>Institution 12</td>
<td>University of California, Irvine</td>
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<td></td>
<td>Partner in scientific research and education</td>
</tr>
<tr>
<td>Institution 13</td>
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<td>Roger Bales</td>
<td>209-724-4348</td>
<td></td>
<td>Partner in scientific research and education</td>
</tr>
</tbody>
</table>
1b. Biographical Information for New Faculty

The only new faculty member added this year was Travis Huxman in the Department of Ecology and Evolutionary Biology at the University of Arizona, working in the River Systems theme area. His biosketch is in Appendix A.
2. Executive Summary

2a. Vision of the Center

Approximately one-third of the land surface of the Earth, including one-quarter of the contiguous U.S., is arid or semi-arid. These regions are experiencing above-average rates of population growth and development, and are therefore faced with the critical problem of how to support sustainable development and, in particular, how to provide sustainable water resources. Key issues faced by such regions include preserving the water supply (quantity and quality) and ecosystem health. Policy decisions, planning, and management are complicated by various factors including a variable and uncertain global climate, strong heterogeneities in ecology and topography, high population growth, and rapidly changing land uses.

The vision of SAHRA, the NSF Science and Technology Center for Sustainability of semi-Arid Hydrology and Riparian Areas, is to develop an integrated, multidisciplinary understanding of the hydrology of semi-arid regions, and to build partnerships with a broad spectrum of stakeholders (both public agencies and private organizations) so that this understanding is effectively applied to the management of water resources and to the rational implementation of public policy. The key question that we seek to address is: How can SAHRA more effectively bring the latest science to bear to help communities manage their water resources in a more sustainable manner? This question highlights SAHRA’s concern both with advancing the understanding of fundamental principles in semi-arid hydrology (through stakeholder-relevant multidisciplinary research), and with developing strategies for implementing scientific understanding on a practical level through aggressive knowledge transfer and strong education initiatives (K-16 and public).

2b. Goals

The overarching goals of SAHRA are to make significant advances in the understanding of semi-arid hydrology, and to help bring that understanding rapidly to bear on the practical problems of water resources policy, management, and operational decision-making. SAHRA’s greatest challenge, therefore, is to bring about a high level of coordination and integration across a broad range of scientific disciplines, and among scientists, policy and decision makers, and the general public. This coordination involves the diverse talents of physical scientists, economists and other behavioral scientists, modelers, educators, practicing engineers (from both public agencies and private companies), legal experts, and decision makers. This challenge can be considered met if new technologies, analytical tools and modeling approaches are rapidly assimilated into the understanding and management of water resources. To achieve this overarching goal, the Center seeks to:

1) **Promote integrated state-of-the-art research:** Promote and conduct large-scale, sustained, state-of-the-art integrated research (including the social and natural sciences) to understand supply and demand of water resources and how these aspects interact.

2) **Increase hydrologic literacy:** Build understanding of key water issues into K-16 science education, and promote hydrologic literacy throughout the population that makes water use and related political decisions.

3) **Extend and transfer knowledge:** Foster a multidisciplinary perspective and build technological skills via knowledge transfer within the national and international professional water resources policy and management communities.

4) **Develop integrated multidisciplinary, multi-institutional and multinational collaborations** among scientists and a variety of relevant stakeholders.

5) **Be recognized as a leader in semi-arid hydrology.**

6) **Achieve post-STC sustainability.**
The overall performance of SAHRA can be assessed and evaluated in terms of progress towards meeting each of these six major goals (see “Performance and Management Indicators” below).

2c. Plans

In addition to pursuing its overall objectives, SAHRA will focus efforts in Year 5 on the following:
1) more strongly integrate research and education activities through a multidisciplinary theme area approach that addresses critical issues in the semi-arid environment;
2) organize and run workshops and field research projects to achieve this goal;
3) demonstrate a renewed commitment to promote the development of a diverse workforce through a focused effort undertaken jointly with other STCs. This will include an expanded campaign to recruit underrepresented minority students to disciplines relevant to SAHRA’s research and to SAHRA partner institutions, with emphasis on native American students;
4) examine which knowledge transfer programs initiated by SAHRA have been most successful and expand these programs to other venues and locations within the country and internationally; and
5) strengthen our research connections at the international level.

2d. Performance and Management Indicators

The performance and progress of the science and management of the Center are evaluated in terms of the six major center-wide goals (see “Goals” above). Each of the major sections of this report (Research, Education, Knowledge Transfer, Partnerships, Diversity, and Management) lists Performance Indicators that are being used to measure and assess progress toward achieving these goals.

2e. Significant Changes from the Original Plans

A comprehensive evaluation of SAHRA activities was conducted during years two and three (2001 and 2002). An integration committee, monthly Executive Committee meetings, a large number of integration workshops and meetings and a comprehensive review of science tasks provided discussion, review, planning, and integration of the science, education and knowledge transfer activities. This process helped to clarify and build a consensus for SAHRA activities to be more strongly coordinated around a river-basin focus. This focus allows for end-to-end integration to occur, linking future climate/population/institutional scenarios to the integration of scientific understanding, integrated modeling, education and outreach, and finally to policy and decision making. Two transboundary river basins were selected around which to focus the bulk of current SAHRA research activities – the Rio Grande/Bravo basin and the San Pedro basin – with supportive work in the Rio Conchos (Mexico) basin and at the regional scale of the southwestern U.S. and northwestern Mexico. Close connections also have been achieved between the science and educational/knowledge transfer activities.

Based on the integrating river basin focus, the planning for SAHRA science has evolved so as to concentrate predominantly on the following integrating Theme Areas: 1) Basin scale water balance, 2) River systems, 3) Regional scale hydrometeorology, 4) Multi-resolution integrated basin-scale modeling, 5) International collaboration, 6) Data and information systems, and 7) Technology and equipment. The basin scale water balance theme evolved mainly out of the natural science and social science work and findings of the original TAs 1, 2 & 5. The river systems theme evolved mainly out of the natural science and social science work and findings of TAs 2, 3 & 5. The regional scale hydrometeorology theme is an extension of the work and findings of TA1 to the mesoscale, to better align with the needs of the integrated modeling, and to take advantage of leveraged research related to mesoscale modeling, climate, and studies of the North American monsoon. The multi-resolution integrated basin-scale modeling theme is a better thought-out and more strongly coordinated implementation of the original modeling TA 4,
responding to the restructured activities under the other theme areas. The international collaboration theme was created to facilitate better coordination of and emphasis on this important activity, as it acquires increased importance in the coming years. The data and information systems theme was created in response to the clear need (previously unplanned or unbudgeted) for coordination and communication in support of both field science and integrated modeling. The technology and equipment theme was created to acknowledge and facilitate the development, adaptation, and improvement of technologies that advance the science studies. In addition to these science themes are the existing education theme and the knowledge transfer theme.

The current organization of science tasks therefore reflects two dimensions: the “theme” focus (science/education/knowledge transfer) and the emergent “river basin” focus. The Integration Matrix below reflects the interactions between the integrating theme areas and the place-based basin focused approach. The columns represent the science, education and knowledge transfer theme areas. The rows represent the places – including the two major river basins, the scale of the encompassing region (southwestern U.S. and northwestern Mexico) and the broader international scale. Science activities are evaluated both in terms of the theme area science goals and in terms of place-based integrated assessment goals related to science, economics, management and policy. Darker matrix cells represent the current focus of most SAHRA activities. Arrows indicate directions in which activities are expanding. For example, the Rio Grande and San Pedro basin activities and findings are now being applied from one basin to the other, modeling is beginning to be applied to Northern Mexico, and education and knowledge transfer activities are being expanded and adapted from Arizona to New Mexico and California.

### 2003 SAHRA INTEGRATION MATRIX

![Integration Matrix Diagram]

**2f. Progress Toward Meeting Fourth-Year Objectives**

Primary objectives of Year 4 were to: 1) continue science integration efforts; 2) strengthen integrated modeling activities; 3) successfully complete the review process for SAHRA’s second 5-year period; and 4) achieve a smooth transition of leadership.

Overall, SAHRA activities proceeded smoothly throughout the year. Meetings and workshops stressing greater integration of research areas included a Rio Grande workshop held in Albuquerque in September 2002, a San Pedro Planning Workshop held at the University of Arizona in October 2002, and a dynamic
simulation modeling workshop held at the University of Arizona in November 2002. Several focused meetings (mini-workshops) of the integrated modeling team also were held in Tucson and Albuquerque.

A significant effort was required to prepare and submit the renewal proposal for Years 6 through 10. The proposal, submitted in February 2003, was well received by both NSF and external reviewers. SAHRA subsequently hosted a very successful site visit by the NSF representatives and external reviewers in May 2003.

SAHRA administrators, staff, and executive committee members also focused efforts on continued development of a strategic planning document, as reported to the External Advisory Committee and to the NSF Site Visit Team in May 2003; this document was revised further at an Executive Committee retreat held in June 2003.

A major issue that SAHRA successfully addressed this year was the transition of leadership for the Center. At the External Advisory Board meeting in May 2003, W. James Shuttleworth was proposed and accepted as Interim Director and Thomas Maddock III as Interim Deputy Director; both officially assumed office August 18, 2003. Plans were successfully developed to issue subcontracts to the University of California campuses at Irvine and Merced to allow Drs. Sorooshian, Bales, and Conklin to continue their SAHRA research and involvement.

2g. Overview of Significant Accomplishments

First and foremost, SAHRA has achieved an integrated, multidisciplinary and multi-institutional approach to research, from which a number of interesting scientific results have begun to emerge. Integration has taken four forms:

- Extensive input from over 100 key water decision makers, researchers and various stakeholders is being integrated into the SAHRA research agenda, through numerous formal and informal meetings.
- A multidisciplinary team drawn from institutions throughout the Southwest has been effectively integrated through frequent team meetings, co-location of full-time research associates, and development of research questions that cut across disciplinary boundaries.
- A process for end-to-end (scenarios to research findings) integration has been implemented. Research activities are designed to provide the information needed to support the supply and demand aspects of decision-making in the context of plausible scenarios that link causes with impacts and responses.
- Hydrologic processes are being studied in the context of their role in the hydrology of an entire basin. Research tasks are designed to fill gaps in existing knowledge, particularly at the interfaces between traditional scientific disciplines. Multi-resolution integrated modeling is being used to help integrate individual local-scale research findings, and to facilitate overall understanding of the complex interactions that occur at various spatial and temporal scales. Given the large size of the team and the immense scope of the modeling endeavor, considerable dialogue has been required to arrive at a workable structure for coordinating model development, and a consensual framework has emerged.

Second, SAHRA research findings already are improving our hydrologic understanding and changing the way water resource managers view policy options. Isotopic analysis of samples from the Rio Grande has revealed that saline groundwater discharge associated with sedimentary basins is the dominant solute input, implying that changes in irrigation and agricultural practices would have little effect on downstream salinity levels. Research on moisture fluxes beneath grasslands and desert shrubs has revealed minimal downward fluxes and even upward fluxes in the vadose zone, suggesting that large areas of the southwestern U.S. have significantly less recharge than previously thought. Research in riparian corridors has shown that flood events are an important driver for nutrient cycling and are a critical control on the structure and diversity of riparian vegetation. Vegetation water source was found to vary based on plant type and season. This information is critical for assessing the groundwater needs of
riparian ecosystems and for developing effective restoration strategies. Overall, SAHRA field research is focused on understanding how vegetative cover controls water balances and the partitioning of precipitation between evaporation, transpiration, runoff, infiltration, and recharge.

Third, SAHRA is broadening the scope and geographic coverage of its international activities. Our primary focus has been to collaborate with researchers in northern Mexico and to promote binational basin coordination of water policy. Collaborations with other countries (e.g., Morocco, Egypt) are also in development, with the initial focus on bidirectional knowledge exchange through scientific meetings and workshops.

Fourth, archiving the large amounts of data produced by SAHRA research and making that data available in appropriate forms has required an investment well beyond what was conceived and budgeted in the original proposal. However, we find it imperative to develop an online data archive to serve this immediate need. In the future, the same system may also serve as a clearinghouse for the sharing of software tools, algorithms, tutorials and other knowledge relevant to SAHRA participants. We also may seek leveraged funding to develop a Web interface that will provide one-stop access for others interested in SAHRA scientific products and knowledge transfer activities.

Fifth, SAHRA has established a cohesive program for building understanding of key water issues into K-16 science education. Our mission is to improve the hydrologic literacy of a broad range of stakeholders, particularly teachers. Considerable effort has been directed toward high school, undergraduate, graduate, and professional-level course development based on a careful assessment of needs. Workshop activities have included high school teacher training on “integrating inquiry and water issues,” and environmental education outreach for Native American K-12 students and teachers. Another important goal is to attract diverse students into hydrology. A comprehensive diversity plan is currently being reviewed and developed.

Finally, SAHRA has developed a diverse and effective approach to knowledge transfer. We have ascertained the needs of key stakeholders in the region and solicited feedback to guide SAHRA’s research efforts. We have developed ambitious Web-based resources that further multidisciplinary hydrologic literacy and communicates research findings, data sets, and tools to water resources managers and policy makers. KT activities also inform the general public through services such as our Web-based “Global Water News Watch” and “Residential Conservation Information” sites, Rural Water Resource Centers, public education displays, and periodic press briefings. SAHRA’s Sabino Canyon display, electronic kiosk and web site exemplify our ability to tap near-real-time data streams and ongoing research efforts to produce informal experiential exhibits that raise hydrologic literacy. We have assumed publication of Southwest Hydrology, a bimonthly print publication for hydrologists, water managers, and other water professionals that provides information about projects, research, technologies, regulations, and innovations unique to the semi-arid Southwest.
II. RESEARCH

1a. Overall Research Objectives

The Center’s overall research objectives have not changed.

1b. Performance and Management Indicators

SAHRA research addresses the many facets of hydrology and water resources in semi-arid regions. The Center program involves a number of researchers from many institutions, working together through long-term, coordinated and interdisciplinary research. Scientists in the Center conduct basic, often high-risk research in partnership with stakeholder groups, leading to the rapid dissemination and application of cutting-edge scientific knowledge. To evaluate the performance of SAHRA research we must consider both the ability to conduct research in a “center mode,” as well as the dissemination and impact of research results. Below we list some indicators by which our success can be gauged, on an annual basis. In the list that follows and in subsequent sections, the information in brackets is a measure of the rate of change of that indicator.

Indicators of “Center Mode” Research
- List / Number of disciplines represented within SAHRA [maintain]
- Number of multidisciplinary presentations and publications [increase %]
- Number of multi-institution presentations and publications [increase %]
- List of integrated field sites / sampling campaigns [increase]
- Number of students with multidisciplinary or multi-institutional thesis committees [increase %]
- Dollar amount of resources being leveraged [increase %]
- List / Number of workshops / meetings held at partner institutions [increase #]
- List / Number of stakeholder partnerships [increase #]
- List / Number of stakeholders participating in SAHRA workshops / meetings [increase #]
- List / Description of SAHRA participation in stakeholder group meetings [increase #]

Indicators of Research Results and Impacts
- List / Number of publications subcategorized as “multidisciplinary authorship,” “multi-institution authorship,” etc. [increase %]
- List / Number of presentations subcategorized as “multidisciplinary authorship,” “multi-institution authorship,” etc. [increase %]
- List / Number of invited talks (professional meetings, peer institutions, public forums etc.) subcategorized as “multidisciplinary authorship,” “multi-institution authorship,” etc. [increase #]
- List of nominations, honors and awards (for individuals and the Center) [increase #]
- List of research sessions organized/chaired at professional meetings [increase #]
- List of student theses, highlighting those having “multidisciplinary” and/or “multi-institution” advisors/committee members [increase %]
- List / Number of edited research monographs [maintain]
- List / Description of participation in relevant local, regional, national and international committees, panels, and boards [maintain]
- List / Description of press coverage of SAHRA research [increase #]
- List / Description of agencies that adopt SAHRA models, incorporate SAHRA data sets in operational use [increase #]
- List / Description of local and state agencies, NGOs that rely on SAHRA research in reaching water policy decisions [increase #]
1c. Problems During the Reporting Period and Anticipated for Year 5

Problems that have hindered progress toward achieving our research objectives can be categorized as a) issues in science coordination; b) financial limitations; c) threats to field sites; d) need for the development of a coordinated knowledge base; e) need for increased emphasis on social science and policy; f) other personnel needs; g) a need for more integration for the student experience; and h) space issues and change of location.

A. Issues in Science Coordination

A shift in personnel (addressed in more detail in Section VII) is being undertaken in summer 2003, with Dr. Sorooshian moving to the University of California, Irvine, and Dr. Bales moving to the University of California, Merced. Both remain on SAHRA’s Executive Committee and will continue their roles in science coordination. Research funds will be issued to them in the form of subcontracts.

We also recognize a need to engage a landscape ecologist to assist in synthesis of plant community processes for scaling up to the landscape, basin, and regional scales. We will attempt to fill this need as soon as available resources allow. Meanwhile, we are actively recruiting a postdoctoral research associate with a background and interest in the interface between hydrology and ecology/vegetation. Also, a proposal to the U.S. Army includes funding to recruit a landscape ecologist with experience in the San Pedro River Basin.

B. Financial Limitations

Our original proposal for the SAHRA Science and Technology Center requested and was awarded approximately $16M of the maximum possible $20M. This budget included insufficient funds to cover inflation in salaries and other costs, and for certain critical activities such as developing the knowledge base. The SAHRA STC includes many more partner institutions than most other STCs; travel and communication overhead is therefore significantly greater. Further, the science ambitions of SAHRA researchers have expanded considerably as the Center has become established, and as the magnitude of the sustainability problem in semi-arid regions has become better understood. In response, SAHRA has sought out and obtained additional funding to help support these needs. New research activities require significant leveraged funding in order to be considered. These additional funding sources will facilitate a more comprehensive implementation of SAHRA’s mission, while spawning offshoots to the primary research initiatives.

We anticipate that our financial situation will improve in the near future, based on a favorable initial response to our renewal proposal request to increase to $4 million for each of Years 6 through 8. Additionally, as of July 2003 we obtained $470,000 in Proposition 301 funds (described further in Section IV) for targeted research by SAHRA investigators.
C. Threats to Field Sites

From June 17 to July 12 of this year, wildfire threatened SAHRA’s eddy covariance tower and micrometeorological network on Mt. Bigelow, north of Tucson. The human-caused Aspen Fire burned 84,750 acres in the Santa Catalina Mountains and consumed 333 structures. The total cost of efforts to fight the fire exceeded $17 million. This is the second consecutive year that wildfire encroached on the Mt. Bigelow site: in May 2002 the Bullock Fire burned another 30,563 acres, mainly in the northeast section of the Santa Catalinas. The 2002 fire proved to have only minimal impact on our research, but fire prevention efforts for this year’s Aspen Fire included some tree removal and surface back burning by fire crews immediately around the main eddy covariance (EC) tower site. Fire crews also removed three of our micrometeorological stations just before the fire reached them. SAHRA personnel removed approximately $50,000 of equipment from the EC tower on June 19, when it came under direct threat and we were allowed access to the site for a few hours. This equipment was reinstalled as soon as we regained access to the site (July 12) so that we could begin collecting post-fire data. Long-term ramifications of the Aspen Fire on our project are still being assessed, but we are already moving forward with pre-versus post-fire analyses of EC data, and a new study investigating soil permeability and water content.

D. Development of Coordinated Knowledge Base

We mentioned in the last annual report the urgent need to develop an easily accessible web-based “knowledge-base” repository of information to enable sharing and communication of research plans and results, and to support science, education and knowledge transfer activities. Progress has been slow and is lagging behind (and hampering development of) the science. Partly, this is because the “knowledge-base” effort has proved to be a more complex task than previously imagined, but a primary reason is that SAHRA personnel have been heavily burdened by other (administrative) tasks such as conducting meetings and workshops, undergoing project review, and responding to NSF’s requests for early preparation of the Annual Report and the Renewal Proposal. HyDIS researcher Eve Halper was recruited and completed the initial phase of this effort; we are currently recruiting a dedicated database specialist.

E. Need for Increased Emphasis on Social Science and Policy

Social science and policy is playing an increasingly larger role in SAHRA’s mission. At our recent retreat, the Executive Committee drafted criteria for determining when SAHRA’s science results are mature and how to decide which projects to target for additional social science, education, and knowledge transfer efforts.

We also discussed how to increase economic and policy analysis, knowledge transfer, and education efforts to ensure that mature science is usable by water managers and policy makers. To help with this effort, SAHRA is seeking a public policy faculty member to join our existing efforts in economic research (UNM), policy analysis (Udall Center), postdoctoral research (natural resource economics; science education), and special projects (riparian flyway valuation; Native American water rights). Additionally, our work with multi-scale models, particularly dynamic simulation models, is designed to allow all stakeholders to explore the consequences of scientific advances and thus to rapidly move the state of scientific knowledge into widespread usage by the public and private agencies responsible for managing our water resources, in line with our mission statement. These efforts require additional resources. The Prop. 301 funds coming to SAHRA for research are being used to support social science work, such as a study by Colby et al. on impacts of riparian habitat on the market value of nearby homes.
F. Other Personnel Needs

The postdoctoral research position for Integrated Modeling remained vacant throughout the year, although the integrated modeling research effort was ably advanced during that period of time by DAAD Fellow Thorsten Wagener. However, SAHRA has now successfully recruited Yuqiong Liu to fill the position, beginning in October 2003. With a strong background in water resources decision support systems, atmospheric modeling, surface water modeling, and parameter estimation theory, she will bring a well-rounded perspective to this research area.

G. Need for More Integration for the Student Experience

SAHRA’s primary postdoctoral research associates (PDRAs) are co-located in one room at the University of Arizona and attend most policy and technical meetings. This environment was created expressly to encourage and facilitate serendipitous creative interactions. Similarly, most SAHRA graduate students at UA are co-located in two student offices for this same purpose. We are committed to training all our students to appreciate and work collaboratively in a highly interdisciplinary environment. To further address this effort, we are exploring new ways to promote multi-institutional faculty mentoring of graduate students, student exchanges, teleconferenced seminars, and Center-wide summer water issue field trips to further promote serendipitous creative interaction among far-flung individuals (SCIFI). One example of a SCIFI effort currently underway involves a UA student undertaking an internship at Sandia National Laboratory, taking courses at UNM, and subsequently returning to UA to share his experiences with both faculty and students. Challenges we face in implementing SCIFI programs include added costs, added time to degree due to student “sabbaticals” at other institutions, inconsistent institutional and departmental graduation requirements, and added faculty advising loads. We have scheduled a student-mediated session at our October 2003 Annual Meeting to address SCIFI issues.

H. Space Issues and Change of Location

As the numbers of SAHRA projects and staff members have grown since 2000, so have SAHRA’s space requirements, especially at the University of Arizona. In late December 2003 we expect to move into new SAHRA facilities, the entire fifth floor of the new Marshall Foundation Building currently under construction. This move was originally scheduled for 2002, but construction was delayed.

2a. Research Thrust Areas

As described in the Executive Summary, SAHRA science has evolved from an initial focus on Thrust Areas to the following integrating Theme Areas: 1) Basin scale water balance, 2) River systems, 3) Regional scale hydro-meteorology, 4) Multi-resolution integrated basin-scale modeling, 5) International collaboration, 6) Data and information systems, and 7) Technology and equipment.

A. Basin Scale Water Balance

1. Basic Information

Semi-arid environments such as those of the southwestern United States demonstrate a division of the water budget that is quite different from that of humid settings. Both precipitation and temperature depend strongly on elevation. As a result, the high-elevation portions of drainage basins tend to be the areas
where precipitation is converted into runoff and deep infiltration and the low-elevation portions tend to be the areas where this “excess” precipitation is returned to the atmosphere by evaporation and transpiration. This organization of the water budget provides a natural structure for SAHRA’s fundamental research at the basin scale.

SAHRA research is focused on understanding and linking the key processes controlling the hydrology in each of these regions. In particular, we seek to understand the mechanisms by which precipitation (rain and snowfall) is partitioned into evaporation/sublimation, interception loss, runoff and infiltration, and how snow and soil moisture storages are partitioned into transpiration, recharge, and streamflow. In addition, we are concerned with how these key variables and processes can be estimated and modeled. To date, SAHRA research has emphasized the following issues:

• Mountain environments: What factors control the partitioning of snow accumulation and melt into evapotranspiration (ET), deep infiltration and runoff?
• Basin floor areas: What are the processes governing water fluxes through thick vadose zones in the basin floor areas? How does vegetation influence the partitioning of water and energy fluxes and soil moisture storage?

A more complete understanding of these issues is necessary to close water budgets at the basin scale and to predict the nonlinear response of the system to long-term water balance perturbations, including a fair assessment of uncertainty in these predictions. Our approach has involved intensive field measurements at test sites, use of remotely sensed data, and modeling.

