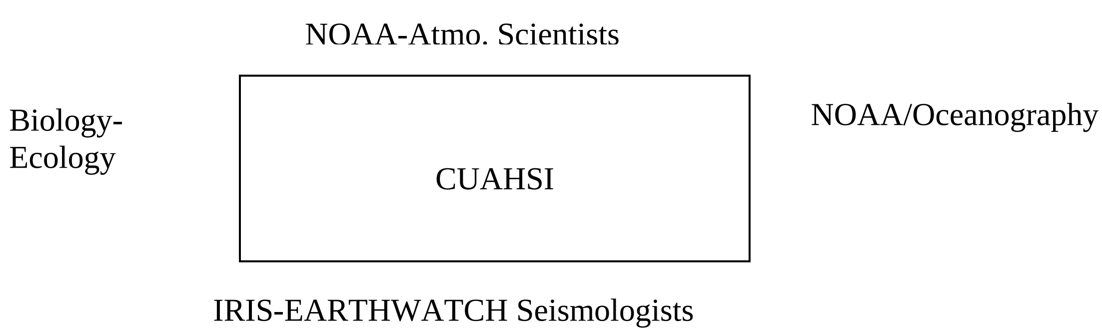
Summary of CUAHSI Southwest Regional Workshop,
Phoenix, Arizona
February 15, 2002

Meeting convened at 8:30 at the Radisson Phoenix Airport. Participants included:

Name	**Institution**
Brian McPherson	New Mexico Tech
William Johnson	Univ. of Utah
John L. Wilson	New Mexico Tech
Hoshin Gupta	Univ. of Arizona
Vijay Gupta	Univ. of Colorado
Marshall Moss	CUAHSI
Ty Ferré	Univ. of Arizona
Steve Jennings	U. Col./CSprings
Tom Piechota	U. Nevada/LV
Jan Hendrickx	New Mex. Tech
Brenda Ekwurzel	U. of Arizona
David Chandler	Utah State Univ.
Roger Bales	U. of Arizona
Ari Michelsen	Texas A&M Univ
Cliff Dahm	Univ. New Mex.
David Goodrich	USDA-ARS
David Maidment	Univ of Texas
Thomas Meixner	UC-Riverside

Day started off with introductions of participants. This was followed by a presentation by Tom Meixner that included a great deal of discussion about the background of CUAHSI and the possible avenues the community endeavor can take. One important item of discussion was where does CUAHSI end and the rest of NSF begin?

David Goodrich offered the following diagram as a way to think about it –



Following the introduction talk by Meixner was a short break. The break was followed by a presentation by Brian McPherson that summarized some of the discussion and contributions from previous workshops. This presentation finished off with proposing 3 breakout groups address the following questions:

1) What could/should be goals of CUAHSI for, or benefits to, researchers?

2) What could/should be goals of CUAHSI for, or benefits to, hydrologic science?

3) What could/should be goals of CUAHSI for, or benefits to, society?

Brian noted that these are "loaded" questions. In answering them, groups could address, for example:

- Facilities/Infrastructure such as LHTOs • Programs (in general -- for example, fellowships for students and postdocs)
- Equipment (the IRIS analogy)
- Specific science questions of a "revolutionary" nature, or those that cannot be answered without a major combined university team effort
- Information Systems

While addressing these questions, each breakout group could review previous workshop summaries, then:
- decide what category (e.g., which question) each previous breakout group addressed
- build on or extend these previous groups' work or conclusions

Other discussion followed on what topics would be covered for the day. Discussion ranged on topics like the possibility of defining a consensus of scope for CUAHSI; perhaps one group would discuss possible societal issues/drivers; another possible group discussion was general complexity- and non-linearity issues. In the end, the workshop agreed that groups segregated by the topics above (the 3 general goals/benefits questions) would be the preferred set of general questions for the breakout groups, but each group could take its respective question and address it in whatever context it deemed appropriate.

Following the breakout into groups, each group met over lunch and for about an hour beyond that. Hour-long presentations were made following the breakout group meetings. Group summaries are attached below stating each group's summary of their discussions.