2. Significant Accomplishments and Findings for Year 4

• A 30-meter micro-meteorological tower (hereafter called the Mt. Bigelow site) was erected and instrumented to measure water, energy and carbon fluxes in a 2,400 m elevation ponderosa pine-Douglas fir forest. Observations revealed that the trees essentially “shut down” during the pre-monsoon season, with the exception of brief periods in the morning and afternoon when CO₂ uptake directly correlates with low rates of ET. After monsoon precipitation, the ecosystem responds rapidly, with Bowen ratios (ratio of sensible to latent heat flux) near one, and high levels of CO₂ uptake (photosynthesis). Micro-meteorological stations distributed throughout the forest showed surface flux potential (surface air temperature gradient) varied significantly over space and time, and was directly related to canopy characteristics and aspect.
• Modeling of high-elevation environments suggests that topography, bedrock permeability and vegetation exert a strong control on deep infiltration, and hence recharge. Topographic and geologic data are readily available. The relationship between these abiotic controls and the biotic components of the system are still unknown, although our simulations show that the interactions are critical.
• Water fluxes in typical basin floor environments under the current climate have been shown to be upward in the top ~50 m of the vadose zone during the Holocene, driven by a combination of very negative water potentials produced by the roots of desert vegetation and by the geothermal gradient. However, comparison of vadose zone profiles under different types of vegetation and modeling of past periods when climate change caused migration of plant communities have both shown that under slightly less xeric types of vegetation, fluxes can be downward through the root zone.
• Hydrologic feedback mechanisms that favor woody species over grassland were identified. The resulting impact on surface and vadose zone water and energy cycling have been quantified through intensive measurements on controlled plots within the Sevilleta long-term ecological research (LTER) site. Overall, the spatial distribution of biomass and the physiology and phenology of plant types exert a fundamental control on water and energy fluxes. More and deeper infiltration occurs beneath plant canopies than in barren interspaces. The total ET flux from these two ecosystems is similar, but drying following rainfall is faster in shrubland. Leaf-level measurements show that ET is partitioned into evaporation and transpiration differently in the two environments, with greater evaporation in the
shrubland due to more bare soil area. Shrub invasion of grassland, the most extensive natural land-
surface change throughout the Rio Grande valley, is expected to continue.

- Analysis of streamflow data has shown that low-frequency oscillations in seasonal to interannual and
decadal climatic forcing coincide with the long time scales of deep soil moisture and groundwater
storage to amplify low-frequency modes in runoff in ephemeral, intermittent, and perennial streams of
the Rio Grande basin. Low-frequency components in mountain front runoff are consistent with the El
Niño-Southern Oscillation, quasi-biennial, and quasi-decadal signature.

- Research on municipal water demand historically has been based on data aggregated over large
georgraphic areas (e.g., service areas) and/or time periods (months/years). A SAHRA research effort has
been developing and analyzing disaggregated demand data. Four research approaches are leading to
improved understanding of water demand: experimental economic work on decision-making at the level
of the individual; development of household dataloggers at the level of individual water uses; time
series analysis of household-level residential data from county-level databases; and factors controlling
residential and industrial water demand evaluated using a large database of household level monthly
demand. A general result is that individual and household behaviors are more significant determinants
of water demand than suspected, whereas physical characteristics of households and landscapes are less
important than previously believed (e.g., operation and maintenance of irrigation systems vs.
landscaping and type of irrigation system).

- A FARM package for MODFLOW-2000 is being developed to aid in the conjunctive management of
surface-water dominated irrigation systems. The package logically integrates, on a farm-by-farm basis,
the surface water delivery, farm delivery requirement, and supplemental well pumping required to
sustain the crops’ growth.

3. Research Partnerships and Their Contributions

Primary partners for this theme area are:

- University of Colorado – Eric Small is working on differences in species’ interaction with subsurface
  water and hydro-ecological explanations of plant community succession in grasslands and riparian
  areas.

- University of New Mexico – a team of economists (Brookshire, Chermak, Krause) is working on
  studies of water demand in the Albuquerque area.

- University of Arizona/New Mexico Tech/USGS – James Hogan (UA) and Fred Phillips (NMT) are
  using USGS samples of groundwater wells in the Albuquerque basin in their work on groundwater
  salinity.

- University of Arizona – data loggers (Woodard) and disaggregated domestic demand analysis
  (Woodard and Stewart)

- New Mexico Tech – mountain front recharge (Wilson)

- International Atomic Energy Agency/UA – are joining isotopic data sets to provide full coverage of
  the Rio Grande basin.

- USDA-ARS – The Southwest Watershed Research Center is a major partner with SAHRA in studying
  numerous hydrologic and watershed processes in the Southwest. SWRC operates the Walnut Gulch
  Experimental Watershed, the most densely instrumented semi-arid watershed in the world, and an
  important outdoor laboratory for SAHRA research.

- Penn State University – investigating temporal variations of water partitioning across a range of
  scales using nonlinear dynamics (Duffy)

- UA-HWR: - understanding land/atmosphere/energy budgets over different seasons in a sky island
  biome (Brown, Bales, Shuttleworth)

4. Goals, Activities, and Outcomes/Impacts in the Current Reporting Period

These have remained essentially the same for Year 4.
B. River Systems

1. Basic Information

River systems integrate the hydrologic and biogeochemical processes that occur in a basin. In semi-arid areas, river valleys are the major location of human settlements and irrigated agriculture. Water resource decisions often directly impact streamflows, and may result in unexpected impacts on water quality, the socio-economic value of the river system, and the structure and diversity of the riparian ecosystem. These decisions are particularly challenging because the water needed to sustain riparian areas, home to much of the regional biodiversity, is the same water needed for urban and agricultural growth.

In the first four years, SAHRA river system research has focused on developing fundamental processes-level understanding in three areas: 1) riparian water balance, 2) nutrient and solute sources and cycling, and 3) ecosystem dynamics and value. To date, research has been conducted on the San Pedro, an unmanaged river with an intact native riparian ecosystem, and the Rio Grande, a highly regulated river with large urban areas, extensive irrigated agriculture, and riparian ecosystems dominated by invasive species.

Specific questions included: 1) What are the controls on riparian evapotranspiration? 2) How are plant water sources partitioned between groundwater, precipitation, soil moisture, and stream flow? 3) What hydrologic and biologic factors control nutrient cycling in riparian ecosystems at the gravel bar and kilometer-reach scales? 4) What are the sources of salinity and how are they partitioned between natural and anthropogenic sources? 5) What hydrologic factors control the structure and function of riparian ecosystems?

2. Significant Accomplishments and Findings During Year 4

- Eddy covariance measurements of riparian ET show tight coupling between understory ET and monsoon precipitation, whereas mesquite tree transpiration does not show significant change with the arrival of monsoon moisture and is closely related to diurnal water table fluctuations (implying a groundwater source). Isotopic analysis of sap water has revealed that mesquite trees actually transpire a mixture of two-thirds groundwater and one-third precipitation/soil moisture.

- Multiple isotopic and chemical tracers show that local discharge of saline groundwater is a significant source of salinity to the Rio Grande, whereas agricultural return flows add little salt. This suggests that water quality improvements can be achieved through interception of saline groundwater or by changes in river management practices. Contrary to popular opinion, changes in irrigated agricultural practices may do little to decrease salt input to the river.

- Nutrients in the Rio Grande, in contrast to salinity, come mainly from anthropogenic sources including sewage treatment plants and agricultural return flows. These inputs are local, however their effects can extend for long distances with minimal biological cycling, ultimately impacting the aquatic and riparian ecosystems far from the original source.

- Hydrologic exchanges across riparian system interfaces result in extremely localized zones of rapid nutrient transformation and retention. However, the overall hydrologic flux across these interfaces is very low at baseflow. Thus biogeochemical connectivity is limited, both between the riparian zone and the stream, and between upstream and downstream reaches during baseflow. Consequently, water quality at any location is quite variable and strongly related to local sources and sinks of solutes. This changes during storm events when large amounts of carbon and nitrogen solutes are flushed from the vadose zone into the stream/hyporheic zone. Elevated baseflow, due to monsoon storm events, results in downstream transport of these solutes, resulting in little variability in surface water carbon and nutrient concentrations, in contrast to low baseflow conditions.
Continuously recording sediment load sensors indicate that scour and fill can result in highly variable respiration rates for microbial communities in stream sediments. Measurement of respiration potentials showed that the zone for aerobic biological activity extends to at least 80 cm, far deeper than previously thought. Dissolved organic carbon appears to be the most important variable controlling microbial respiration, implying carbon limitation.

Groundwater depth, flood disturbance intensity, flow frequency, and rainfall quantity exert strong controls on the structure and diversity of riparian vegetation. These results have important implications for riparian restoration and conservation; riparian managers who wish to restore native broadleaf cottonwood-willow forests to riparian corridors dominated by exotic saltcedar now have guidance on the ranges of groundwater depth and flood inundation frequency needed to adopt a flow-management approach to riparian forest restoration.

3. Research Partnerships and Their Contributions

Primary partners for this theme area are:

- **NMT/UA** – investigating sources of groundwater and the fates of stream water, sediment, salt, and nutrients, using innovative applications of isotopes and sensors (Phillips, Hogan)
- **Arizona State University** – examining vegetation transitions in riparian ecosystems (Stromberg) and biogeochemical processes (Grimm)
- **USDA-ARS-Soil Salinity Lab and University of California, Riverside** – looking at scaling of riparian biogeochemical processes (van Genuchten, Schaap)
- **USDA-ARS-Southwest Watershed Research Center** – hydrologic exchanges and nutrient transformation and retention during periods of elevated streamflow (Goodrich)

4. Goals, Activities, and Outcomes/Impacts in the Current Reporting Period

These have remained essentially the same for Year 4.

C. Regional Scale Hydrometeorology

1. Basic Information

Regional water resources planning requires estimates of the regional water budget and prediction of the natural system’s responses to water balance perturbations, along with assessments of the uncertainty in such estimates. Critical elements in such assessments are precipitation (rain and snow) and evapotranspiration. However, in the mountainous southwestern United States, surface-based observations are limited by spatial heterogeneity and by topographic blockage of rainfall radar. SAHRA has prioritized the development of satellite remotely sensed methods and regional modeling approaches for estimating these variables by addressing the following main science questions:

- What factors control the distribution of snow accumulation and melt?
- To what extent can satellite-based precipitation estimation meet the spatial/temporal resolution requirement for hydrologic applications in semi-arid regions?
- To what degree can one use satellite-based data in conjunction with surface measurements to achieve a higher level of accuracy as compared to the current techniques in estimating snow accumulation in high elevations of the southwestern United States?
- To what extent will the use of satellite-based information results improve the ability of regional climate models to simulate precipitation anomalies in semi-arid regions?

Given the relative complexity and scale of the problem and the relevance of the research to NASA and NOAA, most of the resources are being leveraged from projects supported by these two agencies.
2. Significant Accomplishments and Findings During Year 4

Ongoing research has emphasized: a) developing the means to estimate the quantity and spatial distribution of rainfall using satellite data, radar, and ground measurements; b) developing tools for estimating spatially distributed snow accumulation and snow melt in seasonally snow-covered catchments; and c) adapting a regional climate modeling system to synoptic and climatological characteristics of the southwestern United States.

Noteworthy achievements are:

- Near real-time estimates of precipitation at 6-hourly and 0.25° resolution are being produced over the southwestern United States using infrared and microwave data from 11 satellites processed by the PERSIANN algorithm (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Network). A pilot study showed that the precipitation product may be approaching levels of accuracy suitable for driving a distributed land surface water and energy balance model.
- A real-time global-to-regional climate modeling system, the Global Spectral Model-Regional Spectral Model-Variable Infiltration Capacity (GSM-RSM-VIC) macroscale model is under development. The output data are routinely archived and continually re-analyzed. The modeling system simulates and predicts synoptic and climatological characteristics of the southwestern United States for use in scenario analyses.
- A strategy has been implemented for improving snow water equivalent (SWE) estimates and modeled streamflow using an 8-year data set of 1 km² gridded snow-covered area that we developed from remote sensing data for the southwestern United States. Methods for assimilating this spatial data into hydrologic models are under development for the Rio Grande headwaters.
- The best method for estimating basin-wide SWE from point data has been shown to depend on the spatial arrangement of data and the environmental or physiographic factors that characterize a basin. Interpolation errors are comparable using either SNOTEL or snow course data. Snow surveys appear to provide more accurate spatial maps of SWE particularly during drought years. The implication is, that without improvements in measurement network design, uncertainty in SWE estimates used for decision-making will remain high.
- Remotely sensed snow grain-size data were incorporated into spatially distributed energy-balance snowmelt models, with a 34% increase in accuracy of our prediction of snow pack ablation, and thus basin-scale snowmelt.

3. Research Partnerships and Their Contributions

Primary partners for this theme area are:

- UA-HWR/UC Irvine/UC Merced – estimating spatiotemporal variation in the critical drivers of the semiarid water cycle: precipitation (Sorooshian, et al.) and snowmelt (Bales, et al.).
- Scripps Institute of Oceanography (UCSD) – implementing a macroscale hydrologic prediction model into a regional atmospheric model for the Southwest. The system is being tested using observations from rivers throughout the southwestern U.S. and providing daily to seasonal forecasts on southwestern U.S. hydrology and climate variables (Roads).
- NMT – looking at regional scale evapotranspiration using SEBAL, the Surface Energy Balance Algorithm for Land (Hendrickx).

4. Goals, Activities, and Outcomes/Impacts in the Current Reporting Period

These have remained essentially the same for Year 4.
D. Multi-resolution Integrated Basin-Scale Modeling

1. Basic Information

The primary functions of integrative modeling are to provide a repository of understanding and formal framework for integrating the research findings of SAHRA investigators and to evaluate scenarios that describe potential future changes in the Rio Grande, San Pedro, and other basins. These scenarios project physical (including climatic), socio-economic, and/or institutional stresses and prescribe changes in model boundary conditions.

Given the complexity and multidisciplinary nature of SAHRA and the scope of the modeling endeavor, considerable dialogue has been required to arrive at a workable structure for coordinating model development. A series of workshops and meetings has resulted in a consensual framework, and a core modeling team now provides leadership and structure. Novel elements include a multi-resolution approach, models specifically suited for semi-arid areas, and integration between the physical and behavioral models at different scales.

2. Significant Accomplishments and Findings During Year 4

- A scenario-driven approach has been adopted for design of the integrated modeling, to ensure that the models are applicable to historical situations. Each scenario generates a series of questions that must be answered, thereby defining the requirements for model structure and content. The initial scenario selected for integrated model development is recurrence of a 1950’s-style drought, and current demographic trends and uses within the Rio Grande from its headwaters to the Texas-New Mexico border.

- A three-resolution approach has been adopted for basin-scale integrated models. At “coarse resolution,” a systems model represents the river basin as a linkage of hydrologically relevant units (e.g., all acreage devoted to one type of land use) with uniform properties. The “medium resolution” (1-12 km/sub-daily) and “high-resolution” (~100 m/sub-hourly) models are both grid-based with spatially distributed model parameters and model forcing. The initial focus of the integrated modeling is the Rio Grande Basin. A set of complementary models is being developed and will be compared against a predefined set of benchmarks to evaluate the appropriateness of the spatiotemporal resolutions.

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Fig. 1 – Conceptual model of the Rio Grande for SAHRA integrated model
• All the models will be based on the same general conceptual (perceptual) framework representing the important interactions to be included for the Rio Grande (Figure 1 above). This framework allows the physical system and human behavior components to be developed in parallel, with clear agreement on linkages through land use, engineering, and monitoring.

• Discussions among SAHRA social scientists, economists and hydrologists have shown that a common list of definitions is critical to communication. The gradual process of arriving at a consensus on conceptual model structure has resulted in considerable cross-disciplinary education of all parties involved. Also, we are reviewing integrated modeling systems under development internationally to ensure the best possible use of existing research into the linking of model structures from different disciplines.

• The MMS/PRMS (Modular Modeling System and Precipitation Runoff Modeling System) produced stream discharge forecasts in 21 headwater basins of the Rio Grande that were significantly better than empirical forecasts currently used by water resource managers. Inclusion of spatial snow information and multi-criteria optimization also provided significant improvements. A 10-year pilot study on vegetation representations in MMS/PRMS applied to snow-covered headwater areas yielded significantly different streamflow estimates, with a reclassified 30-m product giving the best model result.

• A dynamic simulation water resources planning model of water supply and demand in the Albuquerque region through the year 2040 has been developed in collaboration with Sandia National Labs. (Figure 2). The Middle Rio Grande Water Assembly will use this model to evaluate and compare management and conservation options for achieving sustainable water use.

• A NOAH land surface model of the San Pedro River basin (at ~12 km and ~4 km spatial resolutions) has been implemented on a parallel computing machine to evaluate model sensitivity to grid size, temporal resolution, and parameter estimation, using mesoscale atmosphere model MM5 forcing and remotely sensed data including SAHRA satellite-based precipitation.

• The Los Alamos Distributed Hydrologic System (LADHS) surface hydrology model has been coupled with the Finite Element Heat and Mass (FEHM) variably saturated multiphase code and the Regional Atmospheric Modeling System (RAMS) Model and implemented using the LANL PAWS (Parallel Application Workspace) linking software to run on massively parallel computers. Initial simulations for the Rio Grande using nested RAMS grids sizes of 80, 20, and 5 km show increased precipitation accuracy as grid cell size is decreased.

• Parameter estimation tools: Previous work on multi-criteria parameter estimation under uncertainty is being extended to distributed and coupled model environments. Testing of a land-atmosphere model
shows increased parameter sensitivity in coupled mode and significant potential for enhanced model accuracy. Testing has shown that the commonly used carbon exchange model needs correcting to work in semi-arid mixed C3/C4 environments. New optimization algorithms, Shuffled Complex Evolution Metropolis (SCEM) and Multi-objective Shuffled Complex Evolution Metropolis (MOSCEM) have been developed for probabilistic parameter estimation. These tools are recently finding wide acceptance at the international level through GEWEX and other organizations.

3. Research Partnerships and Their Contributions

Primary partners for this theme area are:

- **USGS/Desert Research Institute** – USGS and DRI are collaborating on a medium-resolution integrated modeling effort by expanding the MMS/PRMS model of 21 headwater basins in the Rio Grande. This new model capability is being evaluated by URGWOM (Upper Rio Grande Water Operations Model staff to replace current streamflow forecasting methods. (Boyle, McConnell, Bardsley)
- **Sandia National Laboratory** – dynamic simulation water resources planning model of water supply and demand in the Albuquerque region through the year 2040; cooperative sponsorship of dynamic simulation modeling workshop for natural resource managers, held at UA in November 2002. (Webb, Tidwell)
- **Los Alamos National Laboratory** – Everett Springer is co-leader of the integrated modeling team and heads the subgroup dealing with high-resolution modeling of the Rio Grande. He and other LANL staff members are developing the model and providing significant high-performance computing capabilities to SAHRA through the LANL computer system.
- **University of New Mexico** – faculty researchers in the Economics Dept. are contributing to the development of the socioeconomic model components to be built into the decision support system. (Brookshire, Krause, Chermak)
- **New Mexico Institute of Mining and Technology** – Enrique Vivoni was recently recruited to join the integrated modeling team to work on the high-resolution collaboration with LANL.
- **UA-HWR/Utah State University/DRI/UNM** – Hoshin Gupta is co-leader of the integrated modeling team and coordinates the activities of the medium-resolution modeling team, which includes Bart Nijssen (UA), Luis Bastidas (USU), Douglas Boyle (DRI), newly recruited postdoctoral researcher Yuqiong Liu (UA) and David Brookshire (UNM) will assist with conceptual model development and model integration.

4. Goals, Activities, and Outcomes/Impacts in the Current Reporting Period

These have remained essentially the same for Year 4.

E. International Collaboration

1. Basic Information

Rapid growth along the U.S.-Mexico border is increasing demands on the region’s limited surface and groundwater supplies. Mexico also reflects worldwide trends in the privatization, decentralization, and restructuring of water management that is providing many new challenges and opportunities for sustainable water management in semi-arid environments. Improved management of shared binational water resources requires a multidisciplinary and multinational research effort. This effort aims to promote an integrated binational water management policy that takes into consideration the issues and concerns of stakeholders and fills critical knowledge gaps among scientists and stakeholders, including information about climate variability and change, and water quality. This work will a) increase access to hydrologic
and policy information on both sides of the border to improve decision-making related to sustainable development of water resources, and b) conduct focused research projects to develop tools that address surface water and groundwater sustainability across the border region.

2. Significant Accomplishments and Findings During Year 4

• An NSF “Glue Grant” is supporting collaboration between researchers from SAHRA, the CREST center at California State University-Los Angeles, and Universidad Autónoma de Ciudad Juárez. A variety of isotopic tracers were used to study recharge rates, groundwater flowpaths and mechanisms of salinization of the Hueco Bolson aquifer, which serves the binational El Paso-Ciudad Juarez area. Recent analyses unexpectedly revealed that Juárez and El Paso have distinct recharge sources and appear to link predevelopment recharge in Mexico to an extra-basinal source of water, a result with important implications for the sustainability and management of the aquifer and the water supplies of the two cities.

• SAHRA sponsored and participated in the Scientific Committee of the First International Symposium on Transboundary Water Management (http://www.transboundarywatersmexico.org/congress.htm), held in November 2002 in Monterrey, Mexico, through several invited presentations and panels. The proceedings contain more than 65 papers. The second meeting will be hosted by SAHRA in November 2004 at the University of Arizona.

• SAHRA played a major role in fostering the formation of the Asociación Ambiental de Sonora-Arizona (ARASA) stakeholder organization in the Mexican portion of the San Pedro and aided in organizing and facilitating several binational meetings of U.S. and Mexican stakeholders.

• SAHRA was invited by UNESCO to attend a special meeting in Paris in April 2003 that established a Global Network on Water and Development Information for Arid Lands (GWADI). UNESCO subsequently asked SAHRA to develop and provide selected content for a GWADI web portal and is providing seed money toward this effort. The site will include: home page; secure side for remote data entry; reference modules for researchers on specific topics such as hydrologic isotopes; searchable databases on research efforts; GIS data sets in support of research; Global Water News Watch service with email subscriptions; workshop and training support; and educational resource sharing.

• SAHRA worked to build new relationships with Mexican scholars and policy makers in relevant fields; during the past year these included Dr. Patricia Moreno Lankao, Professor of Politics and Culture at the Universidad Autónoma Metropolitana, Campus Xochimilco, who was a Visiting Scholar at the UA Center for Latin American Studies, and Juan Castellanos of Universidad de Sonora, Hermosillo, who spent a sabbatical year at the UA and met with various SAHRA researchers.

3. Research Partnerships and Their Contributions

Primary partners for this theme area are:

• ARASA – working with Udall Center to address issues of water quality and resource management in the Upper San Pedro River Basin

• UNESCO – collaboratively developing with SAHRA the GWADI web site described above

• California State University, Los Angeles/Universidad Autónoma de Ciudad Juárez – Hibbs and Qiu at CEA-CREST are collaborating with SAHRA to study surface water and groundwater systems along the El Paso/Ciudad Juarez metroplex.

• IMTA (Mexican Institute for Water Technology) – collaborating with SAHRA (Valdes) in the development of a drought preparedness plan for the Conchos River Basin, Mexico.

• IMADES (Instituto del Medio Ambiente y el Desarrollo Sustenable) – collaborating with SAHRA on eddy covariance measurements of understory ET (Watts)
4. Goals, Activities, and Outcomes/Impacts in the Current Reporting Period
These have remained essentially the same for Year 4.

F. Data and Information Systems

1. Basic Information

This theme area seeks to develop needed infrastructure support.

2. Significant Accomplishments and Findings During Year 4

- A GIS database (http://hydisweb.hwr.arizona.edu/website/rio_grande/viewer.htm) for the Rio Grande has been developed (with leveraged funding), with the following themes: Los Alamos National Laboratory-derived Rio Grande Basin outline; linear and polygonal hydrography from the USGS; streams coverage from the ERF-1 (EPA) database; reservoirs (USGS); meteorological gauges (NOAA); Snotel sites (NRCS); cities and counties, with some census data, from the National Atlas Data Set; federally owned land, also from the National Atlas Data Set; Statsgo soils (NRCS); HUCs from the USGS and state data for the US and Mexico courtesy of ESRI. A metadata database is still being developed.
- A prototype Web portal for serving software and algorithms to the scientific community has been developed (http://www.sahra.arizona.edu/software).

3. Research Partnerships and Their Contributions

- **UA-HWR** – A leveraged effort with HyDIS (Hydrological Data and Information System), funded by Raytheon, that focused on using remote sensing to better understand and assess the temporal and spatial distribution of precipitation (Sorooshian)
- **UA-HWR** – database administration and management

4. Goals, Activities, and Outcomes/Impacts in the Current Reporting Period
These have remained essentially the same for Year 4.

G. Technology and Equipment

1. Basic Information

SAHRA aims to further the development, adaptation, and improvement of technologies that advance the study of water, energy, and nutrient exchanges. Key efforts that address technology development can be grouped into five categories: 1) invest in necessary capital equipment; 2) develop new technologies or techniques; 3) adapt existing technologies; 4) provide continuity of expertise for the use of advanced technologies; and 5) identify unfulfilled measurement needs.

2. Significant Accomplishments and Findings During the Reporting Period

- The combined use of stream gauge measurements, auto-samplers, and novel pressure sensors measuring sediment scour and fill integrated through a datalogger, allows researchers to record biogeochemical and morphological characterization of flow events at the reach scale.
• A low cost flowmeter/datalogger system was developed through hardware and software modification of consumer handheld computers (PDAs) connected to reed switch flow meters. The PDA loggers are being used to analyze water demand in low-density rural developments.

• Borehole ground penetrating radar (BGPR) has shown promise as a method for monitoring water content changes with high temporal and spatial resolution to great depths. SAHRA researchers have advanced the application of BGPR to water content monitoring under highly transient conditions. This will allow for direct monitoring of water storage changes due to groundwater-surface water interaction and plant root uptake.

• SAHRA researchers are developing a new method of quantifying infiltration and recharge in deep arid vadose zones using the cosmogenic isotope $^{32}$Si. This isotope has a 140-year half-life and thus is a potentially useful tracer for processes on the 100 to 1000 year time scale, a time scale for which there are few other available tracers.

• Through SAHRA efforts in technology development, we have made fundamental improvements in the understanding of the spatial sensitivity of electrical resistance tomography (ERT). These results indicate that ERT will enable quantitative monitoring of transient hydrologic processes with immediate application to groundwater-surface water interactions in ephemeral channels and streambed sediments.

• SAHRA graduate student Karletta Chief is piloting a new approach to measure post-fire permeability of soil. The project uses lightweight, portable air permeameters to measure the density of the hydrophobic layer and the extent to which it repels water.

3. Research Partnerships and Their Contributions

• UA-HWR – Application of time domain reflectometry and BGPR to groundwater/surface water interaction (Ferré).

• Bureau of Reclamation – funded SAHRA’s development of hardware and software to use low-cost PDAs as high-resolution meter loggers for disaggregation of domestic water demand (Woodard).

• Scripps Institution of Oceanography – theoretical development of $^{32}$Si technique for quantifying infiltration and recharge in deep arid vadose zones (Lal).

4. Goals, Activities, and Outcomes/Impacts in the Current Reporting Period

These have remained essentially the same for Year 4.

2b. Research Plans

A. Basin Scale Water Balance

Our first phase of research demonstrated that the most critical “missing links” in our understanding of semi-arid region hydrologic responses are the role of vegetation in water partitioning and the ability to scale up understandings obtained at the plant scale to the basin scale. This has led to a re-evaluation of the critical knowledge gaps and a reformulation of the research questions to be:

• How do eco-hydrological interactions control the water fluxes and storage that constitute the basin scale water balance?

• How can eco-hydrological interactions, which are the outcome of processes that occur at the meter to hillslope scale, be represented at the scale of landscapes to basins?

• How can the important hydro-meteorological, physiographic, and physiological interrelationships be accurately represented in a distributed hydrologic watershed model that includes snow and vegetation processes?
This focus on eco-hydrological interactions is particularly relevant to the goal of promoting sustainable water management. Ecosystems change dramatically on timescales from days to years to decades, due to natural (e.g., fire or drought or climate change) and anthropogenic processes (e.g., logging, grazing, land-use change) that can have significant impacts on basin-wide water and solute budgets. To address these knowledge gaps, we plan to first develop a physically based understanding by investigating water-partitioning processes at the actual plot-to-hillslope scale of these processes. The next step is to identify physically based methods to parameterize these processes at the landscape to basin scale. Once this is accomplished, the conceptual models and parameters can be incorporated into numerical models that can be tested against the actual historical behavior of the integrating system outputs. Finally, these results can be integrated into a model, or series of linked models, that will incorporate human interactions and be employed to predict responses of the system under a variety of imposed stresses and management responses. Thus, our approach is to combine intensive observations at multiple scales with modeling.

The following major tasks are planned (detailed descriptions appear in the SAHRA Five Year Renewal Proposal submitted to NSF on Feb. 1, 2003):

Plot-to-hillslope scale processes
- Expand measurements of landscape features and fluxes (Small, Wilson, Bales)
- Investigate water, energy, and carbon cycling in southwestern U.S. subalpine forests (Shuttleworth, Brown, Bales)
- Model plant-to-hillslope processes across environments (Wilson, Small)

Landscape to basin scale water balances
- Investigate spatial distribution of snow cover, energy balance and melt in seasonally snow-covered catchments (Bales, Davis, Brown).
- Use remote sensing of evapotranspiration at the landscape scale (Hendrickx, Hsu, Gau)
- Investigate recharge through isotope geochemistry (Ekwurzel, Phillips, Eastoe, Hogan)

Linkages between scales
- Investigate vadose zone water recharge across climatic and vegetation gradients (Phillips)
- Investigate temporal variations of recharge across a range of scales using nonlinear dynamics (Duffy)
- Investigate dynamic vegetation transitions across upland ecosystems (Huxman, Scott, Martens, Lin, Williams, Archer, Goodrich)

Human effects on the water balance
- Quantify basin-scale municipal water demand (Brookshire, Chermak, Woodard, Krause)

In addition to these tasks, the landscape-scale water-balance analysis will also explicitly include work described in other theme areas. These include the River Systems theme, which deals with water and salt balance in the river and riparian environments. Upland (watershed) and river water balances must ultimately be linked in order to quantify the water balance at the basin scale. Another explicit linkage is with the Multi-resolution Integrated Basin-scale Modeling theme, because basin-scale models are not just the goal of this research thrust; they are also indispensable tools in developing our understanding of that balance. In addition, there is linkage to SAHRA’s Regional Hydrometeorology theme because basin water balance is ultimately related to hydrometeorological inputs.

The first goal of the individual components listed above will be to develop an understanding of the water balance over semi-arid basins, with a primary focus on the Rio Grande basin, that is physically based and founded on process studies conducted at the appropriate scale. The next goal is to identify methods (again, physically based) to parameterize these processes at the scale of the landscape unit. Once this is
accomplished, the conceptual models and parameters can be incorporated into numerical models that can be tested against the actual historical behavior of the integrating system outputs. Finally, these results can be integrated into a model, or series of linked models, that will incorporate human interactions and be employed to predict responses of the system under a variety of imposed stresses and management responses.

B. River Systems

In the first four years SAHRA river system research has significantly advanced our fundamental processes-level understanding in three areas: 1) riparian water balance, 2) nutrient and solute sources and cycling, and 3) ecosystem dynamics and value. Continuing research is aimed at understanding and evaluating the impacts of natural and anthropogenic changes to support scenario analysis. Scaling, integration with economic valuation, and the development of tools for water management will be the focus for river systems research. In addition, fundamental process-level research is required, particularly for riparian biogeochemistry and to understand the causes and feedbacks of dynamic vegetation transitions.

Based on a reevaluation of the critical knowledge gaps, the current research questions to be investigated are:

• How will vegetation change affect the riparian water balance and nutrient dynamics?
• How do we scale our process-level understanding of nutrient sources and sinks to the length of the river?
• What are the management options to decrease salinity?
• What is the value of a native or restored riparian ecosystem in terms of ecosystem services and market and non-market values?

The following major tasks are planned (detailed descriptions appear in the SAHRA Five Year Renewal Proposal submitted to NSF on Feb. 1, 2003):

Riparian Water-Balance
• Quantify components of riparian water use (Goodrich, Scott, Williams, Huxman, Stromberg)

Nutrient and Solute Sources and Cycling
• Investigate spatio-temporal characterization of riparian biogeochemical processes (Conklin, Grimm, Martens, Brooks)
• Investigate scaling of riparian biogeochemical processes (Brooks, Conklin, van Genuchten, Schaap, Bales, Grimm, Maddock)
• Investigate management strategies to control salinity (Hogan, Phillips, Hendrickx)

Ecosystem Dynamics and Value
• Investigate dynamic vegetation transitions in riparian ecosystems (Huxman, Scott, Martens, Lin, Williams, Archer, Goodrich, Stromberg, Grimm, Conklin, Brooks)
• Investigate the non-market value of riparian ecosystems including impacts on recreation such as birding, and of proximity to riparian areas on market values of homes (Brookshire, Stewart, Stromberg, Goodrich, Brand, Maddock)
• Investigate the market value of riparian ecosystems in terms of the impacts of proximity and quality on home values (Colby, Osgood, Stromberg)
C. Regional Scale Hydrometeorology

The first phase of our research has emphasized: a) the development of means to estimate the quantity and spatial distribution of rainfall using satellite data, radar, and ground measurements; b) development of tools for estimating spatially distributed snow accumulation and snow melt in seasonally snow-covered catchments; and c) adaptation of a regional climate modeling system to synoptic and climatological characteristics of the southwestern US.

New partnerships are being formed with University of California, Merced and Irvine campuses, as described elsewhere in this document. Research that will be performed under these subcontracts is primarily focused in this theme area.

The following major tasks are planned (detailed descriptions appear in the SAHRA Five Year Renewal Proposal submitted to NSF on Feb. 1, 2003): These activities will continue to benefit from substantial leveraging with other funded projects:

Precipitation
• Improve spatiotemporal resolution of precipitation estimates using remote sensing and climate modeling (Hsu, Gao, Imam, Sorooshian, Gupta)

Climate
• Improve modeling of the southwestern U.S. regional climate (Roads, Gao, Hsu)

Snow Properties
• Estimate regional snow properties (Bales, Miller, Fassnacht, Hsu)

Evapotranspiration and Soil Moisture
• Study the regional feedbacks between soil-moisture, precipitation and evapotranspiration (Sorooshian, Hsu, Gao, Hendrickx, Roads, Gupta)

D. Multi-resolution Integrated Basin-scale Modeling

This first phase of work has emphasized detailed investigation of the modeling problem and design of the coordinated overall approach to be followed. It is now understood that major gaps currently limit our ability to integrate feedbacks between physical and behavioral models (including proper representation of vegetation dynamics in semi-arid conditions), which are important to predict and understand river basin changes in energy and water balances across a river basin. Algorithms and tests to compare the three model resolutions are needed to assist both users and scientists in understanding the value of the different resolutions in solving their problems. Based on a reevaluation of the critical knowledge gaps the following major tasks are planned (detailed descriptions appear in the SAHRA Five Year Renewal Proposal submitted to NSF on Feb. 1, 2003):

Model development:
• Improve operational forecasting in the upper Rio Grande (McConnell, Boyle, Leavesley, Markstrom, Bales, Gao, Sorooshian, Gupta)
• Couple behavioral and physical models (Nijssen, Brookshire, Chermak, Stewart, Bastidas, Gupta, Tidwell, Woodard, Wagener)
• Perform scenario evaluation (Springer, Nijssen, Bales, Wagener, Gupta, Bastidas, Gao, Winter, Brookshire, Chermak, Sorooshian, Duffy, Costigan, Woodard, Roads)
• Enhance the medium-resolution model (Nijssen, Bastidas, Gupta, Sorooshian)
• Enhance the fine-resolution model (Winter, Wilson, Phillips, Springer, Costigan, Fasel, Mnewski, Zyvoloski)
• Develop coarse resolution/dynamic simulation modeling for decision support (Tidwell, Woodard, Lansey, Valdés, Yeh, Gupta, Brookshire, Chermak, Goodrich, Duffy, Wagener, Hogan, Valdés)

Other Activities and Products Planned:
• A network and web accessible database to support shared development of the medium scale model (Nijssen, Bastidas, Gupta)
• Expansion of the Web portal for dissemination and tracking of computer software, users guides and relevant data sets (Wagener & Gupta)
• A textbook on the theory and practice of model identification and parameter estimation to be developed during 2004 (Gupta, Wagener, Sorooshian & Wheater)

E. International Collaborations

Based on an evaluation of the collaborations and achievable activities that are likely to be most productive in filling critical knowledge gaps, the following major tasks are planned (detailed descriptions appear in the SAHRA Five Year Renewal Proposal submitted to NSF on Feb. 1, 2003):
• Promote bi-national basin coordination (Varady, Browning-Aiken, Romero, Liverman, Goodrich, Woodard, Shuttleworth, Sorooshian, Bales, Brookshire, Chermak).
  a) Survey rural and domestic water users and water managers about current water management practices and economic valuation of water use in the Mexican portion of the San Pedro and assess the need for additional climate and water information.
  b) Promote further collaboration between Mexican and SAHRA scientists regarding water policy and hydrologic research. In particular, develop a community forum and conduct four to five bi-national dialogues (workshops) on water and climate issues with San Pedro basin watershed groups (Upper San Pedro Partnership [USPP] and ARASA).
  c) Investigate Mexican water policy changes and their potential impacts on bi-national basin management and on supply and demand in the Mexican portion of the San Pedro Basin with a policy paper as a product.
• Characterize water demand for Mexico (Brookshire, Valdés, Varady, Stewart, Browning-Aiken, Aparicio, Hidalgo, Velasco, Chermak).
• Develop a drought management model for the Conchos (Valdés, Aparicio, Stewart, Hidalgo, Velasco, Chermak).
• Investigate recharge, groundwater flowpaths and salinization of the Hueco Bolson aquifer (Hibbs, Eastoe, Granados, Ekwurzel, Hogan).
• Develop an evolving basin assessment tool for water management (Goodrich, Woodard, Yeh, Lansey, Maddock, Gupta, Bastidas, Stromberg, Dixon, Huxman, Archer, Schaap, Brookshire, Conklin, Shuttleworth, Chermak, Sorooshian).
• Pursue relevant education and knowledge transfer activities (Woodard, Valdés, Shuttleworth, Sorooshian).
• Create Rio Grande/Rio Bravo cross-border shared data repositories on mirrored servers at Sandia National Laboratory, IMTA, and SAHRA (Passel, Valdes)

Note that the international efforts crosscut the first four theme areas described previously. Additional international programs outside this area will also be developed with the primary aim of education and knowledge transfer to developing countries; these are addressed in section on Knowledge Transfer Plans.
Workshops and Meetings

- SAHRA will host the 2nd International Symposium on Transboundary Waters Management in Tucson in 2004. (Valdes, Gupta, Woodard, others)
- SUDMED is a research project conducted by CESBIO (Centre d'Etudes Spatiales de la Biosphère in Toulouse, France), in cooperation with numerous Moroccan institutions, on the hydrology and ecology of the Tensift riparian area of the Haouz region of Morocco. In February 2004, representatives of SAHRA (Goodrich, Shuttleworth, Sorooshian, Woodard) will meet in Morocco with SUDMED and CESBIO representatives to discuss opportunities for mutually beneficial collaborative activity.

Other Activities and Products Planned (including research monographs):

- SAHRA will take leadership of the International Association of Hydrological Science’s (IAHS’s) International Commission on the Coupled Land Atmosphere System (ICCLAS) (Gupta, Wagener, Bastidas)
- SAHRA will establish coordination with the UNESCO program on Hydrology for Environment, Life and Policy (HELP) (Shuttleworth, Gupta, Woodard).
- SAHRA will coordinate and host an international meeting on semi-arid hydrology in 2005 to propagate SAHRA science internationally (Executive Committee)

F. Data and Information Systems

Archiving the large amounts of data produced by SAHRA research and making that data available in appropriate forms requires an investment well beyond that conceived and budgeted in the original proposal. However, SAHRA researchers have indicated clearly that it is imperative to develop an online data archive to serve this need. The same system may also serve as a clearinghouse for the sharing of software tools, algorithms, tutorials and other knowledge relevant to SAHRA participants. We also plan to seek leveraged funding to develop a Web interface that will provide one-stop access for others interested in SAHRA scientific products and knowledge transfer activities.

During the first four years, system design and resource needs were identified so that implementation can begin in 2003. Prototype tools for a Web interface have been developed using leveraged funding (http://hydis.hwr.arizona.edu/). Further, a prototype Web portal for serving software and algorithms to the scientific community was developed (http://www.sahra.arizona.edu/software).

Based on a trade-off between the needs of SAHRA researchers and budgetary collaborations, the following major tasks are planned (detailed descriptions appear in the SAHRA Five Year Renewal Proposal submitted to NSF on Feb. 1, 2003):

- Develop a data archive. (Gupta, Shuttleworth, Carpenter)
- Continue development of a database and web site for visualization and knowledge exchange. (Imam, Woodard)
- Develop a 3-D hydrostratigraphic model for the Rio Grande basin, and submit an external proposal submitted for full model development. (Duffy, Springer)

G. Technology and Equipment

Although advances in remote sensing technologies have revolutionized our understanding of water exchange at the basin scale, similar advances are needed at scales relevant to the description of physical
and chemical processes that control the interaction of surface and subsurface water bodies or the movement of water through deep vadose zones. Ongoing research within SAHRA has demonstrated the need for methods that will provide measurements of: water pressure in the vadose zone, water flux throughout the subsurface, direction and magnitude of water flux between the surface and the subsurface, and chemical transport into and out of gravel bars. Based on these needs, the following major tasks are planned (detailed descriptions appear in the SAHRA Five Year Renewal Proposal submitted to NSF on Feb. 1, 2003):

• Continue integration, testing and development of automated hydrologic measurement and data collection system at the river reach scale. (Conklin, Bales)
• Develop methods for determining infiltration in rocky soils. (Ferré)
• Deploy a micro-hydro-meteorological network in the upper Rio Grande using leveraged funding. (Small, Springer, Shuttleworth, Bales, Brown, Petti)
• Acquire and install scintillometer equipment via leveraged funding. (Hendrickx, Petti)
• Develop automated, real-time optimization of infiltration monitoring. (Ferre, Warrick)
• Develop and refine methods for disaggregating water demand, including economic experiments and meter loggers. (Woodard, Stewart)
• Investigate applications of ERT to recharge and water flow in riparian areas. (Ferre, Goodrich, Maddock)
• Continue modification and enhancement of towers and gauges at the micrometeorological towers on Mt. Bigelow. (Brown, Petti)
• Develop new instruments to measure the impact of wildfire on basic hydrologic properties, including infiltration and runoff. (Nijssen, Chief)
• Extend the use of low-cost flowmeter/data logger systems to sampling of representative production wells in the upper San Pedro Basin. (Woodard)
III. EDUCATION

1a. Overall Educational Objectives

The Center’s overall educational and knowledge transfer objectives go hand-in-hand and have evolved gradually over the years. SAHRA aims to 1) promote overall hydrologic literacy, from K-12 to adult learners, and from decision makers to the general public; 2) reach wider audiences who represent diverse populations and a broader geographic base; 3) develop relationships with stakeholders and communicate research findings; and 4) integrate research, education, and knowledge transfer.

1b. Performance and Management Indicators

SAHRA’s education programs can be judged to be successful by their persistence and growth in the numbers of individuals served and quality of product. Successful programs will be offered at multiple locations and will be shared with diverse audiences through publications and presentations. Successful programs will garner positive participant reviews. The most successful activities are likely to attract outside financial support.

One goal is for teachers to turn to SAHRA’s web page for the latest water education activities and workshop information. Likewise, for knowledge transfer, one goal is for the public to accept SAHRA personnel and scientific findings as preferred resources in future water issue debates. Both of these goals are difficult to measure, although web traffic, meeting participation and participant feedback provide positive indications of success and direction for improved implementation.

Several uniform assessment tools are being developed so that we might better track and serve our various constituencies. These constituencies include program participants such as teachers and potential recipients of participant learning such as students. One set of tools will assess changes in hydrologic literacy while another will be fairly open-ended and designed to assess water-related attitudes.

Specific indicators include:

- List / Number of participants (teachers, students) in education programs and potential recipients (students, families) of participant learning [increase #]
- List / Description of impacts of education programs on participant understanding and activity [at least 70% positive impact]
- Summary of feedback on implementation from education program participants
- List of education collaborations [increase #]
- List of publications on education programs [increase #]
- List of presentations on education programs [increase #]
- List of education products developed [increase use]
- List of SAHRA research areas/projects integrated in education programs [maintain]
- List of grants, other forms of monetary and in-kind support of KT activities

1c. Problems During the Reporting Period

Interaction between SAHRA students from geographically dispersed institutions. The nature of SAHRA as a multi-institutional, multidisciplinary Center somewhat inhibits formal interactions between participating students, faculty and stakeholders. Bringing constituent participants together in meaningful interactions is a challenge. We have not had an annual meeting, nor the opportunity for
many spontaneous exchanges between students, researchers and stakeholders for over a year due to our focus on the renewal proposal and site visit. Our next annual meeting is in October 2003 and we are looking forward to a reunion of all personnel. We have scheduled a student-mediated session at the meeting to address how we can better facilitate interaction among SAHRA students.

Financial limitations. Although considerable interest has been expressed in our summer teacher workshops from outside of Tucson, we have limited infrastructure and funds for teacher stipends. We hope to strengthen our collaborations with regional partners so that expansion of our programs can be begun next summer.

Student recruitment. Graduate student recruitment was disrupted this year at UA due to the uncertainty in the future of several important SAHRA scientists. These uncertainties will be much reduced in the future because the status of the UCI and UCM partnerships have been clarified.

2a. Internal Educational Activities

<table>
<thead>
<tr>
<th>Activity Name</th>
<th><strong>Graduate Seminar (HWR696L)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Bales &amp; Washburne</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>SAHRA graduate students</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>10 UA students/yr; Center-focused curriculum</td>
</tr>
</tbody>
</table>

This one-unit seminar class is taught every other spring to help assimilate new graduate students into the interdisciplinary focus of SAHRA. Postdoctoral research associates contribute by reviewing the innovative science and relevant water management issues within their areas of expertise. Participating students learn more about how their project integrates with the Center by making presentations to the rest of the class covering a topic of particular interest. SAHRA scientists lead discussions of fundamental research, management and policy issues that the students will face during their tenure with the Center.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th><strong>Hot Topics in Surface Water Hydrology (HWR696F)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Shuttleworth</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>SAHRA graduate students</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>10 UA students/yr; Center-focused curriculum</td>
</tr>
</tbody>
</table>

This 1- to 3-unit seminar class (depending on student-selected level of participation) is taught every other spring to introduce SAHRA graduate students to the latest interdisciplinary science and policy issues related to semi-arid hydrology. The class is largely built around student presentations on topics selected in conjunction with the instructor. Recent topics have included regional water balances using remote sensing, riparian zone biogeochemistry, and the economics of desalination.
<table>
<thead>
<tr>
<th>Activity Name</th>
<th>Undergraduate Water Issues course (HWR203)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Ekwurzel, Washburne</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>Non-science undergraduates</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>100 UA students/yr; general education program with some Center content</td>
</tr>
</tbody>
</table>

This is a mid-sized (50 student) Tier 2 general education (required natural science) course at the University of Arizona that is offered twice a year. The class is mostly non-science majors. The class goals are to improve the students’ hydrologic and scientific literacy, instill life-long learning and job skills and prepare the students for dealing with as yet undefined water issues in their future. The class is relatively unstructured, from the students’ perspective, although the course is broken into two-week modules which concentrate on issues related to the major themes of: water quantity, watersheds, water quality, water law, ground water, water conflicts and water sustainability. Class reading is drawn from industry and government fact-sheets and reflective essays about current regional water issues. A variety of activities are integrated into the 75 minute class period. Most classes begin with a focus image think-pair-share activity, which is used to introduce new concepts and terminology. A variety of in-class activities engage the students in data collection, analysis and group simulations. The students’ math skills are stimulated by the basic calculations and conversions required within these activities. In many cases, SAHRA science plans can be used to explain the historical development or current needs of various water management applications. We have just begun to encourage the further development of the graduate TA’s teaching skills by sharing the lecture duties for this lively class.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>SAHRA Campus Seminar Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Woodard, Washburne</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>University water research community</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>approximately 8 seminars/yr x 30 in audience; Impacts both internal and external communities</td>
</tr>
</tbody>
</table>

No professional or academic education experience is complete without a forum for the intellectual exchange and debate about current developments and controversies in the field. This need is particularly acute for a large interdisciplinary group such as our own. In conjunction with the Department of Hydrology and Water Resources (HWR) and the Assistant Director for Knowledge Transfer, we are promoting the collegial exchange of professional views in a regular seminar series. Many of these lectures will be video taped for distribution within our Center. This year, we will receive supplemental funding from the Army Corps of Engineers to enhance the professional development aspect of these seminars by bringing in outside guest lecturers to cover a wider range of topics than is possible from local resources.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>MS in Water Resource Engineering (MSEng) Professional Degree Program</th>
</tr>
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<tbody>
<tr>
<td>Led by</td>
<td>Woodard</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>Mid-career water professionals focused initially on Army Corps of Engineers</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>4 beginning in Fall 2003.</td>
</tr>
</tbody>
</table>
This degree program was initially set up in collaboration with all three Arizona state universities (UA, ASU, NAU) to facilitate mid-career academic and professional advancement. An academic program was forged from offerings (particularly distance learning courses) from the three universities and an intensive one-semester on-campus stay to pick up key specialty courses and develop rapport with a faculty advisor. SAHRA finds this opportunity of particular interest because of the interdisciplinary nature of the academic program we have designed for these students, which includes classes in natural resource economics, water law, and environmental ethics. In place of a traditional thesis, a professional project and report related to the student’s work situation will serve as the capstone project. The Army Corps of Engineers is sending four students to this program in Fall 2003. We also have individual students from the Forest Service and an international environmental consulting firm. ACE expects to increase the numbers in Fall 2004 to around 15 students.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>Spring Snow Field Camp (HWR 696F)</th>
</tr>
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<tbody>
<tr>
<td>Led by</td>
<td>Brooks</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>SAHRA graduate students</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>10 students/yr; New course with Center-focused content; 1 to 2 RET positions</td>
</tr>
</tbody>
</table>

This field course covers the basics of snow formation in the atmosphere, distribution on the land surface, and metamorphosis through the season. The basics of avalanche dynamics, water supply issues, and streamflow generation are also covered. The course has several organizational meetings but then meets for the week of Spring Break in the San Juan Mountains of Colorado where snow is studied firsthand. Finally, the course participants contribute to a SAHRA-related snow survey of the upper Rio Grande basin. This summer SAHRA supported a teacher research experience as part of this activity.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>Environmental Hydrology (FOR/GGG 340)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Aregai Tecle (NAU)</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>undergraduate environmental studies majors</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>10 students/yr; new course with some Center content</td>
</tr>
</tbody>
</table>

Aregai Tecle developed an undergraduate emphasis area in rural water and watershed management at Northern Arizona University. The course and the emphasis area are meant to promote the objectives of SAHRA and meet student needs. Environmental Hydrology was developed as a forestry, geography and honors course. The course consists of a 3-credit hour lecture and 1 credit-hour laboratory/field experience. The course was taught in Fall 2002 and 2003 as a web-enhanced course.