In addition to groups' summaries, David Maidment asked everyone for answers to three questions related to the planned work of the Hydrologic and Information Systems committee. These questions might be appropriate to circulate more broadly to the membership. Each participant's response was recorded by David Maidment and his summary is attached below as well.

Group I – Benefits of CUAHSI to Individual Researchers

Membership – Bill Johnson Univ. of Utah; Ty Ferre Univ. of Arizona; Jan Hendrickx, New Mexico Tech; Brenda Ekwurzel, Univ. of Arizona; David Chandler, Utah State Univ.; Ari Michelson, Texas A&M; David Maidment, Univ. of Texas.

We would like to see CUAHSI consider the following points to ensure broad participation of researchers throughout the hydrological sciences. We feel that it is imperative that the consortium balances a focused definition of purpose with consideration of service to the broader hydrologic community.

While the focus of the consortium must be big scientific questions, there will be an emphasis of measurements and investigation of processes at all spatial and temporal scales.

As regards LTHO's, we would like to see these facilities promote integrative studies of, for example, surface and subsurface hydrology. Spending on LTHO's should be limited to a certain fraction of all expenses and should be balanced by funding of distributed measurements. These measurements could be coupled with other existing infrastructure through, for example, Ameriflux networks, LTERs. LTHO's must make every effort to provide a neutral atmosphere with minimization of nepotism. Among the other considerations for LTHO's should be the balance between unperturbed and "natural" sites.

Measurement technologies should support the availability of expensive instruments and the availability of professional technicians to operate the instruments. In addition, training should be available for users of more standard, less expensive equipment. This should be part of an effort aimed at forming standards for measurement methods and reporting along the lines of an ASTM for hydrology. In addition, support should be given to information system infrastructure to promote storage and sharing of currently lacking data, such as isotopic data for precipitation. This effort should also support increased availability of "archived" data. We support the advancement of NCEAS-type meetings to promote collaboration within hydrology and with "other" sciences. Finally, a centralized modeling facility and storehouse should be made available.

CUAHSI should provide a warehouse of stakeholders to provide relevance to scientific research ideas. The consortium could also increase the use of hydrologic data, models and understanding in political and economic decision-making.

Group II Benefits to Hydrologic Science

Members: Hoshin Gupta; Univ. of Arizona; Roger Bales, Univ. of Arizona; Cliff Dahm, Univ. of New Mexico; and Vijay Gupta, Univ. of Colorado.

1. It will be important to be able to fill out the following statement adapted from the Earthscope project plan:

"______________________ is a new Earth Science initiative that will dramatically advance our understanding of _____________________ by _________________. "

e.g. "______________________ is a new Earth Science initiative that will dramatically advance our understanding of the North American continent by investigating the structure of its water resources (in terms of both quality and quantity), and how that structure changes through time. "

2. The group focused on the question "Why are there so many models in Hydrology?"

3. Reasons are a) Evolution of hydrology driven by engineering applications, and b) The inability, given available data, to do diagnostic evaluation of models (falsifiability).

4. Models, in a scientific sense, are the way in which we concretize our conceptual understanding of the hydrologic system, and allow us a means by which to test our understanding.

5. Without diagnostic ability (inability to discriminate between alternative model structures/hypotheses), the science of hydrology cannot advance.

6. The reasons for inability to do diagnostics are a) lack of sufficient and adequate data, and b) poor knowledge about the accuracy and representativeness of available data.

7. Both of these point strongly to the need for properly designed "Infrastructure".

8. Emphasis should be given to providing data with quantified indication of the "Accuracy" of the measurements, and of the "Representativeness" of the data (e.g., at what scale is the measurement relevant). Much diagnostic evaluation of models depends critically on having this kind of information.

9. The infrastructure should include Data Systems (front end data access tools) and

Data Analysis Tools.

10. Question: Should models be part of the infrastructure?
The group felt that the answer is "Yes". Therefore the infrastructure should consist of the triangle - Data Systems - Data Analysis Tools - Models.

11. Question: What infrastructure is necessary to support models? Needs consideration.

12. The Infrastructure discussed above deals with the "What, Where, When" questions in hydrology (Quality, Quantity, and Fluxes).

13. The Infrastructure will lead to better understanding of the "Basic Organizing Principles in Hydrology at Point to Global Scales".