2b. Professional Development Activities

Graduate Research Assistantships / Community Service

SAHRA funds over 40 graduate RAs and TAs to provide the research support and scientific innovation necessary for such a large and diverse Center. Because their specific activities and accomplishments are chronicled elsewhere, the focus here is on some of the unique opportunities this group enjoys. To promote interdisciplinary understanding and friendships, most SAHRA graduate
students are seated in two large office spaces. Most students are required to take one core course that covers the philosophy and an overview of the goals and objectives of the Center (HWR696), co-taught by the Deputy Director. Graduate students are further encouraged to take part in some extracurricular community service project or something that extends their learning outside of class. Examples of some current opportunities are helping to mentor undergraduate interns, staffing the SAHRA public display at professional or professional development meetings, becoming involved with inquiry and research development programs in surrounding school districts, and helping to support special water-related activities (such as Sabino Canyon Days) with cooperating schools. This program involves around 40 RAs and TAs per year and provides around 100 hours of community service and experience with external mentoring and leadership activities.

**Undergraduate Internship Program**

In order to stimulate creative ideas and provide support for non-expert students to explore a wide range of projects related to water sustainability in semi-arid regions, SAHRA provides funding to around eight undergraduates per year who develop a project proposal with a non-SAHRA faculty member. These proposals are fairly simple and of limited duration, but do provide the student with a realistic proposal process experience. Several creative projects are currently being funded including one that is promoting campus water harvesting and one that is exploring ways to use industrial reclaimed water for revegetation projects around maquiladoras in Nogales, Son. Mexico.

**Professional Development Activities with CEA-CREST (Centers for Research Excellence in Science and Technology)**

We have an NSF Glue Grant with the CEA Program at California State University, Los Angeles (described further in Section V), and are exploring other collaborations with the new RESACCA at TAMU-Kingsville. We have implemented some research exchanges with CEA and are interested in recruiting Ph.D. candidates at both locations. The number of anticipated participants is low because we do not want to undercut the CREST Centers’ master’s degree programs.

Channa Gilan of CEA-CREST and Jason Dadakis of SAHRA completed much of their fieldwork on their projects. Both graduate students are writing thesis manuscripts. SAHRA invited CEA-CREST hydrology faculty and students to a field conference in Arizona to study arid basins of the southern Arizona region. Three CEA-CREST students and one CEA-CREST faculty member participated in the field conference. Dr. Hibbs organized a workshop on the water resources of the Hueco Bolson and Rio Grande aquifers that was held in El Paso in February 2003. Participants included faculty, students, and technical personnel from CEA-CREST, SAHRA, Universidad Autónoma de Ciudad Juarez, University of Texas at El Paso, New Mexico State University, and City of El Paso Water Utilities. The workshop will be held again next year. SAHRA and CEA-CREST scientists and students will participate in a symposium on transboundary groundwater issues at GSA’s annual meeting in November in Seattle.

**Sandia National Laboratory Fellowships**

UA graduate student Jesse Roach was the first recipient of a Sandia Fellowship. He interned ½ time at Sandia for 1 semester during 2002/03 while taking classes at University of New Mexico. Sandia will support two new UA SAHRA fellows in 2003/04.
2c. External Educational Activities

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>Integrating Inquiry and Issues in Water Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Madden &amp; Uyeda (Local HS teachers/trainers)</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>High School science teachers in the SW</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>10 teachers/yr. (600 K-12 students) in AZ and NM in 2003</td>
</tr>
</tbody>
</table>

This two-week workshop for high school teachers is aimed not only at increasing their hydrologic literacy, but also to give them much needed experience engaging in inquiry themselves, developing authentic research skills and analyzing complex (interdisciplinary) information. We were able to hold small workshops with the help of two master teachers and many hours of preparation. The regular class sequence is to review some basic concepts, have them read about several on-going issues or conflicts, introduce the Seek/Solve/Create/Share methodology in the context of a water quality problem and finally to work through a week-long problem-based learning (PBL) module constructed around a regional water management plan developed by a small group. SAHRA science and policy work is being integrated into this workshop. We hope to use SAHRA’s distributed network of researchers to support and stay in contact with these teachers who are implementing what they have learned. This has been a successful joint effort between the SAHRA core office and the UA College of Education.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>Student-centric Program for Learning About Semi-arid Hydrology (SPLASH)</th>
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</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Hancock, Woodard &amp; Washburne</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>High school teachers interested in providing integrative science alternatives</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>10 teachers (600 K-12 students), 1 undergraduate student, 1 graduate student in 2003</td>
</tr>
</tbody>
</table>

SAHRA’s Student-centered Program for Learning About Semi-arid Hydrology (SPLASH) is a collaborative effort among high school science and social science teachers, scientists, and science educators to create and implement a regionally focused water curriculum. The project has a goal of creating and implementing a curriculum (in Arizona and New Mexico) that emphasizes hydrologic literacy in the context of the semi-arid southwest. SPLASH seeks to simultaneously advance understanding of regional (semi-arid) hydrology and general water literacy (studied within the context of the semi-arid U.S.). Pursuing regional hydrologic literacy contextualizes student learning and facilitates integration across sciences and across disciplines including social sciences, mathematics, language arts, and the arts. The ultimate goal of SPLASH is to advance the hydrologic literacy of all students.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>Research Experiences for Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Washburne</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>K12 science teachers</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>2 teachers in 2003</td>
</tr>
</tbody>
</table>
Like undergraduates, teachers benefit from a full immersion research experience. Such an experience provides critical career, focused content and a very basic understanding of how science is done that teachers can, in turn, share with their students. Fieldwork in the hydrologic sciences is often constrained by the whim of seasonal weather patterns so it is difficult to plan teacher-scientist interactions strictly on the calendar. We supported teacher participation in UA’s snow hydrology and surface water field camps. This last activity requires close coordination with the Department of Hydrology’s field camp coordinator, Dennis Scheall.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>Joint Water Education Activities – Maricopa Office</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Flowers, Justice</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>K12 science students in SAHRA’s region of interest</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>Teachers in at least 30 schools</td>
</tr>
</tbody>
</table>

In collaboration with three other water centers (see also Joint Water Education Activities – Water Center Collaborations in Section IV), SAHRA leverages funding for a water education specialist in Maricopa County, AZ from Arizona’s Prop. 301 funding and provides additional infrastructure support to the nationally recognized Project WET (Water education for Teachers) program. This collaboration provides the infrastructure needed for SAHRA to expand its K-12 education offerings in the largest population center in Arizona.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>SAHRA/GLOBE Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Washburne, Ferrè, &amp; Nijssen</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>K12 science students in SAHRA’s region</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>20 schools</td>
</tr>
</tbody>
</table>

This major initiative ties together several previous strands of our education effort. The goal of the collaboration is to leverage the resources and abilities of both partners to more effectively sample environmental phenomena at wide space and time scales in SAHRA’s areas of interest. Essentially, this partnership requires significant buy-in and participation at all levels throughout SAHRA as well as in the schools located in our areas of interest. Global Learning and Observations to Benefit the Environment (GLOBE) students are tasked with regular and special sample collection while SAHRA scientists and students will work with the schools to show how the student measurements can be integrated with their scientific datasets for a more complete physical picture of the water balance and water quality. The initial focus areas are the Rio Grande, San Pedro and Four Corners areas. A salinity and water solute sampling program is being set up this Fall along the Rio Grande. Native American schools throughout the Four Corners region, where we have existing teacher training and support efforts, will be tasked to evaluate their regional hydroclimatology within the constraints of GLOBE and SAHRA.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>Environmental Education Outreach &amp; Institute for Tribal Environmental Professionals (EEOP/ITEP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Mansel Nelson</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>Native American K-12 Teachers</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>8 jointly-funded workshops</td>
</tr>
</tbody>
</table>
SAHRA provides travel and participant support matching funds to two pre-existing programs based at NAU to develop, demonstrate and support K-12 water resources and water quality education throughout the Four Corners region. Eight workshops and many on-site demonstrations were given to K-12 teachers and students. The purpose of this partnership is to train teachers who will incorporate the teaching of water and water quality in their science curriculum, and to stimulate students to learn about water and water quality problems that affect their tribal areas. Additionally, we believe this early exposure to water issues and science is crucial to recruiting more college-bound students into our degree program. A brief summary of workshops and knowledge transfer supported, in part by SAHRA, over the last year are:

1. *Tribal Schools Ecological Monitoring Program* (TSEMP) workshop involving a three-day long education program organized and given in cooperation with The Nature Conservancy (TNC) and Navajo Nation Environmental Protection Agency (NNEPA).

2. *Summer Scholars program* (summer 2003). This program was organized in collaboration with four school districts and it provided Middle School students with an emphasis in environmental science, mathematics, and technology in a one-week on-campus, residential experience. The Summer Scholars program involved five one-week sessions and reached 100 students.

3. *School visits* to provide classroom presentations and teacher workshops in tribal schools in throughout Arizona. During the visits, the EEOP staff gave presentations on solid waste and water contamination issues. The EEOP staff also used ground water models to teach students and educators about the importance of proper handling household hazardous wastes in order to keep contaminants out of groundwater.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>Monsoon Madness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Hancock, Colodner</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>Elementary and middle school students</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>45 students in 2003</td>
</tr>
</tbody>
</table>

Three 1-week summer camps for middle school students were offered jointly with Flandrau Science Center. The camp content focused on the hydroclimatolgy of the Tucson Basin, with an emphasis on the summer monsoon. Students broadened their experiences by visiting local scientists, conducting weather experiments, and monitoring the weather. Scholarships were provided to low-income, minority students.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>Data Collection Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Mills, Washburne</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>K-12 schools in Rio Grande Area</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>6 teachers (180 K-12 students) in 2002/03</td>
</tr>
</tbody>
</table>

Schools participate in the collection of water quality data on the Rio Grande. All schools collect pH, electrical conductivity, and temperature data. Some schools collect data concerning the levels of nitrates, alkalinity, dissolved oxygen, and turbidity as well. This data is integrated into ongoing SAHRA research on the salinity of the Rio Grande and provides a much better temporal sampling than we could maintain without the local networks. The project has been active since Fall 2001.
<table>
<thead>
<tr>
<th>Activity Name</th>
<th>High School Intern Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Washburne, Woodard, Hancock</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>High school students headed to UA to pursue sci/eng careers</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>2 high school students in 2003</td>
</tr>
</tbody>
</table>

We select local high school students to help support various research efforts using leveraged funds. The emphasis is on summer fieldwork. We work with science teachers in Tucson high schools that have significant underrepresented populations to identify prospective students for the program. Projects are related to SAHRA research and have included erecting meteorological towers, tree surveys, cold room ice core analysis, analysis of impacts of extreme flow events on stream beds, tree torture experiment, impacts of fire on runoff, programming PDAs, and field testing an innovative household water data logging system. Most interns have enrolled at the UA upon high school graduation and are majoring in science or engineering disciplines. During the summer of 2003, we supported two female minority interns.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>Prop 301 WEDSP: Integrated Water Education Implementation in the Classroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Hancock, Morrill, Elfring</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>K-12 teachers</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>Anticipated impact in 2003/04 of 60 teachers (900 K-12 students), 2 graduate students</td>
</tr>
</tbody>
</table>

This project is designed 1) to facilitate classroom implementation of water education programs aligned with state standards through human and material resources for trained teachers and 2) to facilitate integration of these programs to provide more meaningful learning experiences for teachers and students. This will be accomplished by: developing and providing material support in the form of classroom resource kits for teachers; training pre-service and inservice teachers to use the kits and integrate them into their existing curriculum; and providing human support by training graduate students as water education specialists, who will work regularly with teachers in their classrooms.

<table>
<thead>
<tr>
<th>Activity Name</th>
<th>ECOSTART</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Browning-Aiken</td>
</tr>
<tr>
<td>Intended Audience</td>
<td>K-12 teachers</td>
</tr>
<tr>
<td>Approx Number of Attendees</td>
<td>see below</td>
</tr>
</tbody>
</table>

In collaboration with the Udall Center, we have supported this cross-border environmental education and capacity building effort. Most funding for this is leveraged from other sources. Both GLOBE and Project WET materials are being made available to border (mostly Mexican) schools. Approximately six other organizations are involved in this collaboration, including Hands Across the Border and the Arizona-Sonora Desert Museum. For the present reporting period, we served as consultants for two classes in each of two schools (one in Mexico, one in the U.S.). As of August 2003 we have new funding from EPA for ECOSTART for the academic year, with 2 schools, 6 classes and 6 teachers.
2d. Integration of Research and Education

Education and research are naturally linked with a continuum of student-scientist interactions and independent research thinking occurring throughout the undergraduate-graduate-post doctoral experience. This, however, is business as usual. SAHRA fully expects its students and researchers to work together on the scientific challenges we have set for ourselves, but the expectation does not end there. We expect that both students and scientists will participate in the many extended educational opportunities we provide for them. In fact, the full suite of activities listed above is not possible without contributions from all levels of SAHRA participants.

One important Center product is a new, interdisciplinary curriculum at the university level. Such products are only possible with the participation of key frontier researchers, like Paul Brook’s spring snow field course and the tempered but different perspectives of Roger Bales, Jim Washburne, and Jim Shuttleworth in our SAHRA graduate seminars.

Faculty participation in education activities outside of the realm of normal academic life is also important. We are pleased that two new departmental and Center faculty, Ty Ferré and Bart Niessen, have taken the time to participate as co-investigators with Jim Washburne in the K-12 GLOBE program and to become involved in an inquiry mentoring project with the local school district, TUSD.

SAHRA education staff have coordinated or participated with many school programs over the last year, but these programs would not be viable without the wide and gracious support of departmental students. These programs place our students in basic supervisory positions that allow them to safely experience the joys and rewards of K12 science education without a total commitment. Among the programs that have benefited from the participation of Center personnel are judging projects in the Southern Arizona Science and Engineering Fair, activity leaders for Daughters on Campus Day, field guides for the Esperero Canyon Middle School’s Sabino Canyon Experience, and supervisors for the water quality section of the local Science Olympiad.

We are particularly proud of two students’ extraordinary efforts to integrate research with education. Kyle Blasch, a non-SAHRA student funded through a USGS internship, came to SAHRA last September with a proposal to greatly expand the hydrologic component of their visitor center display through a unique collaboration between SAHRA, the US Forest Service, the US Geological Survey and the area’s docent naturalists. Through his catalytic efforts, the project was completed in October 2002. Karletta Chief, a SAHRA Ph.D. candidate and member of the Navajo Nation, has worked closely with SAHRA education staff to represent the Center at several environmental education conferences for Native American educators and to help us translate our hydrologic literacy message so it is more culturally appropriate. She also mentored two Native American high school students this summer.

2e. Plans for Next Reporting Period

Our primary goal is to refine and broaden or extend the delivery of these programs with special consideration of three key issues: high quality professional development for teachers, increasing attention to water science in high school curricula, and diversity.

An important part of SAHRA’s work will continue to be with K-12 teachers. Any effort to provide professional development for teachers must be guided by high quality models, which emphasize projects that are long-term, collaborative, and linked to practice. Professional development for science
teachers must also include the nature of science, knowledge of content, and professional social interaction. Beyond the professional development experience, we have found that providing teachers with support for implementation is critical. For these reasons SAHRA’s continued interaction with teachers will incorporate more of these principles with emphasis on maintaining supportive relationships with teachers.

As we have pursued educational projects during SAHRA’s early years, the critical need for inclusion of hydrologic literacy and water science in high school courses has become apparent. Achieving this is especially difficult because of the current pressures on schools from state and national accountability efforts. In the southwestern United States, these efforts involve high-stakes tests that currently emphasize mathematics and language skills to the exclusion of earth and social sciences. Another challenge to the inclusion of water issues in high schools is the traditional curriculum structure, which emphasizes specific content areas such as physics or chemistry with little interdisciplinary work. This situation subsequently makes it difficult to recruit high school students into undergraduate hydrologic sciences programs. Awareness of these challenges will continue to guide efforts to have a greater impact on high school curricula and students.

Another educational challenge SAHRA faces is increasing the diversity of participants at all levels, especially in undergraduate and graduate enrollment. We are in the process of critically reviewing our impact in diversity against disciplinary and industry trends and best practices. The outcome of this review will be a comprehensive self-assessment and set of diversity challenges to all levels of our organization. So far, more resources have been allocated to developing career pathways for area minorities (Hispanics and Native Americans) and to increasing the number of women in our graduate programs.

**Programs for Graduate Students** – We plan to expand our offerings for graduate students to include a course that emphasizes the complexity of the San Pedro basin. That complexity moves beyond basic hydrology to include natural, social, economic, and institutional considerations. The course will produce a more interdisciplinary understanding of the San Pedro basin that will ideally be applied to research in the San Pedro and similar semi-arid basins. Approximately 10 graduate students are expected to take this course.

**Programs for Undergraduate Students** – Arizona Water Issues (HWR203), a general education course for non-science majors, will be improved based on the findings of ongoing evaluation. We are expanding our collaboration with NAU and CREST centers at California State University, L.A. (CEA) and at Texas A&M in Kingsville (RESACCA) to attract more undergraduate minority students to SAHRA. Our REU program will be modified to actively recruit minority students and students from local community colleges. Based on early findings of research on our REU program, we will institute monthly colloquia meetings for students and mentors so that they may more clearly articulate hydrologic content and science research culture. We anticipate continuing to support 15 REU students annually.

**Programs for K-12 Teachers** – Most of our teacher workshops have been in a development mode but are now ready for wider distribution and greater enrollments. This will be achieved through better advertising, presentations at teacher conferences, and a greater emphasis on how inquiry and hydrologic science can be integrated into existing physics, chemistry, biology, and environmental science and mathematics courses. Our goal is to achieve annual attendance of 15 teachers per workshop, reaching a minimum of 450 students. A new SPLASH workshop will reach 5 to 10 teachers and 150 to 300 students annually. Considering the guidelines for teacher professional development, we will be adding follow-up components to all teacher workshops with stipend money attached to monthly meetings during the school year following workshop participation. In future
years, we plan to expand our offerings by making the Inquiry and Waters Issues and SPLASH workshops available throughout Arizona and in parts of New Mexico and by developing advanced versions of the workshops for previous participants. To support this effort we will recruit education personnel support in New Mexico. SAHRA researchers at UNM are already engaged in professional development activities in collaboration with the Albuquerque Public Schools. We will expand our new teacher research program to include five preservice and early service science teachers annually. We also plan to hire a preservice or early-service teacher to run the summer camp for middle school students described below.

**Programs for High School Students** – As mentioned, we face challenges in making water science part of high school curricula. In order to meet this challenge, we will facilitate the inclusion of water in high school science curricula collaboratively with high school teachers by making presentations at teacher meetings, networking with teachers, modifying our programs to meet the needs identified by teachers, advertising more widely, and updating our education web site. Members of SAHRA’s educational team are building networks to become more actively involved in district and state level decision-making about science education. Our plans to offer Research Experiences for Teachers (RET) for preservice and early service teachers is designed to work around the traditional science structures in schools by fostering recognition of, and experience with, water science in new teachers. We plan to continue our high school internship program at UA and to expand its implementation at SAHRA’s partner institutions, roughly doubling its annual impact. We are also continuing our involvement with UA’s CATTS Fellows Program (GK-12 grant) to increase the direct involvement of undergraduate and graduate science students in high school science classrooms to facilitate implementation of water science. While none of SAHRA’s partners have GK-12 funds, we plan to support similar fellowships at partner institutions to provide the human resources needed to sustain the teaching of hydrologic literacy in high school classrooms in the southwestern United States.

**Programs for Elementary and Middle School Students** – Much of SAHRA’s early efforts with students in grades K-12 have been with pre-existing programs such as GLOBE and Project WET, which both have quality materials and lengthy track records of success. We are pursuing additional funding in collaboration with other water education projects from Arizona’s Proposition 301. Current options include creating permanent exhibits in public places with field trip support and mobile exhibits that can be used in schools, and providing human and material support for the implementation of GLOBE and Project WET. These efforts will increase our collaboration with state water agencies and Arizona Cooperative Extension. SAHRA researchers at UNM have begun developing and testing protocols for hands-on water demand simulations (closely linked to SAHRA research) that elementary and middle school teachers can use in their classrooms. Combined, these projects have the potential of impacting hundreds of students. New Mexico Tech currently supports a network of schools on the Rio Grande collecting water quality data. This network will be expanded in size and scope to be more useful to SAHRA scientists. At the UA, we are collaborating with the Udall Center and the Bureau of Applied Research in Anthropology to leverage funds for the development of similar networks on the Santa Cruz and San Pedro Rivers. Our plans for these networks include working with 10-20 teachers and 300-600 students on the development and implementation of student inquiry. The Monsoon Madness collaborative project begun in summer 2003 UA’s Flandrau Science Center will be expanded to Albuquerque and Phoenix. Partial scholarships and transportation for low-income minority students will be provided. Future camps will facilitate student development of research projects for science and engineering fairs that continue beyond the camp experience. We anticipate the camp will impact 45 students annually.

**All Educational Audiences** – We are improving and expanding our educational web site to reach a wider audience and support implementation of water education programs. Future improvements will include refined lesson plans and the addition of hydrologic data that can be used by students and other
stakeholders. As SAHRA’s relationship with stakeholder groups has grown, it has become apparent that our educational activities must address specific knowledge gaps and misconceptions. We will use surveys to identify these needs in guiding the content of our educational and knowledge transfer activities.

**Education and SAHRA Science** – The need to extend education to the public and policy makers in order to fill knowledge gaps and dispel misconceptions is apparent to SAHRA scientists. To facilitate integration of cutting edge SAHRA science with decision-making, four specific education/knowledge transfer activities will be developed. They are: 1) creation of a San Pedro Seminar that helps graduate students to understand the complexity of the San Pedro River basin, moving beyond basic hydrology to include natural, social, economic, management, and institutional considerations; 2) creation of interactive educational kiosks that educate the public about water science, semi-arid hydrology, and riparian systems in SAHRA’s research basins. These will be created and installed in Arizona and the Rio Grande in New Mexico; 3) continuation and expansion of SAHRA interactions with San Pedro and Rio Grande stakeholders and decision-makers such as the Upper San Pedro Partnership, to refine the bi-directional interaction between stakeholder needs and SAHRA research. The dialogue will be linked with efforts to engage ARASA and other Mexican stakeholders to participate in and understand the research on both sides of the border on the San Pedro; and 4) application of SAHRA’s dynamic simulation modeling efforts for education.

**Evaluation and Research** – We have used surveys of teachers participating in workshops, interviews with undergraduates participating in research experiences, and qualitative accounts accompanying requests from stakeholders for educational support to evaluate and improve our programs. We recently completed and began implementing a comprehensive evaluation plan for SAHRA’s education and knowledge transfer programs. This primarily involves identification of baseline knowledge and learning outcomes through a survey instrument administered to participants in SAHRA’s education and knowledge transfer programs. The instrument includes items to assist in formative evaluation to guide future program implementation. Another feature of the evaluation program is the use of qualitative and interpretive tools such as interviews to achieve greater depth in our understanding and to consider our education and knowledge transfer programs through the lenses of quality educational practices (such as inquiry-learning). Protocols articulate data collection, analysis, and communication procedures. The evaluation plan is an integral part of SAHRA’s overall strategic plans.
IV. KNOWLEDGE TRANSFER

1a. Overall Knowledge Transfer Objectives

SAHRA aims to 1) promote overall hydrologic literacy, from K-12 to adult learners, and from decision makers to the general public; 2) reach wider audiences who represent diverse populations and a broader geographic base; 3) develop relationships with stakeholders and communicate research findings; and 4) integrate research, education, and knowledge transfer.

1b. Performance and Management Indicators

Performance and knowledge transfer indicators are based primarily on quantifying demand for the information produced. In addition, evidence that the information was of value to, and affected the actions of water managers and others, is also gathered, often in the form of anecdotes. Thus, we monitor the number of people, and their institutional affiliations, that access various types of information made available via workshops, through our Web site, at various public displays, and in print. Some examples of monitoring include:

- List statistics regarding web site access and usage, including: [increase use]
  - numbers of visitors to web site
  - origin of visitors to web site
  - web page where visitors arrive at the web site
  - search terms used by visitors to land on various pages
  - number of pages viewed per visitor
  - browsers used by visitors
- List statistics (similar to above) regarding electronic kiosk access and usage developed for Rural Water Resource Centers. [increase use]
- List statistics (similar to above) regarding electronic kiosk access and usage developed for the Sabino Canyon Visitors Center. [increase use]
- Number of copies of various flyers, pamphlets, reprints, etc. that are produced and given away [increase #]
- List / Description of impacts of knowledge transfer programs on participant understanding and activity [at least 70% positive impact]
- Summary of feedback on implementation from knowledge transfer program participants [at least 70% positive feedback]
- List of SAHRA research areas/projects integrated in knowledge transfer programs [maintain]
- List of grants, other forms of monetary and in-kind support of KT activities
- Statistics on subscribers, sponsors, and pages of content for stakeholder-oriented magazine [increase]

1c. Problems During the Reporting Period and Anticipated for Year 5

Database expertise. Our need for database expertise has increased over the last year to keep pace with the increased amount of data that we are collecting and a very considerable expansion in the number of databases being developed, maintained and enhanced to support knowledge transfer efforts. We lost our database specialist in May and have hired a replacement who will start in October 2003.