14. This better understanding will lead to needed "Unifying Theories Across Scales".

15. These latter two points deal with the "How and Why" questions in hydrology.

16. Finally, The group discussed hydrological science issues relevant to the Southwest and identified "Recharge" and "Precipitation" as critical issues.

Group III Benefits to Society of CUAHSI-Societal Connections/Drivers

Members: David Goodrich, USDA-ARS Tucson; Brian McPherson, New Mexico Tech.; Steve Jennings, UC-Colorado Springs; Tom Piechota, UNLV; Thomas Meixner, UC-Riverside

Societal issues can be broken down into three categories where improved hydrologic science could be of benefit. water quantity, water quality, and breaking the lock between research and practice and aid in the legal acceptance of new models and technology.

Benefits Associated With Water Quantity

1) Societal Connections – benefits of knowing the water balance with greater certainty:
   - A) How much can we (cities, agriculture, industry) grow with a finite water supply
   - B) Assisting in resolving water conflicts (rights) at basin, interstate and international scales
   - C) Better understanding of the impacts of climate variability (change?) on water resources
   - D) Others: Water banking, interbasin transfers, subsidence, etc.

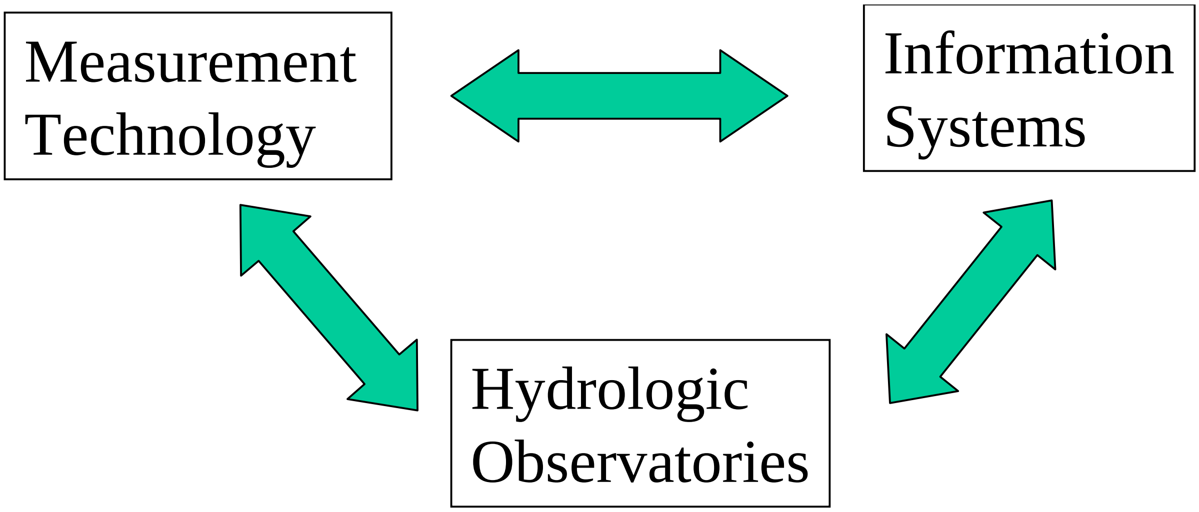
2) Challenges to solving the societal issues-
   - A) How well can we measure water balance components what uncertainty do we have?
   - B) Goal: Measure all components (inputs, outputs, reservoirs) of water balance with greater (XX%) certainty with CUAHSI program.

3) Infrastructure needs Water Quantity
   - A) Distributed, cheap, precise, simultaneous measurements at the basin scale (large scale) of inputs, reservoirs and outputs.
   - B) Measurement technology Point scale and basin characterization (new and existing instruments).
   - C) Hydro. Info systems - High-level digital data in readily accessible geospatial format with analysis tools Basin-scale simultaneous implies some sort of LTHO's

Breaking the Lock between Research and Practice

- A) Develop observations, and procedures to test and evaluate models so they can be legally defensible.
- B) Do we need community models?
- C) Do we need CUASHI endorsed model intercomparisons?
- D) Should there by a CUASHI office of community models, organized observations to validate these models, and serve as an independent tester of models (implies we need LTHO's in multiple hydroclimatic regions, good observation implying good instruments, and IT to organize it all).
- E) Effectively close the triangle between 1) measurement technology, 2) coordinated observations, and 3) model development and testing. As CUAHSI discussions currently exist these three committees have relative autonomy but there is a necessary

tight coupling between the missions of the three committees to ensure the success of CUAHSI's mission.



Closing the triangle

TMDL's Water Quality issues and benefits from CUAHSI

1) Currently missing elements-
   A) Quantifying sources, fluxes and transformations of pollutants of interest
   B) Quantifying sources, fluxes, transformations
   C) Efficacy of BMP's
   D) Model predictability of results
   E) Residence time
   F) Issues of scale
   G) Interbasin transfers
   H) Urbanization – geomorphology interactions
2) Possible benefits to TMDL issues for society
   A) Measurement of joint quantity and quality
   B) Improved models
   C) Better measurement techniques
   D) Geographic geomorphic information
   E) Simultaneous high resolution measurements of multiple fluxes at a high resolution in time and space

TMDL 5 pointer:

- Can we properly estimate fluxes of surface runoff and quality at fine time and space resolutions?

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- We do not have large-scale measurements simultaneously to estimate fluxes and to test our models adequately.

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- We need to simultaneously measure and simulate fluxes of water and material at varying spatial and temporal scales.
- Large long-term field observations aimed at collecting data needed to falsify our models of surface water quantity and quality.

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- Continuous observation of quantity and quality and varying time and spatial scales
- Use of that data to falsify existing policies, models and understandings of watershed water quality.

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- Product - Better models and theories of controlling processes of surface water quality

Results from David Maidment - Questions regarding Hydrologic Information Systems

1) How do you use hydrologic information and models in your research?
2) What infrastructure and services are needed in the CUAHSI Information Systems component?
3) What large, new questions in hydrology could we ask and answer using improved hydrologic information systems?

Here are the participant's responses, as typed and edited by David Maidment

Name	Responses to Questions
Roger Bales Dept of Hydrology and Water Resources, University of Arizona, Tucson AZ	1. **Hydrologic Information:** Correlations between climate, hydrology, spatial data, topographic, and remote sensing data. 2. **Infrastructure Needs:** Make data more readily and seamlessly available. Make linking and merging datasets easier to do. Analysis tools and modeling support are not available in individual investigator grants. 3. **New Questions:** facilitate some data analysis for linkages from smaller to larger spatial scales, better aggregation and scaling schemes for C, N & water fluxes. Multidisciplinary correlations between datasets.
David Chandler Dept of Plants, Soils and Biometeorology, Utah State University, Logan, UT	1. **Hydrologic Information:** Use scale-appropriate information to quantify dynamic processes between hydrology, ecology and land use. 2. **Infrastructure Needs:** A central clearing house for data, including a living directory of what other clearing houses contain, and small tutorials on how to extract information. Education of data users. Scripters available to choose lowest common denominator of temporal and spatial scale and homogenize data from different data sets for a particular use and screen off inappropriate data. 3. **New Questions:** Expanding interest in hydrology beyond strict engineering sense to understand bio-geo-hydrosphere, opportunity to allow critical development and testing of climate change theories and (paleo data also needed for that). Process based models remain in 1-D and 2-D; need to see 3-D models.
Cliff Dahm Dept of Biology, University of New Mexico, Albuquerque, NM	1. **Hydrologic Information:** Focuses on aquatic ecosystems, 1-D transport in streams to do surface water - groundwater interaction, Use groundwater transport models for fate and processing of solutes in shallow groundwater. Studies C, N, S, trace metals. Transfers between riparian corridor and atmosphere and using GIS to scale up. 2. **Infrastructure needs:** good spatial and temporal coverage of measurements of ET for open water and wet channel