Outreach to professional community. A modest increase in our partner institutions and a major increase in research results has added to the challenge of identifying and transferring key findings to those who can most benefit from them. We have addressed this by hiring in August 2003 a postdoctoral research
associate in knowledge transfer to publish a magazine aimed at stakeholder groups. Discussions at the Executive Retreat in June 2003 have helped us to determine how to identify mature science results and how best to tailor knowledge transfer activities for each. We are partially funding a new position at the UA (shared with the Water Resources Research Center and the Institute for the Study of Planet Earth) that will focus on continuing education programs for water resource professionals.

2a. Knowledge Transfer Activities

<table>
<thead>
<tr>
<th>Sabino Canyon Display, Kiosk, and Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
</tr>
<tr>
<td>Gary Woodard</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Organizations Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
</tr>
<tr>
<td>U.S. Forest Service (Sarah Davis, Jeff Klas)</td>
</tr>
<tr>
<td>USGS (Kyle Blasch, Chris Smith, Dan Evans)</td>
</tr>
<tr>
<td>NASA Goddard Space Flight Center</td>
</tr>
</tbody>
</table>

Informal experiential displays take advantage of large concentrations of people in settings that provide opportunities to informally educate them through entertaining experiences. At the request of the U.S. Forest Service, which is providing weather data and information on fire data, and with the assistance of the USGS, which is helping to provide real-time data on streamflow and flood conditions, SAHRA completed in October 2002 a public display, electronic kiosk, and Web site for visitors to Sabino Canyon. This desert mountain canyon, located just north of Tucson, receives 1.4 million visits per year. Visitors range from tourists traveling from Europe and Asia to Tucsonans taking advantage of the canyon’s hiking trails. The displays contain information on Sabino Creek, an ephemeral stream that rises in the Sky Island mountaintops and descends through several biomes to the Sonoran Desert. The kiosk and website display near-real-time data from weather stations at the top, center, and base of the canyon that are operated by SAHRA, USGS, and the Forest Service, respectively. NASA contributed a satellite zoom-in of the area. See www.sabinocanyon.arizona.edu.

The goal of this project is to educate people on desert streams, addressing basic issues as: Where does the water come from? Why does the flow stop part of the year? What are the conditions that produce flash floods? How does elevation affect climate, flora, and fauna?

The outcomes we seek include: attracting a large percentage of the estimated 350,000 persons who pass through the Visitors Center annually to the static displays and electronic kiosk; having a large percentage of local residents who call the Center staff for information on streamflow and weather instead access that information via the Web site; and luring people who visit the Web site for weather and streamflow information to other parts of the Web site that explain the hydrology and biology of the stream.
Rural Water Resource Centers

Led by Gary Woodard

Organizations Involved

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cooperative Extension Service, Cochise County (Susan Pater)</td>
<td>Benson, AZ</td>
</tr>
<tr>
<td>2 Cooperative Extension Service, Yavapai County (Jeff Schalau)</td>
<td>Prescott, AZ</td>
</tr>
</tbody>
</table>

Rural Water Resource Centers serve members of the public who are actively seeking information on local water conditions, issues, and resources. The ultimate goal is to have one in each rural county. Centers are being completed in Cochise County (Upper San Pedro River) and Yavapai County (Verde River) and work has begun on centers in two additional counties. Developed in cooperation with Cooperative Extension offices, each center has a collection of print and electronic publications and databases, some developed specifically for that county. Users can take away pre-printed materials, custom printed information, and CD-Rs, as well as email information to themselves and others.

The goal is to serve diverse populations, including educators, home owners, and policy makers who seek specific information relevant to their local basins.

Outcomes will be measured in terms of numbers of users and the amounts and types of information they receive. This information will guide the design and implementation of centers developed in 2004.

Dynamic Simulation Workshop

Led by Gary Woodard, Vince Tidwell

Organizations Involved

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Dept. of Hydrology and Water Resources</td>
<td>Univ. of Arizona, Tucson, AZ</td>
</tr>
<tr>
<td>2 Dept. of Civil Engineering</td>
<td>Univ. of Arizona, Tucson, AZ</td>
</tr>
<tr>
<td>3 Dept. of Ag. &amp; Resource Economics</td>
<td>Univ. of Arizona, Tucson, AZ</td>
</tr>
<tr>
<td>4 Office of Arid Lands Studies</td>
<td>Univ. of Arizona, Tucson, AZ</td>
</tr>
<tr>
<td>5 Sandia National Laboratories</td>
<td>Albuquerque, NM</td>
</tr>
<tr>
<td>6 Dept. of Geology &amp; Geophysics</td>
<td>University of Utah, Salt Lake City, UT</td>
</tr>
<tr>
<td>7 Mexican Institute of Water Technology (IMTA)</td>
<td>Jiutepec, Morelos, Mex.</td>
</tr>
<tr>
<td>8 School of Architecture and Planning</td>
<td>University of New Mexico, Albuquerque, NM</td>
</tr>
<tr>
<td>9 The Nature Conservancy</td>
<td>Bisbee, AZ</td>
</tr>
<tr>
<td>10 Dept. of Agricultural Economics</td>
<td>New Mexico State University, Las Cruces, NM</td>
</tr>
<tr>
<td>11 Environmental Studies Dept.</td>
<td>University of Nevada, Las Vegas, NV</td>
</tr>
<tr>
<td>12 Environmental Sci. and Resource Economics</td>
<td>Washington State University, Pullman, WA</td>
</tr>
<tr>
<td>13 Dept. of Economics</td>
<td>Siena University, Loudonville, NY</td>
</tr>
<tr>
<td>14 Idaho Ntl. Engineering &amp; Environmental Laboratory</td>
<td>Idaho Falls, ID</td>
</tr>
</tbody>
</table>
In Tucson November 1-2, 2002, SAHRA jointly sponsored with Sandia National Laboratory a workshop for researchers using dynamic simulation modeling to model environmental resources. The workshop was the first of its kind to target environmental resource managers and attracted 35 scientists from the 14 academic departments and organizations listed above.

### Displays at Professional Conferences/Meetings

Led by Jim Washburne, Gary Woodard

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
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</thead>
<tbody>
<tr>
<td>1 American Geophysical Union</td>
<td>San Francisco, CA</td>
</tr>
<tr>
<td>2 European Geophysical Society</td>
<td>Nice, France</td>
</tr>
<tr>
<td>3 European Union of Geosciences</td>
<td>Nice, France</td>
</tr>
<tr>
<td>4 American Meteorological Society</td>
<td>Boston, MA</td>
</tr>
<tr>
<td>5 Arizona Science Teachers Association</td>
<td>Phoenix, AZ</td>
</tr>
<tr>
<td>6 Arizona Hydrologic Society</td>
<td>Flagstaff, AZ</td>
</tr>
<tr>
<td>7 SACNAS</td>
<td>Santa Cruz, CA</td>
</tr>
</tbody>
</table>

SAHRA’s static displays, electronic kiosks, and printed materials are used at professional conferences to spread word about SAHRA, develop new partnerships, and recruit students. Professional conferences and meetings where SAHRA has had major displays in the last 12 months include:

- Society for the Advancement of Chicano and Native American Students (SACNAS) conference, Los Angeles, Sept. 2002
- Arizona Hydrologic Society annual meeting, Flagstaff, AZ, Sept. 2002
- American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, Dec. 2002 (approximately 15 posters and 10 papers presented, 1 session chaired)
- Joint Assembly of the AGU, European Geophysical Society, and European Union of Geosciences, Nice, France, April 2003 (approximately 10 SAHRA talks and 10 posters presented, 1 panel presentation)

### Water Education Activities – Water Center Collaborations

Led by Gary Woodard

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
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</thead>
<tbody>
<tr>
<td>1 AZ Water Resources Research Center (Megdal, Schwartz)</td>
<td>UA</td>
</tr>
<tr>
<td>2 ERC for Environmentally Benign Semiconductor Manufacture (Clement, Ogden)</td>
<td>UA</td>
</tr>
<tr>
<td>3 Water Quality Center (Pepper, Falls)</td>
<td>UA</td>
</tr>
<tr>
<td>4 Cooperative Extension (Young, Pater, McReynolds)</td>
<td>UA</td>
</tr>
</tbody>
</table>
Voters in the State of Arizona approved an increase in the sales tax in November 2000 to increase funding of education. While 85% of these funds are earmarked for K-12 education, the remaining 15% is distributed to the state’s community colleges (5%) and three state universities (10%). Each university selected a small number of program areas to receive increased funding. The University of Arizona selected water resources as one of its targeted areas.

These additional funds are distributed to four water centers at the UA, including SAHRA. Some 80% of the funds support targeted research, but the four Centers agreed to each contribute 20% to a Joint Water Education and Outreach program. This program is coordinated by Gary Woodard and managed by SAHRA’s Business Office. In state FY02-03, $85,000 was earmarked; in FY03-04, $200,000 has been budgeted. In addition, a new program this fiscal year is funding proposals submitted by UA researchers that are linked to the activities of one or more of the water centers. For 2003/04 this funding source will provide $1 million at the University of Arizona, with eight grants tied to SAHRA, including a grant to Cochise County Cooperative Extension to support research and development of an interactive display at Kartchner Caverns State Park on mountain block recharge and the hydrology of caves. Two other grants have significant knowledge transfer components.

<table>
<thead>
<tr>
<th>Media Briefings</th>
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<tbody>
<tr>
<td>Led by</td>
<td>Gary Woodard</td>
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<tr>
<td>Organizations Involved</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Address</td>
</tr>
<tr>
<td>1 Institute for the Study of Planet Earth</td>
<td>UA</td>
</tr>
<tr>
<td>2 Arizona Dept. of Water Resources</td>
<td>Phoenix, AZ</td>
</tr>
<tr>
<td>3 U.S. Forest Service</td>
<td>Tucson, AZ</td>
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<tr>
<td>4 USGS</td>
<td>Tucson, AZ</td>
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</table>

SAHRA initiated with UA’S Institute for the Study of Planet Earth (Climate Assessment Project for the Southwest) a series of targeted media briefings on drought-related issues. Briefings were held in Tucson, July 22, 2002 and Jan. 9, 2003; in Phoenix, Aug. 26, 2002 and March 20, 2003 (hosted by the Arizona Department of Water Resources); and in Albuquerque, Sep. 26, 2002. SAHRA also joined with USGS, the U.S. Forest Service, and several state and local water agencies for a media briefing on National Water Monitoring Day (Oct. 18, 2002). These briefings generated numerous stories and articles in newspapers and on TV and radio via the following outlets:

- The Arizona Daily Star
- The Arizona Republic, Phoenix
- East Valley Tribune, Mesa, AZ
- KATA Radio, Phoenix
- KGUN, Channel 9 Tucson (ABC)
- KNXV, Channel 15 Phoenix (NBC)
- KPHO News 5, Phoenix
- KPNX News 12, Phoenix
- KSAZ, Channel 10 Phoenix (FOX)
- KUAT/KUAZ Radio, Tucson
- KVOA EyeWitness News, Channel 4 (NBC)
- Southwest Hydrology
- The Tucson Citizen
- The Tribune, Phoenix
• UA news
• Water Resources Research Center

**Science Radio**

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<tr>
<th>Led by</th>
<th>Gary Woodard</th>
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<td><strong>Organizations Involved</strong></td>
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<tr>
<td>Name</td>
<td>Address</td>
</tr>
<tr>
<td>1 SoundPrint</td>
<td><a href="http://www.soundprint.org">http://www.soundprint.org</a></td>
</tr>
<tr>
<td>2 KJZZ Radio</td>
<td>Phoenix, AZ</td>
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</table>

SoundPrint’s NSF-funded series on Models and Forecasting on NPR stations aired Water is Gold on November 25, 2002. In addition to providing interviews of researchers for this program, SAHRA developed a special web site for KJZZ - Phoenix. See http://water.soundprint.org/

**Global Network on Water and Development Information for Arid Lands**

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<tr>
<th>Led by</th>
<th>Gary Woodard</th>
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<td><strong>Organizations Involved</strong></td>
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<td>Name</td>
<td>Address</td>
</tr>
<tr>
<td>1 UNESCO</td>
<td>Paris, France</td>
</tr>
<tr>
<td>2 IAEA</td>
<td>Vienna, Austria</td>
</tr>
<tr>
<td>3 Regional Centre on Urban Water Management</td>
<td>Tehran, Iran</td>
</tr>
<tr>
<td>4 Regional Centre for Training and Water Studies of Arid and Semi-arid Zones</td>
<td>Cairo, Egypt</td>
</tr>
<tr>
<td>5 Water Centre for Arid and Semi-arid Regions of Latin America and the Caribbean</td>
<td>La Serena, Chile</td>
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<tr>
<td>6 UNESCO IHE Institute for Water Education</td>
<td>Delft, Netherlands</td>
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</table>

SAHRA has begun a collaboration with the United Nations Educational, Scientific, and Cultural Organization (UNESCO) to develop and provide selected content for a website for the Global Network on Water and Development Information for Arid Lands (GWADI), which includes the centers and institutes listed above. UNESCO has confirmed it will initially provide $10,000 in seed money toward this effort. SAHRA will develop and provide selected content in the following areas:

• Home page
• Private or secure side to support remote data entry
• Reference modules for researchers on specific topics such as hydrologic isotopes (in cooperation with IAEA Hydrology Section)
• Searchable databases on research efforts
• GIS data sets in support of research
• Global Water News Watch service with email subscriptions
• Workshop and training support
• Educational resource sharing
**CESBIO/SUDMED Initiative**

<table>
<thead>
<tr>
<th>Led by</th>
<th>Goodrich, Shuttleworth, Woodard</th>
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<tr>
<td>1 CESBIO</td>
<td>Toulouse, France</td>
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<tr>
<td>2 SUDMED</td>
<td>Toulouse, France</td>
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</table>

- As described in Section II, SUDMED is a research project conducted by CESBIO (Centre d'Etudes Spatiales de la Biosphère in Toulouse, France), in cooperation with numerous Moroccan institutions, on the hydrology and ecology of the Tensift riparian area of the Haouz region of Morocco. In February 2004, representatives of SAHRA (Goodrich, Shuttleworth, Woodard) will meet in Morocco with SUDMED and CESBIO representatives to discuss opportunities for mutually beneficial collaborative activity.

**Water Outreach Connection Web Resource**

<table>
<thead>
<tr>
<th>Led by</th>
<th>Gary Woodard, Claire Zucker</th>
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<td>Name</td>
<td>Address</td>
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</tr>
<tr>
<td>1 Pima Association of Governments</td>
<td>177 N. Church Ave., Suite 405, Tucson AZ 85701</td>
</tr>
<tr>
<td>2 City of Tucson</td>
<td>Tucson, AZ</td>
</tr>
<tr>
<td>3 Pima County</td>
<td>Tucson, AZ</td>
</tr>
<tr>
<td>4 University of Arizona</td>
<td>Tucson, AZ</td>
</tr>
<tr>
<td>5 State of Arizona</td>
<td>Phoenix, AZ</td>
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</table>

The Pima Association of Governments and SAHRA are creating a participant-updated website that focuses on water resources and water quality outreach and education, in order to enable outreach personnel from various agencies working on water issues to better communicate. SAHRA will provide technical support to create the website. Agencies that plan to use the website include the City of Tucson (Tucson Water Dept., Stormwater Section of the Transportation Dept., and Environmental Management Dept.), Pima County (Dept. of Environmental Quality, Wastewater Management Dept.), the University of Arizona (Center for Toxicology and the Water Resources Research Center), and the State of Arizona (Dept. of Environmental Quality and Dept. of Water Resources).

**Information Share Meeting**

<table>
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<tr>
<th>Led by</th>
<th>Gary Woodard</th>
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<td>Organizations Involved</td>
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<td>Name</td>
<td>Address</td>
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</tr>
<tr>
<td>1 Apache Junction Water Company</td>
<td>Apache Junction, AZ</td>
</tr>
<tr>
<td>2 Arizona Dept. of Water Resources</td>
<td>Phoenix, AZ</td>
</tr>
<tr>
<td>3 Central Arizona Project</td>
<td>Phoenix, AZ</td>
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<tr>
<td>4 City of Flagstaff</td>
<td>Flagstaff, AZ</td>
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<tr>
<td>5 City of Mesa</td>
<td>Mesa, AZ</td>
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<tr>
<td>6 City of Payson</td>
<td>Payson, AZ</td>
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<tr>
<td>7 City of Peoria</td>
<td>Peoria, AZ</td>
</tr>
<tr>
<td>8 City of Phoenix</td>
<td>Phoenix, AZ</td>
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</tbody>
</table>
On April 2, 2003, SAHRA hosted water conservation professionals at the Sabino Canyon Information Share. Forty-five individuals attended from 21 agencies throughout the state of Arizona. Five attendees gave presentations, among them Woodard, who spoke on incorporating real-time water data in public exhibits, kiosks, and websites.

### 2b. Outcomes/Impacts of Other Knowledge Transfer Activities

#### A. Internal Information Sharing

The SAHRA Intranet has been considerably expanded and improved to help facilitate communication among SAHRA members of affiliated institutions and organizations. Components are: the comprehensive Online Management System (described in Section VII); Forms (for hiring, purchases, travel reimbursement, etc.); Documents (annual reports, original proposal and renewal proposal for the STC, site visit reports and responses, etc.); Multimedia (PowerPoint templates, logos, screensaver); Resources (cameras, tripods, scanners, special printers, projectors, and software available for use or checkout, and contact person); Administration (workstation maps, travel and purchasing authorization procedures, how to acknowledge NSF and SAHRA support in publications); and Meetings (minutes of important meetings, frequently used PowerPoint slides).

#### B. Web-based Information Resources

SAHRA has continued to develop/enhance a number of searchable databases of useful information for water managers, educators, students, and the general public. Enhancements during the past year include:

- **Water NewsWatch** (www.sahra.arizona.edu/newswatch) – now covers seven languages (English, Spanish, French, Italian, Portuguese, Farsi and Greek), and includes summaries of over 6,500 articles in 13 categories from 136 countries. The home page highlights high-profile stories and recent developments. Search capabilities have been expanded to include automatic searching of alternate spellings and related terms.
- **Glossary** – a searchable glossary of over 500 water-related terms that can be used like a conventional print glossary, but has increased functionality (intelligent search functions). This database also drives and enhances the search function for NewsWatch.
- **Water quotes** – a searchable database of over 200 water-related quotes, searchable by keyword, hydrologic topic, or quote type.
• *Isotopes in Hydrology* – significantly expanded in late 2002, this resource contains a clickable periodic table that links elements with isotopes useful in hydrology to web pages that provide basic information about that isotopic system as well as important hydrologic applications. Information includes how an element’s isotopes are measured, how much analyses cost, and details about major applications of these isotopes in hydrology. The site also includes information on different types of isotopes and methods of analysis.

• *Residential Water Conservation* house has expanded information for homeowners looking to reduce water consumption and information on conservation resources, including website links, books, landscaping resources, botanical gardens, and cooperative extension offices. Extensive use of graphics and Flash animation on the site invites users to explore additional potential water conservation options.

C. Sponsored Meetings

SAHRA's Committee on Integration hosted the following science integration meetings:

• Rio Grande river basin workshop on September 26-27, 2002, in Albuquerque, NM
• San Pedro planning workshop, October 2002, at the Institute for the Study of Planet Earth (UA)

SAHRA also co-sponsored the AGU Chapman Conference on Eco-hydrology of Semi-arid Landscapes, Interactions, and Processes in Taos, NM on September 9-13, 2002.

D. Indian Water Rights Monograph

SAHRA is jointly funding and contributing to publication of the 2nd ed. of *Indian Water Rights: Negotiating the Future*, by Bonnie Colby and John Thorson, retired Special Master, Gila River Adjudication. Native American tribes have been awarded, and have made claims based on the Winters Doctrine, on vast amounts of water in the Western U.S. This project updates a book published in 1994 that examines in detail the state of Indian water rights. The new edition was to be published in December 2002 but has been delayed due to illness of one of the authors. Publication is now anticipated in late 2003.

2c. Plans

A. Future Informal Experiential Displays

In Spring 2003, SAHRA began to plan the addition of a hydrologic display for the Discovery Center at Kartchner Caverns, Arizona’s newest and most popular state park, which draws 250,000 visitors per year. Cochise County’s Cooperative Extension Office received a Prop. 301 grant for 2003/04 to develop outreach materials for the Discovery Center, to include physical displays, a touch-screen kiosk, presentation, content, and a website on the hydrology of caves. Topics include: mountain block recharge and cave formation; movement of water from mountain/cave to Upper San Pedro basin groundwater; use of isotopes in hydrology; and the role of riparian habitats in desert settings. Real-time data from cave-based instruments will be incorporated. The SAHRA Knowledge Transfer staff is helping develop the physical displays and program the kiosk and website.

At the request of the U.S. Geological Survey and National Park Service, SAHRA has also been part of preliminary planning meetings to develop hydrology displays at Grand Canyon National Park. The focus will be on the effects of dam releases in preserving and rebuilding canyon beaches and conserving native fish species.
SAHRA has also begun discussions with two science education centers, UA Flandrau Science Center in Tucson and Explora Science Museum and Children’s Center in Albuquerque, about helping to develop displays and exhibitions related to water resources. Flandrau will be relocating in 2004 as part of the Rio Nuevo downtown revitalization program and is interested in expanding its exhibits to include more coverage of environmental and atmospheric sciences. Explora will open in 2004, and plans to devote a significant portion of its exhibit space to water science and education.

**B. Trade Publication for Water Professionals**

Beginning in August 2003, SAHRA acquired and assumed publication of *Southwest Hydrology*, an established bimonthly print publication for hydrologists, water managers, and other water professionals that provides information about projects, research, technologies, regulations, and innovations unique to the semi-arid Southwest. We plan to expand readership above the current level of 3,600 and to lengthen it from 40 to 48 pages. This will accommodate adding a monthly column that highlights education and outreach activities at SAHRA. The publication will also be able to draw on the efforts of Water NewsWatch in identifying news stories and topics to feature. The publication will have a circulation of approximately 4,500.

**C. Short Courses**

Executive Training Programs in the form of short courses on topical water issues will be offered beginning in 2004. Content will include Robert Glennon (University of Arizona College of Law) and Thomas Maddock III (UA-HWR), and addressing hydrologic and legal connections and disconnects between groundwater and surface water; Bonnie Colby (UA College of Agriculture) and John Thorsten (Special Master, ret.), focusing on Indian water rights; and various SAHRA PIs on impacts of land cover changes on basin-wide water balances.
V. EXTERNAL PARTNERSHIPS

1a. Overall Objectives for Developing External Partnerships
The Center’s overall objectives for developing external partnerships have not changed.

1b. Performance and Management Indicators
SAHRA will measure progress in developing and involving partners via the performance indicators listed below:
· List / Number of partner institutions [maintain]
· List / Description of projects undertaken with partners [increase #]
· List of data, information, and human and capital resources interchanged with partners [increase #]

1c. Problems Encountered During the Reporting Period and Anticipated for Year 5
SAHRA continues to have numerous opportunities to partner with many diverse organizations. The challenge remains one of managing the rate of growth, and bringing new partners into SAHRA in a controlled way that leverages our resources, creates synergies for all concerned and contributes to integrating our activities.

2a. Partnership Activities Not Reported Elsewhere

<table>
<thead>
<tr>
<th>Partnership Activity</th>
<th>CEA-CREST-SAHRA Glue Grant Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led by</td>
<td>Hibbs, Phillips</td>
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</tbody>
</table>

Organizations Involved (add rows as necessary)

<table>
<thead>
<tr>
<th>Name of Organization</th>
<th>Shared Resources (if any)</th>
<th>Use of Resources (if applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 CSU-Los Angeles</td>
<td>as described below</td>
<td>as described below</td>
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<tr>
<td>2 UACJ</td>
<td></td>
<td></td>
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<td>3 NMSU</td>
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<td>4 UTEP</td>
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CEA-CREST faculty members at California State University, Los Angeles and Universidad Autónoma de Ciudad Juarez researchers are working with SAHRA to study the surface water and groundwater systems along the City of El Paso/Ciudad Juarez international metroplex. The twin cities share the water resources of the Hueco Bolson and smaller basin-fill aquifers that span the international border. Over-pumping of these aquifers has resulted in excessive drawdown of the water table, encroachment of brackish groundwater, and the early retirement of wells.

The CEA-CREST – SAHRA research team is age-dating groundwaters with radioisotopes, tracking stream/aquifer interactions with stable isotopes, and assessing mixing of saline and fresh waters with halides. Analyses focus on 135 groundwater samples collected by Dr. Hibbs and other members of the binational research team. Other institutions collaborating in this study include New Mexico State University, Universidad Autónoma de Ciudad Juarez (UACJ), and the University of Texas at El Paso.

Formal agreements were established with UACJ for collaborating on the study. UACJ in turn was given permission to sample water wells operated by Mexican governmental entities. UACJ collected
35 groundwater samples on the Mexican side of the international border, and the binational team is analyzing these samples. Some of the most important results to date indicated that groundwater beneath Ciudad Juarez is isotopically distinct from groundwater in other parts of the Hueco Bolson. Recharge to the Mexican portion of the aquifer was derived from infiltration of pre-dam, snowmelt runoff in Colorado that flowed into the Rio Grande before reaching recharge areas along the El Paso/Juarez narrows. In other parts of the Hueco Bolson, recharge is derived locally from mountain front recharge. Historically it had been thought that virtually all of the predevelopment recharge to the Hueco Bolson was derived locally. Our isotope date provide a completely new interpretation of recharge to parts of the Hueco Bolson aquifer.

<table>
<thead>
<tr>
<th>Partnership Activity</th>
<th>USDA-ARS-SWR/SAHRA Joint Activities</th>
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<tr>
<td>Led by</td>
<td>Dave Goodrich</td>
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<th>Organizations Involved</th>
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<tr>
<td><strong>Name of Organization</strong></td>
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<td>USDA</td>
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The Walnut Gulch Experimental Watershed operated by the Southwest Watershed Research Center (SWRC) of USDA-Agricultural Research Service in Tucson, Arizona is a premiere semi-arid experimental watershed. The watershed drains 150 square kilometers in southeastern Arizona and is representative of the approximately 60 million hectares of grass- and brush-covered rangeland found throughout the semi-arid southwest and northern Mexico. It lies in a transition zone between the Chihuahuan and Sonoran Deserts. The scientific instrumentation and research infrastructure at Walnut Gulch are unparalleled. Detailed experiments and long-term observations are conducted to improve understanding of semi-arid rangeland hydrology and erosion. No comparable semi-arid hydrologic database exists in the world (see http://www.tucson.ars.ag.gov).

The Walnut Gulch facility consists of 29 nested watersheds that range in drainage area from 0.002 to 150 square kilometers. Rainfall and runoff instrumentation (including 85 recording rain gauges) has been in place since 1964. Eleven of the nested watersheds are gauged for runoff with concrete supercritical flumes that are specially designed to give very accurate estimates of runoff (notoriously difficult to obtain in semi-arid regions). Extensive monitoring of erosion and sediment transport is conducted on eight of the smaller sub-watersheds. Hydro-meteorological instrumentation at two locations, one grass dominated and the other brush dominated, provide measurements of the energy balance, soil temperature, soil moisture and CO₂ fluxes. Biotic characterization has been ongoing. A high-resolution GIS database for the watershed has been created. All of the recording instrumentation is currently undergoing conversion to digital systems with telemetry for remote data transfer. The NEXRAD radar system installed by the National Weather Service at Tucson provides radar coverage. The ARS Walnut Gulch headquarters facilities outside Tombstone include soils and sediment laboratories, and workshops for electronics, machine and welding/fabrication. The facilities and instrumentation are maintained by four full-time support staff, and on-site lodging is available for up to six visiting scientists.

The Walnut Gulch watershed and the containing San Pedro basin continue to be a venue for highly instrumented large-scale multidisciplinary research and watershed characterization conducted by a variety of agencies, universities, and members of the Upper San Pedro Partnership to more accurately estimate the semi-arid water balance and understand the water needs of the first Congressionally designated Riparian National Conservation Area. Ongoing ground, aircraft and satellite data remote
sensing collections continue as these watersheds serve as the primary semi-arid validation site for NASA’s Earth Observing System. SPOT and LANDSAT images are being routinely archived.

A variety of SWRC resources are being used to enhance the collaborative SAHRA research effort. The Walnut Gulch facility serves as an important outdoor laboratory of SAHRA research. Research knowledge, observation, and understanding from the watershed are being used in a variety of SAHRA activities, ranging from rainfall characterization, infiltration, ephemeral channel recharge, to erosion. SWRC instrumentation (rain gauges), facilities (shops, labs, housing for visiting scientists and students) and vehicles are utilized by SAHRA collaborators.

<table>
<thead>
<tr>
<th>Partnership Activity</th>
<th>Los Alamos National Laboratory Collaboration</th>
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<td>Led by</td>
<td>Everett Springer</td>
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Organizations Involved

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<tr>
<th>Name of Organization</th>
<th>Shared Resources (if any)</th>
<th>Use of Resources (if applicable)</th>
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<td>LANL</td>
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The Los Alamos National Laboratory (LANL) is well known for its expertise in advanced computing and numerical simulation of physical phenomena. The capabilities of the Los Alamos computers allow very highly resolved simulations to be performed, based on which up-scaling schemes can be designed through sensitivity experiments. The new computer at Los Alamos, built by Silicon Graphics, is capable of $10^{12}$ operations per second and is based on 2,048 R10K processors running at a rate of 250 MHz each. Memory consists of 512 Gbytes of RAM and 5 terabytes of local disk. Later generations of this machine will be capable of 10-100 teraflops with correspondingly larger numbers of processors.

Research at LANL includes the development of high-resolution computer models of coupled hydrologic systems, with Department of Energy funding at the level of $900K/year for 5 years. The study is designed to provide insight into how the discrete physical components of coupled hydrologic/environmental systems (e.g., atmosphere and land surface) interact nonlinearly and operate at different time and space scales. In particular, the current research emphasizes the importance of inter-domain exchanges of mass and energy, which have not previously been represented with enough detail because adequate computational resources and physical models have been unavailable. The goal is to develop a new generation of modeling tools that can be used to assess, manage, and eventually predict, the evolution of regional catchments. These tools will facilitate the study of a large variety of future environmental security issues ranging from global challenges such as CO$_2$ and water cycles, to local and regional problems such as fresh water supply, agriculture, and flooding.

The research at LANL addresses advances in both the computer and physical sciences, for efficient parallelization (development of a new communicating asynchronous processes alternative to the standard massively parallel computing method), data mining, numerical schemes capable of accurately representing large gradients, gridding methods capable of representing highly variable geologic media (such as those found in groundwater basins), new turbulence schemes to support high-resolution modeling, methods of scaling to assure commensurability of data passed among individual physical components, and upscaling through averaging techniques, scaling laws, and sensitivity analysis.

Los Alamos Labs and SAHRA have several joint studies: 1) SAHRA data provide essential input to, and help validate the LANL Rio Grande Basin hydrologic model; and 2) fine-resolution integrated...
modeling of the Rio Grande Basin benefits science-based decision making by water managers/policy makers, supported by a $500,000/yr. match from LANL. These efforts are described further in Section II.

<table>
<thead>
<tr>
<th>Partnership Activity</th>
<th>USGS/SAHRA Collaboration</th>
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<tr>
<td>Led by</td>
<td>Stan Leake</td>
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<td>Organizations Involved</td>
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<tr>
<th>Name of Organization</th>
<th>Shared Resources (if any)</th>
<th>Use of Resources (if applicable)</th>
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<td>1 USGS Arizona Dist.</td>
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The Arizona District of the U.S. Geological Survey conducts extensive research on the groundwater resources of the southwestern U.S. Many of the projects conducted by the Arizona district programs have great relevance to SAHRA’s effort. In addition, scientists in the USGS National Research Program provide research tools and models that are standard to groundwater analysis and research in the United States.

Located in Tucson, the Arizona District of USGS leads a multidisciplinary groundwater project called the Southwestern Groundwater Project that is highly relevant to SAHRA. The project involves research and evaluation of the spatial and temporal variability of groundwater recharge and outflow in shallow aquifer systems. It consists of five parts: a) a regional synthesis and review of existing groundwater models, particularly those related to surface water/groundwater interactions; b) an evaluation of the effects of climatic variability on groundwater recharge and outflow; c) development of new geophysical and geochemical techniques for identifying and quantifying the spatial and temporal variability of groundwater recharge; d) development of techniques for using riparian vegetation as a tool for assessing the long term stability of shallow groundwater systems; and e) development of new tools to more realistically model the temporal and spatial variability of groundwater recharge and outflow. The 5-year project began October 1, 1998 and was funded at $1-2 million per year, in addition to existing USGS projects with state and local cooperators. The project provides several opportunities for collaboration SAHRA, including studies of ephemeral wash recharge and groundwater outflow in the middle Rio Grande basin near Albuquerque, New Mexico, and the San Pedro River National Conservation Area in southern Arizona. These investigations provide important research opportunities for students in the hydrology and ecology programs. Additionally, the USGS Arizona District office is conducting a detailed investigation of groundwater resources of the upper San Pedro River Basin. That project and SAHRA have continuing collaboration on data collection and analysis relating to the groundwater flow system.

USGS also operates the most extensive set of streamflow gauging stations in the U.S., providing an essential long-term database from which to evaluate outflow from shallow groundwater systems such as the San Pedro River. The USGS also has geophysical tools for assessing characteristics of aquifer systems. A drill rig is maintained in Menlo Park, CA, and is available to the Arizona District for drilling high-quality monitoring wells. A national database system maintains information on wells and groundwater geochemistry.
## Partnership Activity: Sevilleta LTER

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<td><strong>Name of Organization</strong></td>
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<td>University of Colorado</td>
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<td>University of New Mexico</td>
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This Long Term Ecological Research site (LTER) in New Mexico is used for watershed-scale and riparian research. Given its history of biological and other research, the Sevilleta has been an excellent resource for SAHRA. Major advantages to conducting research on the LTER include: a) security, since it is fenced and patrolled, b) existing instrumentation networks for measuring rainfall, solar radiation, soil temperature and moisture, wind speed and direction, and other climate variables, c) ongoing hydrologic studies, and d) available satellite data. Eric Small (University of Colorado) and Will Pockman (UNM) have obtained additional funding from DOE ($290,000 over 3 years, beginning June 2003) for water addition experiments to parallel their SAHRA-sponsored drought experiments here.

## Partnership Activity: Sandia National Laboratories Collaboration

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<td><strong>Name of Organization</strong></td>
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Sandia National Labs and SAHRA continue to develop dynamic simulation models (DSM) for water supply and demand in the Albuquerque region. Shared resources include Ph.D. fellowships and internships. The disaggregated behavioral market model is being used by the Middle Rio Grande Water Assembly to evaluate alternative water conservation and basin management strategies. The broader goal of increasing the use of DSMs for water resource management is being pursued through joint efforts such as a recent workshop for researchers using DSMs to model environmental resources, which attracted 35 scientists from 14 institutions and is described further in Section IV.

SAHRA is also participating with Sandia Labs and Instituto Mexicano de Tecnología del Agua in a project to collect and distribute critical data on the Lower Rio Grande/Rio Bravo via databases on mirrored servers located at all three institutions.
2b. Describe any other outcomes or impacts of partnership activities not listed elsewhere.

None to report.

2c. Describe your plans for partnership activities for the next reporting period with attention to any major changes in direction or level of activity.

The University of California campuses at Irvine and Merced are being added as institutional partners because of the moves of Drs. Sorooshian, Bales, and Conklin. SAHRA has issued subcontracts to these institutions so that these individuals can continue to undertake and oversee the research they initiated at the University of Arizona.
VI. DIVERSITY

1a. Overall Objectives in Increasing Diversity at the Center

SAHRA’s main diversity objective is to increase involvement by under-represented minorities and women in water resources research and educational programs at all grade levels, and to use knowledge transfer activities to provide assistance to minorities with significant water resource management challenges in the form of accessible scientific knowledge and decision support tools. Given our location and field research emphasis on the semi-arid Southwest and border regions, we are focusing these efforts on Native American and Hispanic populations. Specific objectives include:

- Maintain and refine current K-8 programs (e.g., targeted scholarships for Monsoon Madness summer science camp) and expand delivery to other urban areas in the Southwest through SAHRA’s academic partners;
- Further develop, evaluate and refine water education programs for high school students, targeting delivery to schools and school districts with diverse populations, both to increase hydrologic literacy and to recruit students into college programs related to water resources;
- Maintain or increase the involvement of women as students and junior researchers and increase the involvement of women as senior researchers and administrators;
- Continue to develop and strengthen career opportunities for student and professional Native Americans (e.g., short course planned on Indian Water Rights Settlement Efforts);
- Attract more Hispanic students into the field and improve student and researcher exchanges with Mexico, taking advantage of a re-energized diversity initiative at the University of Arizona; and
- Actively work with other NSF centers to recruit qualified under-represented minorities.

1b. Performance and Management Indicators

SAHRA will measure progress in diversity via the performance indicators listed below:

- List / Number of individuals (and groups) participating in SAHRA’s activities and programs, identifying gender, race, ethnicity, disability and citizenship [increase diversity]
- List / Number of individuals and groups applying to SAHRA’s programs, identifying sex, race, ethnicity, disability and citizenship [increase diversity]
- Maintain or increase the percentage of students and junior researchers who are women, and increase the percentage of senior researchers and administrators who are women
- Increase the number of Native Americans who are SAHRA-supported students, technical staff, and researchers
- Increase the number of Hispanics who are SAHRA-supported students, technical staff, and researchers
- Increase the number of stakeholders that are from under-represented groups and women
- Describe novel and expanded efforts by SAHRA to involve diverse individuals and groups.

1c. Problems During the Reporting Period and Anticipated for Year 5

We funded and participated to a limited degree in Laurel Lacher’s Tribal Watershed Workshop during the summer of 2001 in an effort to work more closely with tribal water professionals. The concept was great, and the first year’s program was a success, but we have struggled to sustain it and expand it to more tribes. In addition to its considerable cost, the effort requires prolonged efforts at
trust building. A major problem last year was the Rodeo-Chediski fire on the White Mountain Apache Reservation, which forced cancellation of the program. The status of this year’s course is uncertain.

We are supporting development of a book on Indian water rights, which has been delayed some 18 months by unanticipated events, including the inability of one Native American author to get tribal clearance for publication. We believe the book is back on track, and anticipate using it as the main text for a short course on tribal water rights settlement efforts.

Hispanic enrollment continues to follow pre-STC patterns and represents a very small part of SAHRA-supported students. We hope that several new efforts with the University of Arizona, our Glue Grant partner at California State University-Los Angeles, state community colleges, and local high schools will strengthen the representation of this important regional group.

2a. Activities That Contribute to the Development of U.S. Human Resources

Summer Camps
- “Monsoon Madness,” three 1-week summer camps for middle school students, was offered jointly with Flandrau Science Center at the University of Arizona in 2003. The camp content focused on the hydroclimatology of the Tucson Basin, with an emphasis on the summer monsoon. Students broadened their experiences by visiting local scientists, conducting weather experiments, and monitoring the weather. Scholarships were provided to low-income, minority students.
- The NAU Summer Scholars program was organized in collaboration with four school districts with high Native American populations. It provided middle school students with an emphasis in environmental science, mathematics, and technology in a one-week on-campus, residential experience. The Summer Scholars program involved five one-week sessions and reached 100 students.

Teacher Workshops
- SPLASH is collaborative effort among high school science and social science teachers, scientists, and science educators to create and implement a regionally focused water curriculum. The project has a goal of creating and implementing a curriculum (in Arizona and New Mexico) that emphasizes hydrologic literacy in the context of the semi-arid southwest. SPLASH seeks to simultaneously advance understanding of regional (semi-arid) hydrology and general water literacy (studied within the context of the semi-arid U.S.).
- Inquiry and Water Issues is a two-week workshop for high school teachers is aimed not only at increasing their hydrologic literacy, but also to give them much needed experience engaging in inquiry themselves, developing authentic research skills and analyzing complex (interdisciplinary) information. We were able to hold small workshops with the help of two master teachers and many hours of preparation.

Internships
- Our Research Experiences for Undergraduates program will be modified to actively recruit minority students and students from local community colleges. Based on early findings of research on our REU program, we will institute monthly colloquia meetings for students and mentors so that they may more clearly articulate hydrologic content and science research culture. We anticipate continuing to support 15 REU students annually.
High school interns are chosen annually to help support various research efforts using leveraged funds. The emphasis is on summer fieldwork. We work with science teachers in Tucson high schools that have significant underrepresented populations to identify prospective students for the program. Most interns have enrolled at the UA upon high school graduation and are majoring in science or engineering disciplines. During the summer of 2003, we supported two female minority interns.

Non-science interns: In order to stimulate creative ideas and provide support for non-expert students to explore a wide range of projects related to water sustainability in semi-arid regions, SAHRA funds around eight undergraduates per year who develop a project proposal with a non-SAHRRA faculty member. These proposals are fairly simple and of limited duration, but do provide the student with a realistic proposal process experience. For example, one currently funded project is exploring ways to use industrial reclaimed water for revegetation projects around maquiladoras in Nogales, Sonora, Mexico.

**Graduate Education**

- Hot Topics in Surface Water Hydrology is a seminar class taught every other spring to introduce SAHRA graduate students to the latest interdisciplinary science and policy issues related to semi-arid hydrology. The class is largely built around student presentations on topics selected in conjunction with the instructor. Recent topics have included regional water balances using remote sensing, riparian zone biogeochemistry, and the economics of desalination.
- The Graduate Seminar Program is offered every other spring to help assimilate new graduate students into the interdisciplinary focus of SAHRA. Postdoctoral research associates contribute by reviewing the innovative science and relevant water management issues within their areas of expertise. Participating students learn more about how their project integrates with the Center by making presentations to the rest of the class covering a topic of particular interest. SAHRA scientists lead discussions of fundamental research, management and policy issues that the students will face during their tenure with the Center.

**Professional Programs**

- Environmental Education Outreach & Institute for Tribal Environmental Professionals (EEOP/ITEP) – SAHRA provides travel and participant support matching funds to NAU programs to develop, demonstrate and support K-12 water resources and water quality education throughout the Four Corners region. The purpose of this partnership is to train teachers who will incorporate the teaching of water and water quality in their science curriculum, and to stimulate students to learn about water and water quality problems that affect their tribal areas. Additionally, we believe this early exposure to water issues and science is crucial to recruiting more college-bound students into our degree program. Workshops and knowledge transfer supported, in part by SAHRA, over the last year include: 1) *Tribal Schools Ecological Monitoring Program* (TSEMP) workshop involving a three-day long education program organized and given in cooperation with The Nature Conservancy (TNC) and Navajo Nation Environmental Protection Agency (NNEPA); 2) *Summer Scholars program* (discussed above); and 3) *School visits* to provide classroom presentations and teacher workshops in tribal schools in throughout Arizona.
- The MS in Water Resource Engineering (MSEng) Professional Degree Program was initially set up to facilitate mid-career academic and professional advancement. At the UA, SAHRA offers an intensive one-semester on-campus stay to allow participants to pick up key specialty courses and develop rapport with a faculty advisor, supplemented by a professional project undertaken at the student’s home agency, and additional master’s level coursework that may be completed through distance learning or at an institution of the student’s choosing. This interdisciplinary academic program includes classes in natural resource economics, water law, and environmental ethics. In place of a traditional thesis, a professional project and report related to the student’s work situation
serves as the capstone project. The Army Corps of Engineers is sending four students to this program in Fall 2003, and up to 15 students are expected to begin in Fall 2004.

**K-12 Programs**

- SAHRA supports field trips involving data collection and hands-on learning opportunities for science classes and science clubs from high schools with large numbers of Hispanic, Native American and other minority students, such as trips by Amphitheater High School students to Mt. Graham to do tree surveys.
- The GLOBE/SAHRA collaboration also allows us to target schools with significant populations of underrepresented groups and have them participate in data gathering, to help them gain experience that is directly relevant to water research efforts. We are working to further develop a network of schools along the borders. GLOBE students are tasked with regular and special sample collection, while SAHRA scientists and students will work with the schools to show how the student measurements can be integrated with their scientific datasets for a more complete physical picture of the water balance and water quality. Initial focus areas are the Rio Grande, San Pedro and Four Corners areas. A salinity and water solute sampling program is being set up this fall along the Rio Grande. Native American schools throughout the Four Corners region, where we have existing teacher training and support efforts, will evaluate their regional hydroclimatology within the constraints of GLOBE and SAHRA.

**2b. Impact of the Programs/Activities on Enhancing Diversity**

SAHRA’s education and knowledge transfer programs are successfully reaching the broad audiences they were designed to reach. We have found that interest in water resources management and sustainability are widespread. Nonetheless, changes in academic diversity profiles take time, particularly at the faculty level. There is no question that more faculty recognize the importance of these issues than ever before. Overall, enrollment of women and Native Americans in our programs has increased.

In the past, we have followed a traditional model for recruiting targeted and underrepresented students to the University. However, these standard practices of aggressive follow-up on minority applications, word-of-mouth recommendations, regional networking and mentoring high school and undergraduate students have yielded steady interest and significant applications from women (45% student ratio) and Native Americans (one Navajo, PhD candidate, one Taos Pueblo MS candidate; one Tohono O’odham December applicant, and one Navajo HS summer intern). We are currently exploring career opportunities with the Hopis as well.

**2c. Plans**

Our diversity plan has always been to focus on locally under-represented populations, particularly Native American and Hispanic students, by building career pathways (e.g., introducing the basics of hydrologic literacy in K-12 classrooms on the reservation [Nelson] and by developing SPLASH, with its emphasis on the diverse 9-12 classrooms of southwest urban school districts [Hancock]). Hispanics are a critical part of the culture and general population of the southwest, especially in the border region with its unique water issues and where considerable SAHRA research and knowledge transfer is focused. Native American tribes control huge amounts of land and water, some of which will be the basis of significant negotiations in the near future. Thus, SAHRA is targeting significant resources to both Hispanic and Native Americans as stakeholders, not just as students.
Meeting our diversity goals of encouraging the enrollment of underrepresented groups in postsecondary science degrees and advancing the hydrologic literacy of all stakeholders has been a challenge. We are currently developing a diversity plan to guide and strengthen our efforts. That plan will include targeted recruiting and scholarships for graduate enrollment, specific undergraduate REU opportunities, greater involvement with CREST centers, greater participation with other university minority programs, and encouraging tribal participation in watershed cooperative groups. Many tribes in the Southwest employ water and natural resource scientists who are graduates of the institutions involved in SAHRA. We will formalize our relations with these groups to increase recruitment of tribal students into our programs.

The University of Arizona announced in August 2003 the creation of a new position at the vice president level that will work toward the goal of increasing the numbers of Hispanic students at the UA from 11 percent to 25 percent. We look forward to working closely with this new office to meet our common objectives. Also this fall, we are working with other Earth Science and Engineering NSF centers to collaboratively recruit and discuss career opportunities with interested students at SACNAS and AISES. At the same time, NSF has funded several new diversity initiatives to support recruitment and internships. We are actively participating in two of the three programs. We are also exploring building more direct relationships with Tribal Colleges (like Dine College) and other community colleges in the Southwest (such as Pima Community College).
VII. MANAGEMENT

1a. Organizational Strategy and Its Underlying Rationale

The Center’s organizational strategy and underlying rationale have not changed. An organization chart was not included in the last annual report. A current version is attached as Appendix B.

As reported elsewhere in this document, the Center’s management is undergoing a transition. At the External Advisory Board meeting in May 2003, W. James Shuttleworth was proposed and accepted as Interim Director and Thomas Maddock III as Interim Deputy Director. Both officially assumed office August 18, 2003. Dr. Shuttleworth replaces Soroosh Sorooshian, who has accepted a position at the University of California, Irvine. Dr. Maddock replaces Roger Bales, who has accepted a position at the University of California, Merced. SAHRA is issuing subcontracts to the University of California campuses at Irvine and Merced to allow Drs. Sorooshian and Bales to continue their SAHRA research and involvement; both will continue on the SAHRA Executive Committee and remain as co-PIs for the Center.

1b. Performance and Management Indicators

SAHRA will measure the performance of management via the performance indicators listed below:

Indicators related to strategic planning (descriptive) [internally judged to be helpful]
- List of planning and coordination activities
- List of review activities
- List of planning documents

Indicators related to support for research, education, and knowledge transfer activities. [overall increase support in each area]
- List / Descriptions of Center infrastructure (space, furnishings, computer systems, communication network, supplies, laboratories and field sites)
- List of scientific, technical, and administrative staff
- Statistics regarding staff retention and development
- Description of structures developed and used to facilitate management of finances (budgeting, accounting, disbursement)
- Number / List of grant proposals submitted to NSF and other funding sources
- Description of structures developed and implemented to:
  - facilitate communication
  - manage information (collecting, organizing, disseminating)
  - coordinate activities (meetings, workshops, report preparation, project reviews)
  - coordinate and prepare documentation
  - recruit and support students towards achieving their educational and professional goals

Performance indicators related to meeting contractual obligations to NSF [100% of obligations met]
- List of contractual obligations met (with comments)

Performance indicators related to promotion of Center activities [increase # of each]
- List of statistics that monitor Web site access and usage
• List / Summaries of information provided to the public and to the media, and articles, stories, and broadcasts that resulted
• List / Summaries of participation by Center representatives in conferences, meetings, and visits to other organizations/institutions
• List / Summaries of participation by Center representatives on key committees and research initiatives

Performance indicators related to achieving post-NSF sustainability
• List / Summaries of grant proposals (submitted / awarded) to non-NSF funding sources [increase #]
• List / Descriptions of successful/unsuccessful efforts to seek out and nurture cooperative/collaborative relationships with other organizations and individuals [increase # successful]
• List / Descriptions of access to and usage of SAHRA infrastructure (field sites, laboratories, equipment, etc.) by non-SAHRA members of water resources community [increase #]
• Evidence (including testimonials) to create and maintain a physical and psychological organizational environment that is exciting and rewarding for Center participants (including staff) and which promotes creativity, growth and long-term involvement [internally judged to be helpful]
• Evidence (including testimonials) to create and maintain an organization that is externally considered to be valuable to the water resources community and therefore worthy of continued existence [increase # testimonials]

1c. Problems During the Reporting Period and Anticipated for Year 5

There have been no changes to the Center’s organizational strategy and management objectives. No major problems were encountered in Year 4.

2. Management and Communications Systems

A comprehensive Online Management System (OMS) has been developed, tested, and is being used as of May 2003 at SAHRA to collect data on research, education, knowledge transfer, diversity, personnel, and management for future reports and to help us to evaluate our own efforts. We will continue to enhance the system and seek to improve its compatibility with NSF reporting requirements. The OMS aims to 1) serve as a centralized repository of current information on SAHRA personnel, projects, resources, and activities, and 2) eliminate the duplication of effort previously required to request, research, obtain, and compile data for numerous reports.