	sediment, transpiration losses, groundwater recharge on stream corridors. 3. **New Questions:** Linking plot-based measurements with remote sensing data across spatial scales. Scaling up from measurements along a riparian corridor to larger scales.
Brenda Ekwurzel Dept of Hydrology and Water Resources, University of Arizona, Tucson, AZ	1. **Hydrologic Information:** Hydrologic basins and their residence time using geochemical tracers. Recharge into basins (e.g. Available precipitation data, stream gauge data, IAEA Global Network for Isotopes in Precipitation data sets). 2. **Infrastructure Needs:** Most current precipitation networks in the United States don't have geochemical data. Need data networks for geochemistry, in addition to typical precipitation gauge measurements (e.g. volume, temperature, barometric pressure). Carbon input in recharge is important in setting C^{14} values. Need better QA/QC. Need to be able to go to the top of each database column, click on it and a window pops up and describes the data, explains the units, and provides an explanation of data. Most databases don't do this. 3. **New questions:** Linking climate variability forcing functions and their signal amplification or modification through the hydrologic system that has various residence times in the different components of the hydrologic cycle.
Ty Ferré Dept of Hydrology and Water Resources, University of Arizona, Tucson AZ	1. **Hydrologic Information:** Acquire hydrologic models to understand geophysical measurements. 2. **Infrastructure needs:** Ready source of simple hydrological and geophysical models. 3. **New questions:** quality of data points and representativeness of data points. How does a single measurement relate to the large scale properties of the medium?
David Goodrich USDA-ARS, Southwest Watershed Research Center, Tucson AZ	1. **Hydrologic Information:** Ditto Roger Bales on #1, 2. **Infrastructure needs:** Access to diverse sets of measurements, plant sap measurements, streamflow, etc. Need a nice geospatial interface to those data, supporting queries in time and space with some analysis tools. To answer statistical as well as geospatial questions. 3. **New Questions:** Spatial Scaling!
Hoshin Gupta Department of Hydrology & Water Resources, University of	1. **Hydrologic Information:** Meta-analysis, how do you identify, parameterize and diagnose hydrologic models? 2. **Infrastructure needs:** definition of the accuracy and representativeness of the information that has been collected e.g. LTHO's. Can we falsify models? This needs

Arizona, Tucson AZ	information about accuracy and representativeness of observed data which is often not available. Are prediction intervals on the model tighter than prediction intervals on data? 3. **New Questions:** Unifying across scales, point scale to plot scale. Can you do the appropriate math? How much detail is it necessary to build into a model? Complex models are built because we don't know how to test the merits of simpler versus complex models.
Vijay Gupta Dept of Civil, Environmental and Architectural Engineering, University of Colorado, Boulder CO	1. **Hydrologic Information:** Developing new testable mathematical models to understand spatial scaling statistics of floods and low flows on channel networks in terms of coupled bio-physical processes. They are based on research pathways across multiple scales of space and time, which consist of scaling, coupling, diagnosing and modeling, as explained in the WEB report. 2. **Infrastructure needs:** Information systems could really help by building up ancillary data sets that a large number of people can use. For example, several large river basins from different climates can be selected. Some of these basins will be highly developed and some will be more pristine to explore the effect of human-induced changes. On these basins, different coordinated data sets for several years (say up to 25 yrs.) can be produced as following examples show. (i) space-time precipitation gridded over 1 sq. km. pixels every 15 minutes for several years with attendant errors. (ii) DEM data sets at 30 m. resolution with given errors in elevations. (iii) Evapotranspiration over 1 sq. km. every 2 to 3 days using two or three models for estimation and potential errors. (iv) Hourly streamflow data for research purposes at several gauges with rating curves and attendant errors. (v) At-a-station and downstream hydraulic geometric data sets with high spatial sampling density. (vi) Hydroclimatic data sets as indicators of ENSO and interdecadal climatic variability. Producing these data sets would require developing and or using innovative ways to extrapolate point measurements combined with remotely-sensed measurements when available into gridded estimates. Techniques for interpolation need to be explained for users of these data sets. Need a research level GIS to investigate large scale issues. 3. **New Questions:** My research is focused on understanding nonlinearity in coupled hydrologic systems over larger scales of space and time than plot and laboratory. This body