The system was complicated and time-consuming to develop, due to the vast amount of data to be collected and the number and diversity of SAHRA activities and participants. Further changes to the system will be required for the following reasons: 1) the shifting nature of NSF’s reporting requirements; 2) to adequately and accurately reflect SAHRA’s evolving focus from thrust areas to theme areas; and 3) to ensure compatibility with our strategic plan and performance and management indicators, which are still under review by the Executive Committee.
3. Internal and External Advisors

Minutes of the External Advisory Committee meeting are attached as Appendix C.

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<tr>
<th>Name</th>
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<tbody>
<tr>
<td>1 Devendra Lal, Scripps Institute of Oceanography</td>
<td>External Advisory Board, Chair</td>
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<tr>
<td>2 Susan Avery, Univ. of Colorado</td>
<td>External Advisory Board member</td>
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<tr>
<td>3 John Bernal, Pima County, AZ Public Works</td>
<td>External Advisory Board member</td>
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<td>4 Peter Eagleson, MIT</td>
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<td>5 Julie Luft, Univ. of Texas at Austin</td>
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<td>6 Charles Howe, Univ. of Colorado</td>
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<td>7 Harold Mooney, Stanford Univ.</td>
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<td>8 Bonnie VanDorn, Assoc. of Science-Technology Centers</td>
<td>External Advisory Board member</td>
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<td>9 David Goodrich, USDA-ARS</td>
<td>Executive Committee member</td>
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<td>10 Fred Phillips, NMT</td>
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<td>11 Everett Springer, LANL</td>
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<td>12 Juan Valdés, UA</td>
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<td>13 David Brookshire, UNM</td>
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<td>14 Diana Liverman, UA</td>
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<td>15 Stanley Leake, USGS</td>
<td>Executive Committee member</td>
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4. Changes to the Strategic Plan

The Center’s strategic plan is under development through a series of meetings, workshops, and retreats. A copy of the draft strategic plan is available on request. There are no major changes to report at this time.
VIII. CENTER-WIDE OUTPUTS AND ISSUES

1a. Center Publications

Peer-reviewed:


Burness, S., and J. Little, Municipal water conservation policy: Options and design, submitted to Land Economics.

Burness, S., and J.M. Chermak, Sustainability, incentives and behavioral models of resource use, submitted to Nat. Resour. J.


Furman, A., T.P.A. Ferré, and A.W. Warrick, Optimization of ERT Survey for rapid hydrological measurement using perturbation sensitivity approach and genetic algorithm, submitted to Vadose Zone J.


Han, J., and J. Roads, U.S. climate sensitivity simulated with the NCEP regional spectral model, forthcoming in J. Climate Change.

Harlow, R.C., E.J. Burke, and T.P.A. Ferré, Measuring water content in saline sands using impulse time domain transmission techniques, forthcoming in Vadose Zone J.
Harlow, R.C., E.J. Burke, T.P.A. Ferré, J.C. Bennett, and W.J. Shuttleworth, Measuring spectral dielectric properties using gated time domain transmission measurements, forthcoming in Vadose Zone J.


Kim, T., C. Yoo and J.B. Valdés, A nonparametric approach for estimating effects of ENSO on return periods of droughts, submitted to *KSCE J. of Civil Eng.*


Roads, J., Experimental weekly to seasonal, global to regional U.S. precipitation forecasts, submitted to *J. Hydrology*.


Uyeda, S., J. Madden, J.A. Luft, and J. Washburne, Using PBL to connect school to the real world, submitted to *Science Teacher.*


Wagener, T., Evaluation of catchment models, forthcoming in *Hydrological Processes.*


Zhu, J., B.P. Mohanty, and A.W. Warrick, Correspondence and upscaling of hydraulic functions for steady state evaporation in heterogeneous soils, submitted to Vadose Zone J.

Books and book chapters:


**Non-peer reviewed:**


**Theses and dissertations:**


McHugh, K., Western water law and the stream-aquifer system and how models are used to determine permitting and compliance of rules governing ground and surface water interaction, MS Thesis, Hydrology, University of Arizona, 2003.


Wilder, M.O., In name only: Water policy, the state, and ejidatario producers in northern Mexico, Ph.D. Thesis, Geography and Regional Development, University of Arizona, 2002.


1b. Conference Presentations


Brookshire, D.S., Restoration, replacement, or acquisition of damaged groundwater resources, public forum presentation sponsored by the New Mexico Office of Natural Resources Trustees, Sept. 2002.


Eastoe, C., Isotope geochemistry and groundwater studies, invited talk presented at Universidad Autónoma de Ciudad Juarez, Nov. 2002.


Gupta, H.V., Advances in automatic calibration of watershed models, invited talks presented at the Departments of Civil Engineering of the University of California, Berkeley, California, and Utah State University, Logan, Utah, Mar. 2003.


Hancock, E. S., and J. Washburne, J., Considerations for sustained research: A specific case, round table discussion presented at the Annual Meeting of the Nation Science Foundation Research Center Educators Network, Santa Cruz, CA, Oct. 2002.
Hancock, E. S., J. Washburne, and B. Austin, Hydrologic literacy among undergraduate non-science majors, poster presented at the Annual Meeting of the Association for the Education of Teachers in Science, St. Louis, MO, Jan. 2003.


Mills, S., Quantifying salinization of the upper-middle Rio Grande using a basin-scale water and chloride mass balance model, talk given at the American Geophysical Union fall meeting, San Francisco CA, Dec. 2002.


Mohanty, B.P., and J. Zhu, Guidelines for aggregating hydrologic parameters from local scale to model scale, paper presented at the EGS-AGU-EUG Joint Assembly, Nice, France, Apr. 2003.


Moreno, D., Asociación Regional Ambiental Sonora-Arizona: Grassroots environmentalism along the U.S.-Mexico border, presented at HELP Symposium, "Towards Integrated Catchment Management:


Small, E., Dynamics of evapotranspiration in semiarid grassland and shrubland during the summer monsoon season, central NM, paper presented at the Chapman Conference on Ecohydrology, Taos, NM, Sept. 2002.


Sorooshian, S., presentation at the Los Alamos National Laboratory 60th Anniversary Meeting on Water, Drought and New Mexico Science Vision, Santa Fe, NM, April 2003.

Sorooshian, S., Global water resources issues: The role of desalination in a sustainable water supply, presented at the Straw Bale Forum, Hat Ranch, Williams, AZ, July 2003.


Sorooshian, S., H.V. Gupta and T. Wagener, Two decades of advances in watershed model identification, invited talk presented at the EGS-AGU-EUG Joint Assembly, Nice, France, Apr. 2003.


Valdés, J.B., Climate change and variability impact on semi-arid region basins, paper presented at the ZEF Center for Development Research, University of Bonn, Bonn, Germany, July 2002.

Valdés, J.B., Climate variability and change in the La Plata Basin, paper presented at the Conference on Global Change and Large Scale Basins, University of Litoral, Santa Fe, Argentina, June 2003.


Valdés, J.B., chaired the session on drought at the Annual Meeting of the American Geophysical Union, San Francisco, CA, Dec. 2002


Wilson, J.L., H. Guan, and L. Goodwin, Modeling investigation of mountain front recharge from typical mountain blocks, paper presented at the GSA annual meeting, Denver, Colo., 2002.

Woodard, G., Disaggregating residential water demand for improved forecasts and decision making, paper presented at the EGS-AGU-EUG Joint Assembly, Nice, France, April 2003.
Woodard, G., Knowledge transfer initiatives for arid and semi-arid regions: support for improved forecasts and decision making, presented at UNESCO meeting, Paris, France, April 2003.


1c. Other Dissemination Activities

SAHRA’s research results are being widely disseminated through national science radio programming. SoundPrint interviewed several SAHRA researchers for Water is Gold, a 28-minute piece in its Series on Models and Forecasting, which aired on National Public Radio on November 25, 2002. SAHRA developed a companion website, “Water in the Desert,” for SoundPrint KJZZ in Phoenix to complement the airing of the program (see http://water.soundprint.org/) and provide additional information and resources related to drought and arid/semi-arid lands of the Southwest.

SAHRA’s education and knowledge transfer programs were more widely disseminated as a result of efforts by Dana Flowers, funded by State of Arizona Prop. 301 funds. Ms. Flowers is involved in cross-training water educators from throughout Arizona in each others’ programs and familiarizing them with SAHRA’s programs. She has developed media contacts and ties in the Phoenix metropolitan area.

With UA’s Institute for the Study of Planet Earth, SAHRA also initiated a series of drought briefings for media professionals in Tucson, Phoenix, and Albuquerque, beginning in July 2002. The following SAHRA participants made presentations:

**Tucson, July 22, 2002:**
Gary Woodard, “Drought-related research and forecasts”
Soroosh Sorooshian, “Fire impacts on watersheds’ infiltration, runoff, and siltation”

**Phoenix, August 26, 2002:**
Gary Woodard, “The demand side of drought: limits to conservation”
Soroosh Sorooshian, “Fire impacts on watersheds’ infiltration, runoff, and siltation”

**Albuquerque, September 26, 2002:**
Gary Woodard, “Drought-related research and forecasts”
Soroosh Sorooshian, “Fire impacts on watersheds’ infiltration, runoff, and siltation”
Eric Small, “Drought, vegetation, and water cycling in the semiarid southwest”
Fred Phillips, “Drought and salts in the Rio Grande”

**Tucson, January 9, 2003:**
Roger Bales, “Snow measurement, melt, and runoff research in the Santa Catalinas”
Gary Woodard, “Using near-real time data in knowledge transfer and education: Sabino Canyon gauges”

**Phoenix, March 20, 2003:**
Noah Molotch, “Snow measurement, melt, and runoff research at the University of Arizona”
(Presenters also included Arizona Governor Janet Napolitano, who spoke on Arizona’s role in
drought planning and fire risk management, and issued a proclamation establishing the state’s
first Drought Planning Commission.)

2. Awards/Honors

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<tr>
<th>Recipient</th>
<th>Reason for Award</th>
<th>Award Name and Sponsor</th>
<th>Date</th>
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<td>Luis Bastidas</td>
<td>elected</td>
<td>Vice President of the International Commission for Atmosphere, Soil, Vegetation Relations (ICASVR) of the International Association of Hydrological Sciences (IAHS)</td>
<td>July 2003</td>
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<td>Karletta Chief</td>
<td>academic merit</td>
<td>Don &amp; Betty Chastain Trust Scholarship, UA American Indian Scholarship Committee</td>
<td>May 2003</td>
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<td>Kevin Dressler</td>
<td>travel award to the 2003 IUGG General Assembly in Sapporo, Japan.</td>
<td>AGU Young Scientist Travel Grant, American Geophysical Union</td>
<td>July 2003</td>
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<td>Kevin Dressler</td>
<td>poster presentation at the 13th Annual El Dia del Agua at University of Arizona</td>
<td>Hargis Award: Best Poster Presentation, Hargis and Associates, Inc.</td>
<td>April 2003</td>
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<td>Brenda Ekwurzel</td>
<td>for excellence in teaching at the University of Arizona Department of Hydrology and Water Resources (HWR)</td>
<td>Aquaman Award for Excellence in Teaching, Hydrology and Water Res. Student Assn. (UA)</td>
<td>2003</td>
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<tr>
<td>Brenda Ekwurzel</td>
<td>excellence in teaching and student guidance.</td>
<td>Award for Excellence at the Student Interface, UA College of Engineering and Mines - HWR</td>
<td>May 2003</td>
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<td>Ali Faridhosseini</td>
<td>outstanding GPA</td>
<td>World Lab Fellowship, World Lab</td>
<td>2002/03</td>
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<td>Ty Ferré</td>
<td>the twelfth university professor to receive this national award for contributions to the USGS mission</td>
<td>John Wesley Powell Award, USGS</td>
<td>March 2002</td>
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<td>(previously unreported)</td>
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<tr>
<td>Ty Ferré</td>
<td>First recipient of this award, which recognizes scientists who have made outstanding contributions in Soil Physics within six years of completing a Ph.D.</td>
<td>S-1 Early Career Award, Soil Physics section of Soil Science Society of America</td>
<td>Nov. 2002</td>
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<td>Dave Goodrich</td>
<td>academic achievement</td>
<td>Alumni Achievement Award</td>
<td>May 2003</td>
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<td>11</td>
<td>Hoshin Gupta</td>
<td>Elected</td>
<td>President of the ICASVR of the IAHS</td>
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<td>12</td>
<td>Andrew Hinnell</td>
<td>merit and financial need</td>
<td>Kenneth D. Schmidt HWR Surface Water Field Camp Scholarship, HWR Foundation</td>
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<td>Andrew Hinnell</td>
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<td>Andrew Hinnell</td>
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<td>Jessica Jensen</td>
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<td>Datatel Scholarship, Datatel Foundation</td>
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<td>21</td>
<td>Jessica Jensen</td>
<td>environmental service and outreach</td>
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<td>Suzanne Mills</td>
<td>for oral presentation</td>
<td>Outstanding student paper award, AGU</td>
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<td>23</td>
<td>Noah Molotch</td>
<td>best oral presentation</td>
<td>The Montgomery Prize, Erol Montgomery and Associates and HWR</td>
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<td>24</td>
<td>Noah Molotch</td>
<td>writing competition</td>
<td>Graduate Student Scholarship, HWR</td>
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<td>John Roads</td>
<td>for developing a coordinated water and energy budget synthesis</td>
<td>GCIP Award, GCIP Management</td>
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<td>26</td>
<td>Soroosh Sorooshian</td>
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<td>member, National Academy of Engineers</td>
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<td>27</td>
<td>James Shuttleworth</td>
<td>for providing consistent quality program direction and guidance to GCIP</td>
<td>GCIP Award, GCIP Management</td>
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<td>28</td>
<td>Steven Uyeda and Dan Potts</td>
<td>best of show poster in Academic Showcase</td>
<td>First Place - Graduate Student Ed.Division, UA Graduate and Professional Student Council</td>
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3. Undergraduate, M.S. and Ph.D. Graduates During Year 4

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<td>Ken Bagstad (ASU)</td>
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<td>Tim Bardsley (DRI)</td>
<td>M.S. Hydrol.</td>
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<td>Luis Bastidas (UA)</td>
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<td>Eric Edwards (UA)</td>
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<td>Teri Gorham (DRI)</td>
<td>M.S. Hydrol. Sci.</td>
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<td>Jennifer Hamblen (UA)</td>
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<td>Sung-ho Hong (NMT)</td>
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<tr>
<td>Kevin Hultine (UA)</td>
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<td>pursuing Ph.D., U Wyo.</td>
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<tr>
<td>Anne Huth (UA)</td>
<td>Ph.D., Hydrol.</td>
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<td>maternity break</td>
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<td>Jiming Jin (UA)</td>
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<td>Newsha Khodatalab (UA)</td>
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<td>David Lawler (UA)</td>
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<td>P. Phillips (NAU)</td>
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<td>Srinivasa Raghava Krishnamurthy (UA)</td>
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<td>G. Seymour (NAU)</td>
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<td>Jennifer Shepherd (UA)</td>
<td>M.S. Geog. &amp; Reg. Devt.</td>
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<tr>
<td>Leah Stauber (UA)</td>
<td>M.A. Anth.</td>
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<tr>
<td>John Villinski (UA)</td>
<td>postdoc</td>
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<td>pursuing career as photographer</td>
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<tr>
<td>Soni Yatheendradas (UA)</td>
<td>M.S. Hydrol.</td>
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<td>Enrico Yepez (UA-Ag)</td>
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<td>continuing on for Ph.D.</td>
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4a. Patents, Licenses, and Start-Ups

None to report.

4b. Other Outputs of Knowledge Transfer Activities

None to report.
### 5. Participants and Affiliates

<table>
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<tr>
<th>Participant Name</th>
<th>Category</th>
<th>Institutional Affiliation</th>
<th>Department (if applicable)</th>
<th>Gender</th>
<th>Disability Status</th>
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<tr>
<td>Beery Adams</td>
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<tr>
<td>Javier Aparicio</td>
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<td>Hydro Tech</td>
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<td>Barb Austin</td>
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**Category:** (a) undergraduate students, (b) graduate students, (c) faculty, (d) visiting faculty, (e) other research scientists, (f) postdoctorates, (g) pre-college students, (h) teachers, (i) educators and (j) other participants (click underlined terms for definitions)

**Institutional Affiliation Key**
- Col Bios = Columbia University, Biosphere 2
- CSU = Colorado State University
- CSU-LA = California State University, Los Angeles
- CUNY = City University of New York
- DRI = Desert Research Institute
- IMADES = Instituto del Medio Ambiente y Desarrollo Sustenable del Estado de Sonora
- IMTA = Instituto Mexicano de Tecnología del Agua
- ITSON = Instituto Tecnológico de Sonora
- LANL = Los Alamos National Laboratory
- LBNL = Lawrence Berkley National Laboratory
- MUSD = Marana Unified School District
NAU = Northern Arizona University
NMSU = New Mexico State University
NMT = New Mexico Institute of Mining and Technology
PSU = Penn State University
Sandia = Sandia National Laboratory
SVPS = Sierra Vista Public Schools
Tex AM = Texas A&M
TUSD = Tucson Unified School District
UA = University of Arizona
UACJ = Universidad Autónoma de Ciudad Juarez
UAM-X = Universidad Autónoma Metropolitana-Xochimilco
UC = University of Colorado, Boulder
UCR = University of California, Riverside
UniSon = Universidad de Sonora, Hermosillo
UNM = University of New Mexico
USDA-ARS = Agricultural Research Service, U.S. Dept. of Agriculture
USGS = U.S. Geological Survey
USSL-ARS = U.S. Salinity Laboratory, Agricultural Research Service, USDA
USU = Utah State University
UT = University of Texas, Austin
UW = University of Wyoming
WRRC = Water Resources Research Center

Department Key
ARE = Agricultural and Resource Economics
BioAg Eng = Biological and Agricultural Engineering
BMB = Biochemistry and Molecular Biphysics
CEE = Civil and Environmental Engineering
CEEM = Civil Engineering and Engineering Mechanics
CES = Center for Environmental Studies
CLAS = Center for Latin American Studies
Coop Ext = Cooperative Extension
Curr Inst = Curriculum and Instruction
EDAC = Earth Data Analysis Center
EEB = Ecology and Evolutionary Biology
EES = Earth and Environmental Sciences
ECPC = Experimental Climate Prediction Center
Flandrau = Flandrau Science Center
GLOBE = Global Learning and Observations to Benefit the Environment
HWR = Hydrology and Water Resources
ITEP = Institute for Tribal Environmental Professionals
PC = Politics and Culture
RNR = Renewable Natural Resources
SWES = Soil, Water, and Environmental Sciences
Udall = Udall Center for Studies in Public Policy
WRRI = Water Resources Research Institute

Key to all other categories
Gender: Female (F), Male (M).
Disability: Hearing Impairment (HI), Visual Impairment (VI), Mobility/ Orthopedic Impairment (M/OI), Other (O), None.
Ethnicity: Hispanic or Latino (H/L), Not Hispanic or Latino (Not H/L).
Race: American Indian or Alaskan Native (AI), Asian, Black/African American(B/AA), Native Hawaiian or Other Pacific Islander, White.
Citizenship: U.S. Citizen (US), Permanent Resident (PR), Other non-U.S. Citizen (other non).
## 6. Non-academic Partners

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<td>Moffett Field, CA</td>
<td>Dixon Butler</td>
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<td>31</td>
<td>HyDIS</td>
<td>other</td>
<td>University of Arizona, Tucson, AZ</td>
<td>Soroosh Sorooshian</td>
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<td>33</td>
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<td>other</td>
<td>Vienna, Austria</td>
<td>John Gibson</td>
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<td>Brenda Bobinsky</td>
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<td>Diane Dalbotten</td>
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<td>41</td>
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<td>Upper San Pedro Project; Tucson Office</td>
<td>Holly Richter</td>
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<td>Rolf Schmidt-Peterson</td>
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<td>Jim Gosz</td>
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<td>Soc. for the Advancement of Chicanos &amp; Native Americans</td>
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<td>Jo Falls</td>
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<td>Tucson Unified School District</td>
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<td>1010 E. 10th St., Tucson, AZ</td>
<td>Gail Paulin, Rachel Hughes</td>
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<td>56</td>
<td>U.N. Educational, Scientific &amp; Cultural Org. (UNESCO)</td>
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<td>Paris, France</td>
<td>Abdin Salih</td>
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<td>USGS, Tucson Office</td>
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<td>USGS, NASQAN Program</td>
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<td>Reston, VA</td>
<td>Rick Hooper</td>
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<td>Ian Pepper</td>
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<td>Ft. Apache, AZ</td>
<td>Laurel Lacher</td>
<td>Div., KT</td>
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<td>Yavapai County Water Advisory Committee</td>
<td>other</td>
<td>Prescott, AZ</td>
<td>John Munderloh</td>
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7. Summary Table

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<th>the number of participating institutions (all academic institutions that participate in activities at the Center)</th>
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<td>2</td>
<td>the number of institutional partners (total number of non-academic participants, including industry, states, and other federal agencies, at the Center)</td>
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<td>4</td>
<td>the total leveraged support (sum of funding for the Center from all sources other than NSF-STC)</td>
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8. Media Publicity

Miscellaneous Articles:

Joey Bunch, “Water too cheap to conserve, prof says,” Denver Post, 17 February 2003. (David Brookshire interview on how the cost of water hinders conservation)

“Featured partner: SAHRA at the University of Arizona,” CEA-CREST Quarterly, Fall 2002. (describes new CEA-CREST/SAHRA partnership)

“Lessons in H2O,” Herald Review, 8 November 2002. (describes Water Wise education program used by Buena High School students)

“Region 7 report,” Arizona Science Teachers Association Newsletter, Fall 2002. (more on Buena High and the WaterWise program)

Marwaan Macan-Markar, “Porto Alegre, una isla,” Tierramerica, (quotes Juan Valdes at Third World Water Forum in Kyoto, Japan, on water resources in Mexico, 26 March 2003.)
(talks about upcoming move into new Marshall Building by UA tenants, including SAHRA)

(covers LANL and SAHRA research, discussed at public meeting, “Water, Drought, and New Mexico.” Quotes Soroosh, Costigan, Brookshire.

(article on NSF’s SGER grant to SAHRA to study effects of Aspen Fire on post-fire soil and runoff)

(feature article on the new Sabino canyon display and kiosk)

(covers the Nature Conservancy’s purchase of 2,156 acres of land on San Pedro for conservation and research efforts).

Weather forecasters from KGUN-TV, Tucson (ABC affiliate) and KVOA-TV Eyewitness News, Tucson (NBC affiliate) used webcam shots from Mount Bigelow in March 2003 to show snow, and credited the “SAHRA webcam.”

**Publicity Resulting from SAHRA media briefings:**

**from Tucson 7/22/02 briefing:**
“Drenching nice, but drought’s a long way from over,” *Tucson Citizen*, 23 July 2002.

Jeff Harrison, “Drought to stay with us,” Jeff Harrison, uanews.org, 22 July 2002.


**from Phoenix 8/26/02 briefing:**

**from Tucson 10/18/02 briefing:**
“UA Hydrologists create Sabino creek exhibit,” LQP Faculty & Staff News listserv and uanews.org, 22 October 2002.

**from Tucson 1/9/03 briefing:**

**from Phoenix 3/20/03 briefing:**


**TV/radio coverage:**
Local TV stations in the metropolitan Phoenix and Tucson areas also covered the media briefings. These include:

- KATA Radio, Phoenix
- KGUN, Channel 9 Tucson (ABC)
- KNXV, Channel 15 Phoenix (NBC)
- KPHO News 5, Phoenix
- KPNX News 12, Phoenix
- KRVI Radio, Ruidoso, NM
- KSAZ, Channel 10 Phoenix (FOX)
- KUAZ/KUAT Radio, Tucson
- KUNM Radio, Albuquerque
- KVOA EyeWitness News, Channel 4 (NBC)
IX. INDIRECT/OTHER IMPACTS (Optional)

Nothing to report.
APPENDIX A
Biographical Sketch – TRAVIS E. HUXMAN

Department of Ecology and Evolutionary Biology  Tel: (520) 621-8220
University of Arizona  Fax: (520) 621-9190
Tucson, AZ  85721  E-mail: huxman@email.arizona.edu

A. PROFESSIONAL PREPARATION

CA. State Univ. San Bernardino  Biology  B.S., 1993
CA. State Univ. San Bernardino  Biology  M.S., 1996
University of Nevada, Las Vegas  Biology  Ph.D., 2000
University of Colorado, Boulder  Biology  2000-2001

B. APPOINTMENTS
Assistant Professor  Department of EEB, University of Arizona  2001- present
Postdoctoral Associate  Department of EPO Biology, UC-Boulder  2000-2001
Research Assistant  Department of Biological Sciences, UNLV  1996-2000

C. PUBLICATIONS

FIVE MOST RELEVANT
Response of net ecosystem gas exchange to a simulated precipitation pulse in a semiarid
Interannual and seasonal variation in fluxes of water and CO₂ from a riparian woodland
ecosystem. Agricultural and Forest Meteorology.
metabolism from organisms to ecosystems. Nature 423:639-642
Huxman TE, Turnipseed AA, Sparks JP, Harley PC, Monson RK (2003) Temperature as a control
light and intercellular CO₂ concentration: implications for the evolution of stomatal

ADDITIONAL SIGNIFICANT PUBLICATIONS
Huxman TE, Smith SD (2001) Photosynthesis in an invasive grass and native forb at elevated
Monson RK, Turnipseed AA, Sparks JP, Harley PC, Scott-Denton LE, Sparks K, Huxman TE
8:459-478.
Smith SD, Huxman TE, Zitzer SF, Charlet TN, Housman DC, Coleman JS, Fenstermaker LK,
Seemann JR, Nowak RS (2000) Elevated CO₂ increases productivity and invasive species


D. SYNERGISTIC ACTIVITIES


E. COLLABORATORS

S. Smith – Univ. of Nevada, Las Vegas M. Loik – Univ. of California, Santa Cruz
E. Hamerlynck – Rutgers Univ. R. Monson – Univ. of Colorado
J. Sparks – Univ. of Colorado D. Thompson – Univ. of Nevada, Las Vegas
A. Peterson – Biosphere 2 Facility S. Schwinning – Biosphere 2 Facility
B. Nowak – Univ. of Nevada, Reno L. Venable – University of Arizona
J. Coleman – Desert Research Institute P. Harley – NCAR
D. Williams – University of Arizona B. Enquist – University of Arizona
W.J. Shuttleworth – University of Arizona T. Maddox – University of Arizona
J. Bronstein – University of Arizona G. Davidowitz – University of Arizona
A. Huete – University of Arizona W. Pockman – University of New Mexico
R. Scott – USDA ARS Tucson J. Weltzin – Univ. of Tennessee

F. GRADUATE AND POSTDOCTORAL ADVISORS

Dr. Michael E. Loik, Dept of Environmental Studies, University of California, Santa Cruz
Dr. Stan Smith, Department of Biological Sciences, University of Nevada, Las Vegas
Dr. Russ Monson, Department of EPO Biology, University of Colorado, Boulder

G. THESIS AND COMMITTEE ADVISOR

Alex Eilts – University of Arizona Jessie Cable – University of Arizona
Enrico Yepez – University of Arizona Sergio Castrezana – University of Arizona
Vanya Moreno – University of Arizona Chuck Price – University of Arizona
Daniel Potts – University of Arizona Megan McCarthy – University of Arizona
Cristian Solari – University of Arizona Kate Baird – University of Arizona
Danielle Ignace – University of Arizona
APPENDIX B: SAHRA Organization Chart – Administration and Management

**Founding Director**
Soroosh Sorooshian

**Director**
W. James Shuttleworth

**Interim Deputy Director**
Thomas Maddock III

---

**Program Coordinator**
Rannie Fox

**Business Manager**
Jill Gibson

---

**Accountant**
David Lane

**Office Assistant**
LaQueena George

---

**Science Teams**

- **TA1**
  - Roger Bales, Leader
  - Constance Brown, PDRA
  - Doug Boyle
  - Paul Ty Ferre
  - Xiaoang Gao
  - David Goodrich
  - Kuo-lin Hsu
  - Joe McConnell
  - Binayak Mohanty
  - Jim Shuttleworth
  - Soroosh Sorooshian

- **TA2**
  - Fred Phillips, Leader
  - James Hogan, PDRA
  - Roger Bales
  - Christopher Duffy
  - Christopher Eastoe
  - David Goodrich
  - Jan Hendrickx
  - Devendra Lal
  - Austin Long
  - Eric Small
  - John Wilson

- **TA3**
  - David Goodrich, Leader
  - Martha Conklin
  - Brenda Ekwurzel
  - Paul Ty Ferré
  - Olympic
  - Nancy Grimm
  - Stan Leake
  - Tom Maddock
  - Marcel Schap
  - Russel Scott
  - Julie Stromberg
  - Art Warrick

- **TA4**
  - Everett Springer & Hoshin Gupta, Co-Leaders
  - Thorsten Wagener, Visiting Scientist
  - Roger Bales
  - Hoshin Gupta
  - Luis Bastidas
  - Tom Maddock
  - Bart Nijssen
  - John Roads
  - Diana Liverman
  - Gary Woodard
  - William Yeh

- **TA5**
  - Juan Valdes & David Brookshire, Co-Leaders
  - Steven Stewart, PDRA
  - Janie Chermak
  - John Dracup
  - Kate Krause
  - Kevin Lansey
  - Diana Liverman
  - Tom Maddock
  - Robert Varady
  - Gary Woodard

- **Int’l**
  - Diana Liverman, Leader

---

**Education Team**

- **TA6**
  - Jim Washburne, Leader
  - Elizabeth Hancock, PDRA
  - Dana Flowers
  - Pam Justice
  - Mansel Nelson
  - Aregai Teele

---

**KT Team**

- **TA7**
  - Gary Woodard, Leader
  - Betsy Woodhouse, PDRA
  - Dana Flowers
  - Pam Justice
  - Mansel Nelson
  - Aregai Teele

---

**Technical Support**

- John Petti, Instrument Specialist
- Dean Jones, Support Systems Analyst
- Jim Broermann, Systems Programmer, Senior

---

**Marketing & Web**

- Gary Woodard, Leader
- Kyle Carpenter
- Brad James
- Database Spec., Mktg & Web

---

**Editors**

- Mary Black

---

**Newswatch**

- Louise Shaler
- Beery Adams
APPENDIX C
SAHRA External Advisory Board
Meeting/Teleconference Minutes
November 25, 2002

Participants:
Advisory Board:  Susan Avery, John Bernal, Peter Eagleson, Charles Howe, Devendra Lal, Harold Mooney, John Schaake, Bonnie Van Dorn
Executive Committee:  Soroosh Sorooshian, Roger Bales, Hoshin Gupta, Gary Woodard, Jim Washburne, Fred Phillips, Larry Winter, Juan Valdes, Diana Liverman
Research Associates:  Constance Brown, James Hogan, Thorsten Wagener; Rannie Fox

PROCEEDINGS:

Introductions of all participants; short intros of new board members Bonnie Van Dorn and John Schaake. Soroosh gave short intro of Julie Luft, also new to the board.

Introductory Comments

Soroosh:

➢ Thanked everyone for joining in the meeting.
➢ Announced that Kenneth Schmidt has resigned from the board, and that Devendra Lal has agreed to be the chair of the board.
➢ In July we submitted our annual report to NSF, and they conducted their site visit in August. Comments from the site visit report were very positive, and we are currently preparing a response to their comments.
➢ NSF has asked us to push forward with the next 5-year proposal, due February 3, and the review panel suggested we ask for the maximum funding amount of 4 million. The renewal proposal is coming together, and we will send a copy to all. There is a limit of about 30 pages. Deadline for submission is February 3.
➢ The NSF Site Visit is scheduled for May 29-30, 2003.
➢ We have conducted several workshops to improve integration, since both the advisory board and NSF have suggested strengthening our efforts there.
➢ Conducted project reviews, requesting that each project submit past accomplishments, future plans, and renewal proposal information. Projects were ranked, and resources were adjusted, taking into consideration how the project fit into the basin scale studies.
➢ We are currently going through a financial audit – we have an outstanding business manager, Jill Gibson, and good people in her office, who have been able to work with the auditors. This is a state audit from the central general auditors office.
➢ We still hope to have a face-to-face meeting with advisory board, perhaps in April, so we can have the benefit of their comments before the site visit. And maybe some would like to attend the site visit as well.

Open Discussion:

Question was asked about the definition of sustainability; Gary indicated that the definition we are using has been posted on the Web in our Glossary. It stresses dynamic water use, not static.
Suggestion was made that we look for patterns, then use that to look at what science needs for the future. Soroosh responded that we agree that this is a good plan, but that we also need to keep in mind the proposal content, that we not move too far beyond what NSF is funding us for, and that we are looking for additional sources of funding for further studies. We are also linked with other studies that focus on complementary topics. We understand that we need to look more at agricultural land; it was suggested that we make sure we don’t lose sight of this important point. We have a post-doc who is an agriculture instructor starting in January who will help in this area.

Science Overview

Hoshin Gupta provided highlights of the last year, including publications, science activities (workshops, tower installed, integration matrix development, project reviews, AGU special sessions), modeling activities, and administration and staffing issues.

The 2003 schedule was provided as follows:
- Renewal proposal, due February 3
- EGS-AGU-EUG Special Session, April 7-11
- NSF Site Visit, May 29-30
- NSF STC Meeting, August 18
- Annual Meeting, October

Knowledge Transfer Overview

Gary Woodard gave an overview of knowledge transfer activities over the past year, including developing teleconferencing rooms for communication within SAHRA; developing the SAHRA Website; presentations to the water community; creating educational opportunities (particularly the Army Corps of Engineers and Mexico); conducting media briefings; and developing Sabino Canyon display. Future plans include increasing leveraging (i.e. Prop 301 funds).

Education Overview

Jim Washburne discussed Education activities, including: Arizona education of students, education of high school teachers, and SPLASH, a student-centric program. We are attempting to develop a full-year curriculum at the high school level. So far we have been keeping programs close to Tucson as we are developing them. The goal for the next couple of years is to finish developing these programs and move them into a larger geographic region. We have a good program for REUs and undergraduate students interested in studying water.

Discussion regarding Education and Knowledge Transfer discussion included comments regarding our interactions with Cooperative Extension, and how these SAHRA programs can be self-sustaining after NSF funding is over, through obtaining other resources.

Diversity Discussion

Jim Washburne led discussion regarding diversity. Some comments included the fact that because SAHRA is a large program, and widely distributed, it is difficult to develop diversity over the full program. We have money to solicit underrepresented populations, and are working with other groups that have underrepresented students, but they also want the same students. In collaboration with the GLOBE program, we are trying to get high school students to collect baseline data for us to use, to help them gain experience. We are working with other groups to develop a network of schools along the borders.
Board Members’ Overall Comments:

Devendra Lal (chair) said that the board will want to look at the renewal proposal, then communicate with each other.

A suggestion was made that we send information of upcoming SAHRA events so the board members can attend when they are available.

Future meeting:

It was suggested that we have an in-person meeting next spring, 1-2 days, perhaps at the end of April. This would be after the renewal proposal was sent, but before the NSF site visit, so we could have direction from the board before meeting with NSF.

Board members still present agreed April 28-30 would be good dates for the meeting. Will check with other board members for consensus.

Soroosh thanked participants for their time, and all signed off.
SAHRA External Advisory Board
Meeting Minutes
April 29, 2003

Present: EAB: Susan Avery, Peter Eagleson, Charles Howe, Devendra Lal, Julie Luft, John Schaake, Bonnie VanDorn; Executive Committee: Soroosh Sorooshian, Roger Bales, Hoshin Gupta, Jim Washburne, Gary Woodard, Fred Phillips, David Goodrich, David Brookshire, Juan Valdes, Everett Springer, Diana Liverman, Stan Leake; Research Associates & Staff: Constance Brown, Anne Browning, Elizabeth Hancock, James Hogan, Steven Stewart, Thorsten Wagener, Kyle Carpenter, Rannie Fox, Mary Black

PROCEEDINGS

Many presentations were PowerPoint slides, and can be found on the SAHRA Web site, www.sahra.arizona.edu.

Introductions made.

Soroosh: We are asking the Advisory Board to help us in planning the direction for the five years of renewal, to continue to advance SAHRA.

NSF and the Advisory Board has always pushed us for how to integrate all the thrust areas. We have added the concept of a basin focus to better accomplish this. We have also had a number of workshops to plan where the various studies fit.

For this meeting, in the presentations, we have separated where we have been and what we plan for the future (new proposal).

We do leverage heavily with other research projects we have.

We went through a project review evaluation at three years, and will be considering how to do the evaluations in the future. Created review teams for each basin.

Management issues:

Centers are large in terms of size – putting a good group of folks together is a critical aspect. We have been fortunate to put a fantastic team together. Owe a lot to Hoshin, and Gary and Jim for stepping in -- good teamwork among them. Also Roger as deputy director, and research associates, James, Thorsten, Constance, Anne, Steve S.

New opportunities have come up for Soroosh and Roger. Soroosh will be taking a position at UC Irvine, and Roger will be taking a position at UC Merced. The Executive Committee has agreed that Jim Shuttleworth will be the best choice to take the role of Director. Hoshin will remain in his position as Associate Director. Soroosh will make available as much time as needed for easy transition. We will be able to tell NSF that we have a good plan in place, and are very comfortable with it. The department has been extremely supportive of the Center. The new building where SAHRA will be housed will be ready by the end of the year. Both Soroosh and Jim Shuttleworth have stopped by the Dean’s office, and the Dean offered to stop by this meeting.
to let the Advisory Board know he is fully on board with the changes. Roger will have a presence at UA until the end of the year (students and some staff). The dean will advertise and interview to replace Roger, Soroosh, and Martha in the spring.

**Presentations**

- Thrust Area 1 Results – Roger Bales – *See slides on Web*
- Thrust Area 2 Results – Fred Phillips – *See slides on Web*
- Thrust Area 3 Results – Dave Goodrich – *See slides on Web*
- Thrust Area 4 Results – Dave Goodrich/Everett Springer – *See slides on Web*
- Thrust Area 5 Results – Juan Valdes – *See slides on Web*
- Thrust Area 5 Results – David Brookshire – *See slides on Web*

**Basin Scale Water Balance**

Have restructured the process of what we are doing to meet our requirements. Cut across the boundaries of the Thrust Areas.

Devendra Lal (EAB Chair) asked that each speaker tell us the new, unexpected results that are leading us in our future directions.

**River Systems** – Future plans

Can’t isolate the river system – need to get a large-scale land ecologist involved.

On matrix (see slides on Web), made decision that we will focus students on the linkages between the boxes rather than in the boxes. Their committees will be more varied than before.

David Brookshire: Summarizing – reminder we will be including the Rio Conchos and Bravo along the Mexico boundary. Need to learn about how Mexico gets their water – we don’t concern ourselves with water quality, but in Mexico that is a concern.

- Moving to a water banking system
- Ajudication – prove that you have a right to the water.
- Difficult to move water from Agriculture to urban.

**Regional Scale Hydrometeorology** – Soroosh Sorooshian

This section is highly leveraged with other projects we have.

We are staying with higher resolution.

John Schaake: This is the science that we could do. The weather service can’t do this science, but SAHRA can.

Soroosh: Emphasize to go to the higher resolution. These are the challenges, and only through more concentrated science.

Hoshin: There is a connection between this and the modeling.
**Integrated Basin Modeling** – Everett Springer – *See slides on Web*

Developing plans to bring all the areas together into the modeling.

*Question* re how we test our models. That will allow us to move ahead.

**Hoshin**: The system is designed to use data from three types of measuring to use the strengths of all three.

**John Schaake**: Hydrologic systems are highly non-linear, and the finer scale you go increases the uncertainty.

**Hoshin**: We want to reflect what kinds of models we want to use for what kinds of research. We think this hasn’t been done anywhere else before – using the different scales on the information to compare.

**International Activities** – Juan Valdes – *see slides on Web*

**John Schaake**: Agree that international needs is a bottomless pit, there are so many needs. There was a lot more diversity in thinking about their approach in Europe than we have – we need to look at diversity.

**Roger**: Data management has become a problem, and we have a priority to set up a way to handle our data. We are accumulating extensive data, and need to set up an interface for it. We have discussed setting up more integrated databases that are user-friendly. We will be seeking leveraged funding. What we’re planning is to link for intra-SAHRA linking to the researchers.

**Discussion**

**Diana**: May want to develop metrics on measuring if you have had the effect you think you have. Maybe we can develop something to show -- whether on the whole or just knowledge transfer. It’s a lot of work, but need to determine if we are doing enough.

**Soroosh**: Most of the renewal proposal was based on the results of the workshops. It is a question of whether we work on a couple of efforts, or on more projects as we promised. Need to be very careful when you talk about the five years, don’t consider it a phase-out – SAHRA is to be continued with other money. Hydrologic sciences needs five more of these centers – we should not be seeing this as an ending, but a beginning.

We need to keep the integration – the loss of this would detract from the Center. Don’t yet see the three or four integrating questions that we are going to answer that brings all of this together. As the EAB gets into these decision support areas, what is the relationship of SAHRA with CLIMAS. These are two very visible programs, how do they relate? Between the two of them will be the opportunity to extend beyond the 10 years.

**Diana**: The relationship with Prop 301 is also important.
Soroosh: The question we hope to address from NSF is: The whole is greater than the parts. We have been able to get Prop 301 funds, and the university needs to keep their promise for funding.

**Education** – Jim Washburne – See slides on Web

The challenge for education and knowledge transfer is how to present the Center to the larger public. This is important to NSF.

**Knowledge Transfer** – Gary Woodard – See slides on Web

Knowledge transfer is similar to education, but without a captive audience.

Introduction of the on-line management system.

*Question:* Lal: On slide of students – how do you quantify, and do you track your contacts?

Jim W: Quantitative is fairly easily tracked. Qualitative is harder to measure.

Liz Hancock: A questionnaire is in the works to measure after students have left – we will be using it.

*Question:* Same question re teachers you have worked with.

Liz: evaluation of those programs is ongoing.

Julie Luft: One of the more exciting things we did is the REU program – to evaluate what those students have really learned. We found that they are not learning the science – they learn the process, but not the content. Because of the nature of the tasks they are asked to do. We need to teach them better.

*Question:* How much do you focus on the general public – is there any input on how much those people want to know.

Gary: We can put them in two different categories – 1) teachable moment for a large number people (fires, drought) – or 2) different people, who are searching for info, such as looking at the kiosk.

*Question:* Lal – Do educators use SAHRA as a resource?

Gary: That is happening more and more – that is our goal.

Julie: A lot of people we work with have access to the Web. But we are missing a large population of people who don’t have the funds – how do we reach them?

Gary: Agrees this is a challenge – we search out schools with demographics that will reach all economic levels, that are not the highest schools, etc.

Bonnie: Very impressed with the plans for the future of education & knowledge transfer.

Soroosh: Has presented several times to UNESCO and they have been impressed.
John Schaake: Have we identified the areas of the world that are climatologically similar to what we are studying?

Soroosh: We haven’t done systematic studies – but we do know in general, and UNESCO does have those studies. In terms of physical or socioeconomical contexts we do know have some information. With UNESCO, in the next couple of years we will have a lot of answers.

Question: John Schaake -- Are we getting advice from NSF, and is it good advice. What does the Advisory Board need to know about this?

Soroosh: One thing NSF has tried to do is have some continuity among the review team. We had a very good review at the last site visit, and have suggested we go for the full amount on the renewal.

John Schaake: Susan asked about integration – re integrating questions – these are difficult questions – if we could come up with one good answer would be good. Again, have lots of separate projects, and how to bring them together.

Dave G and David B: Enough water for all the needs – in a constrained environment.

Hoshin: It is not so difficult to do integrating questions. It’s much harder to do integrating science questions.

John Schaake: Look for Driving Issues: Do each of the areas in the grid have similar questions.

John Schaake: You have spent this time figuring out what you want to do, now you need to stay the course – get what you have planned accomplished.

Hoshin: Handouts – Doug James keeps coming back to saying you are doing a lot of good things, but you can’t get the scope of what you are doing on paper.

External Advisory Board met together without SAHRA representatives to discuss their feedback.

Discussion

Everyone was very appreciative of the science and presentations. Everybody was very excited. Hope this kind of leadership and science will continue. The written part of the response will just be changes the EAB thinks should happen.

Suggest that more emphasis be put on the integration. It is clear you are already doing it, but need more.

Need to have an active program for sharing all the problems so everyone can work on the same issues, work together.

Need to work closely with CLIMAS. The San Pedro is excellent example.

Need more emphasis on decision making unit. Pay more attention to policy.

Models proposed by Los Alamos are quite sophisticated – would be nice if they were made more clear.
The complexity of modeling the whole basin cannot be accomplished in a reasonable time. Need to concentrate on the decision model. Look at the science questions that were previously posed.

Need good support of large-scale modelist for basin scale – need to hire someone.

Education: Center has explored many avenues – during the next phase need to select three or four programs that have long-term and national emphasis, such as a national school network system.

Questions & clarifications:

Hoshin & Everett: There are preliminary results from the Los Alamos model – we are running the model and evaluating results. Only one of the three models comes from Los Alamos – the fine scale model. The others come from the UA, and Utah State is doing the meso-scale model. The third is the poor scale model, river reach type level, larger scale, lumped.

Soroosh: This is leveraging because Los Alamos has the resources. We will be receiving the benefit of the scientists there.

Everett: Scale and scale relationships, saturation is difficult in larger scale. Using the smaller scale model, can get the information, then move it back out to larger scale models.

Fred: Reinforcing Everett’s statement. It is the effort to come up with the appropriate conceptual model and the appropriate scaling that drives the science that we are working on. If we are going to come up with something significant, it is to produce a model that will do this.

Hoshin: The last year has been very exciting and very productive – we are only now, last week, starting to see the results of the modeling efforts. We have had numerous meetings, where we addressed the issue of why we want the three resolutions. The fine modeling is the closest we can get to physics. Medium resolution is where we can use engineering. Coarse resolution is where we can use policy.

Diana: Integration of SAHRA & CLIMAS – there are differences between them. STC is much more model-based – the physical side and economics is more complex than CLIMAS. They are quite complementary – CLIMAS is more sectoral. CLIMAS is on sectors, SAHRA is on the basin scale. CLIMAS has started focusing on the urban areas, while SAHRA is on the state as a whole. In looking to CLIMAS – they are doing integration quite differently. To force them together too closely would change them. CLIMAS is working with smaller groups – SAHRA is larger.

Soroosh: Our proposal was that we relied heavily on what other activities we had. Only a few things linked us – we were not going to do things that other groups were doing. Even with those interfaces, this is the type of thing that we’re talking about here. SAHRA is a beneficiary of HyDIS work.

Soroosh: Stakeholder – need to understand the perception about stakeholders, you’re talking about the small users, individual people. When we are talking about high-level precision, the stakeholder is the weather service.
Chuck Howe: The unique strength of SAHRA is the integration. The question is whether the resources that are needed are available. Need to move from the building blocks, need now to emphasis those links and interdependencies. At some point need to move more and more toward the integration.

Soroosh: The ultimate test is if we have multidisciplinary papers that we can write. But where would we publish them? Or do we need to partition it out in order to publish. The Center has to take risk and do it anyway.

Dave G: Emergence of global scale hydrology – how do you educate the generalist? How do you publish to the generalist – will have to shop around to publish.

Soroosh: Hopefully, the impression, if you think, we are one of the first STCs for science, and we will have more problems, but now new STCs are being supported in science because of our success.

End of meeting; discussion continued through dinner.
APPENDIX D: Media Publicity Materials
Southwest Hydrology Merges with SAHRA

We’re pleased to announce the merger of Southwest Hydrology with the National Science Foundation’s Science and Technology Center for Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA), based at the University of Arizona. As of this issue, we are combining resources to improve the quality of both the magazine and the Web site. More good news: although we continue to rely on our advertisers to sustain production of the magazine, we are returning to free subscriptions, bringing our distribution back up to 4,000. (Paid subscribers will receive printed and electronic versions.)

Southwest Hydrology will continue to be the same magazine with the same focus except it will become bigger and better. This merger brings more staff, a larger reporting network, and new departments to cover international water issues and water education. We will also expand coverage of water law and economic issues, and soon, back issues will be available on our Web site. In addition, we will regularly survey our readers for feedback, to further our primary goal, to be the voice of the semi-arid water community.

Our focus in this edition is remote data acquisition—how to get the data you need from simple to complex.

We thank all the contributors to this issue, listed on the opposite page, and encourage your comments and contributions, particularly as we implement our improvements.

Southwest Hydrology remains a magazine by and for our readers.

Bert Woodman
SWH Publisher

Gary Woodman
SAHRA Knowledge Transfer
Remote Data Acquisition

Remote water resource monitoring systems are now being used in applications as simple as monitoring soil moisture at a golf course to as complex as multi-sensor systems that provide snow melt, stream discharge, reservoir level, meteorological, and water quality data in order to adjust flow through a regional water distribution system. Recent advances in sensor and data transmission technologies have made these systems more feasible than ever. Furthermore, Internet capabilities allow widespread access to the data. Our feature authors discuss various kinds of remote monitoring systems and their applications.

12 Equipment Developments Offer Remote Monitoring Options to Many
Gregg Guroff and Linda Chapman
The small size and low power requirements of today's electronics make possible highly sophisticated data collection and transmission systems.

14 Telemetry Options for Remote Data Acquisition
John Skaggs
Phone modem, cellular modem, line-of-site radios, and satellites: how, when, and where do they work for transmitting remotely acquired data?

16 Meeting the Challenges of Real-Time Data Transport and Integration: HPWREN and ROAHiNet
Betsy Woolwine and Ted Hansen
Southern California researchers have developed networks that allow inter-disciplinary researchers to acquire near-real-time data from remote sites and allow data access by all.

18 The Wireless Watershed of the Santa Margarita Ecological Reserve
Dan Cayan, Mark VanSevy, Michael Perlinger and John Belfy
Scientists have begun the daunting task of instrumenting the rugged walls and canyons of a California coastal watershed to characterize the workings of the sub-watershed-native interface.

20 Water Quality Monitoring in the Las Vegas Wash
X aquing Zhou, Dobie Van Rooymelen, Robert Harding, Kevin Clur, Peggy Reeder and Kimberly S. Zisman
Near-real-time monitoring in Las Vegas Wash and its tributaries helps scientists manage the wash to maximize its environmental health.

22 The Real Time Data Network of the U.S. Geological Survey
Betsy Woolwine
Streamflow data and a variety of other water resource parameters are available for locations across the nation from a single Web site.

23 Remote Monitoring of Soil Moisture
Howard Glatz
Soil moisture monitoring systems that automatically collect and transmit data are being used in settings as diverse as golf courses, copper mines, and nuclear waste dumps.

24 Santa Water Conservancy District: Strutting into the 21st Century
Roger B. Reamer and Dave Berger
With the click of a mouse, real-time environmental conditions throughout the San Rafael River Basin can be obtained.