	of research will provide new fundamental understanding of how the Water cycle is coupled with the Earth systems and Biota (WEB) at multiple scales.
Jan Hendrickx Dept of Earth and Environmental Science, New Mexico Tech, Socorro, NM	1. **Hydrologic Information:** Use models for hypothesis testing. Educational applications of models. Virtual experiments performed using models. 2. **Infrastructure Needs:** Quality control of data is important. 3. **New questions:** remote sensing for evapotranspiration. Can effective hydraulic properties be determined at the mesoscale to predict correct ET. Can you upscale models for ET?
Steve Jennings Dept of Geography, University of Colorado, Colorado Springs, CO	1. **Hydrologic Information:** What happens to the drainage basin away from the stream, and how does the basin affect the stream? Study vegetation in the context of hydrology. 2. **Infrastructure needs:** Remotely sensed data about the surface, air photos, satellite imagery, in GIS for ready analysis. 3. **New questions:** Quantify hydrologic properties of vegetation The use of LIDAR needs to be explored as a valuable tool in remotely sensing the environment.
Bill Johnson Dept. of Geology and Geophysics, University of Utah, Salt Lake City, UT	1. **Hydrologic Information**: Works at small scale, uses models for understanding what controls transport of solutes and colloids in subsurface media. 2. **Infrastructure needs:** Description of heterogeneity in properties for subsurface transport. 3. **New Questions:** Better characterization of heterogeneity of bacterial and media properties, and understanding of how to go from pore scale to field scale. Capacity to look at microbial transport in the subsurface and study its ecological effects.
Brian McPherson Dept. of Earth and Environmental Science, New Mexico Tech, Socorro, NM	1. **Hydrologic Information:** use standardized GIS and other similar databases off the web in research. 2. **Infrastructure needs:** Suggestion for the community-at-large: join or merge different sources of data, such as GIS databases, into one central database. A set of standards could be defined (and published) for the database. Users could submit data according to the standards, leading to better integration of data. It is desirable to extract non-electronic data (e.g. in file cabinets) into electronic form and added to databases accessible to the public. 3. **New Questions:** Upscaling physical processes of the earth, both spatially and temporally.
David Maidment Dept of Civil Engineering, University of	1. **Hydrologic Information:** Using standardized GIS datasets to support water resources analysis and modeling. 2. **Infrastructure Needs:** Better integration of national datasets of both geospatial and temporal hydrologic

Texas, Austin TX	information. Capacity to integrate researcher-developed data at local scale with standardized regional data. 3. **New Questions:** Understanding the functioning of large river basins, better connection land and water systems, better integration of water quantity, quality and ecological impacts.
Ari Michelsen Texas Agricultural Experiment Station, Texas A&M University, El Paso, TX	1. **Hydrologic Information:** Understanding hydrologic conditions to develop integrate water resources conditions, impacts, institutional adjustments and policy analysis. 2. **Infrastructure Needs:** Inter-jurisdictional data analysis, such as between states and countries on the Rio Grande River. This is a huge project. Access through linkages to other databases. Research support for combining water quantity and quality modeling. 3. **New Questions:** (a). How to marry remote sensing and large scale data and models with local level research (b) Training hydrologists to integrate hydrologic, legal and policy analysis.
Tom Piechota Dept of Civil Engineering, University of Nevada, Las Vegas, NV	1. **Hydrologic Information:** Use info for model Calibration/Verification, evaluating long term trends in data, 2. **Infrastructure Needs:** Hydrologic information systems for education, data for visualization of concepts. Data for students to use. Better quality control of the data. More uniformity of data. Grad students spend a lot of time processing data and not enough time on basic research. Better ease of access to data. 3. **New Questions:** Las Vegas is the fastest growing city in nation. How can water quality in runoff from urban areas be characterized? Would be nice to have access of every one else doing research on this topic. This would be valuable for comparing model parameters.
John Wilson Dept. of Earth and Environmental Science, New Mexico Tech, Socorro NM	1. **Hydrologic Information:** Interested in how water moves through mountain blocks, which requires that fluxes be defined at the input boundaries. Requires precipitation and evapotranspiration data. 2. **Infrastructure needs:** a gridded version of the input variables needed to compute boundary fluxes and models to go along with that so as to enable fluxes to be computed. Go to one place and get whatever data and models are required. 3. **New Questions:** Closing the water balance.