INCLUDING TRADEOFFS IN STAKEHOLDER WATER ALLOCATION DECISIONS: AN EXPERIMENTAL APPROACH

Kate Krause, Janie M. Chermak, and David S. Brookshire
Department of Economics
The University of New Mexico

Karl Benedict and Richard Watson
Earth Data Analysis Center
The University of New Mexico

Allocation of resources among competing uses is a central concern of economics. The market sometimes solves this problem well. For consumer goods, an increase in demand provides an incentive for producers to increase supply. Sometimes markets cannot or do not allocate resources well. Water in the Middle Rio Grande Valley is one example. More water cannot be produced easily when demand increases, and there are reasons to question the wisdom of using a market to allocate water to the highest bidder. However, given the scarcity of the resource, coupled with increasing demand from a growing population, addressing allocation issues is critical. This led us to investigate preferences for water allocation in the Middle Rio Grande Valley. (This research is funded by NSF and the EPA Science to Achieve Results (STAR) program.)

When economists cannot learn about consumer preferences by observing market purchases, they often turn to experimental methods. Economic experiments can place participants in simulated markets and ask them to make choices that yield economic consequences. Because the settings are simulated, participants can make choices over situations that they cannot directly choose in the outside world. Because they offer the potential to measure preferences for non-marketed goods, experiments are a promising way to consider alternative allocations of water. We designed an economic experiment in which stakeholders in the Middle Rio Grande Valley could make choices about how to allocate water by "virtually" moving water among competing uses, and then observing the consequences of those allocations.

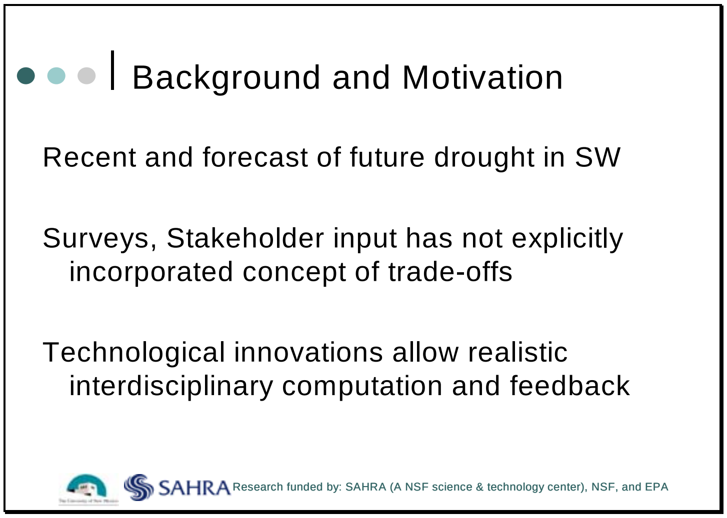
The approach combines a hydrological model of the Middle Rio Grande with economic models that calculate the financial benefits of given quantities of water to agricultural and urban water consumers. Economic models were also used to impute a dollar value to preservation of the bosque. This interdisciplinary model calculates the estimated physical and economic effects of increasing or decreasing the amount of water available to various users in the valley. To make the decisions meaningful, participants had to be able to "see" the allocations and the consequences of their decisions. We developed maps and graphical displays that provide rich visual information and feedback to meet this need.

Experiment participants, seated at computers, were assigned to one of three Middle Rio Grande user groups: urban, agricultural, or habitat. Information about the starting status of the river, from the perspective of each user group, appeared on each participant's monitor. Participants submitted their allocation decisions to the underlying hydrological/economic model, the model aggregated the decisions and calculated the results, and a visual display of the physical and economic consequences of the collective decisions was returned to each participant's screen. Payment for participation was based on the economic value of the water allocated to the participant's sector. Thus, the participants had some incentive to demand a large share of water. However, if all of the allocation requests, when aggregated, exceeded the available water supply, participant earnings were reduced and they were asked to try again. Thus, there was also an incentive to avoid over-allocation. By interacting with this computer program, participants could make water allocation choices and adjust their decisions in response to information-rich feedback.

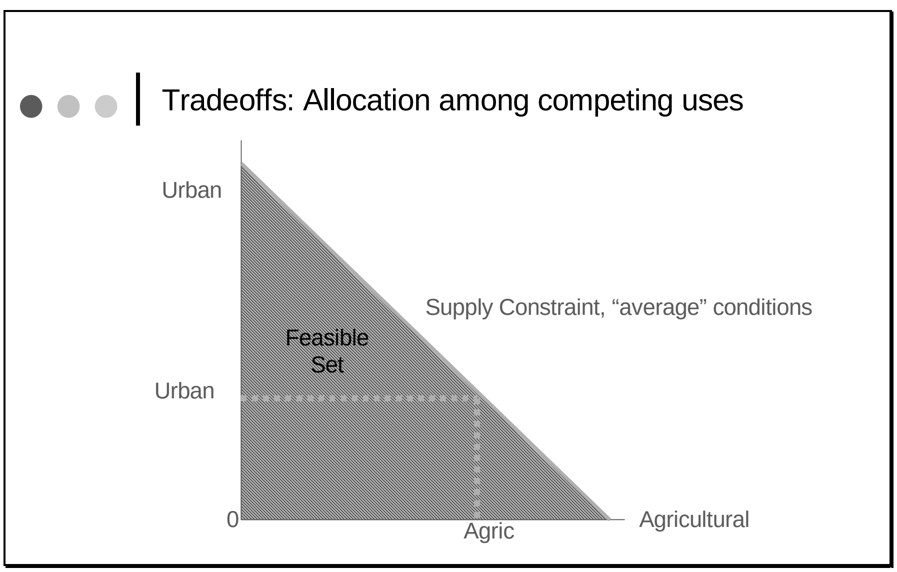
For some of the multiple-round experiment sets participants were told the sector they would be representing. For some sets, though, participants were not told their sector assignment, and were asked to make allocation decisions for all three user types. This treatment was included to identify participants' ideas about what constitutes equitable, as opposed to self-serving, allocations. Preliminary analysis of the data suggests that people behave very differently when they are making decisions, with financial consequences, for themselves compared with how they behave when they are making decisions on behalf of the community as a whole.

A lab experiment is not designed to, and will never be able to, replicate all of the real-world effects of economic decisions. However, better information and feedback enhances the quality of the decisions made in the artificial environment of the lab. Linking geographic information and displays with the underlying physical and economic models allowed the researchers to show stakeholders from the Middle Rio Grande Valley how alternate water allocation scenarios would play out. We look forward to using this tool to help policy makers identify ways to cope with potential water shortages in the future.

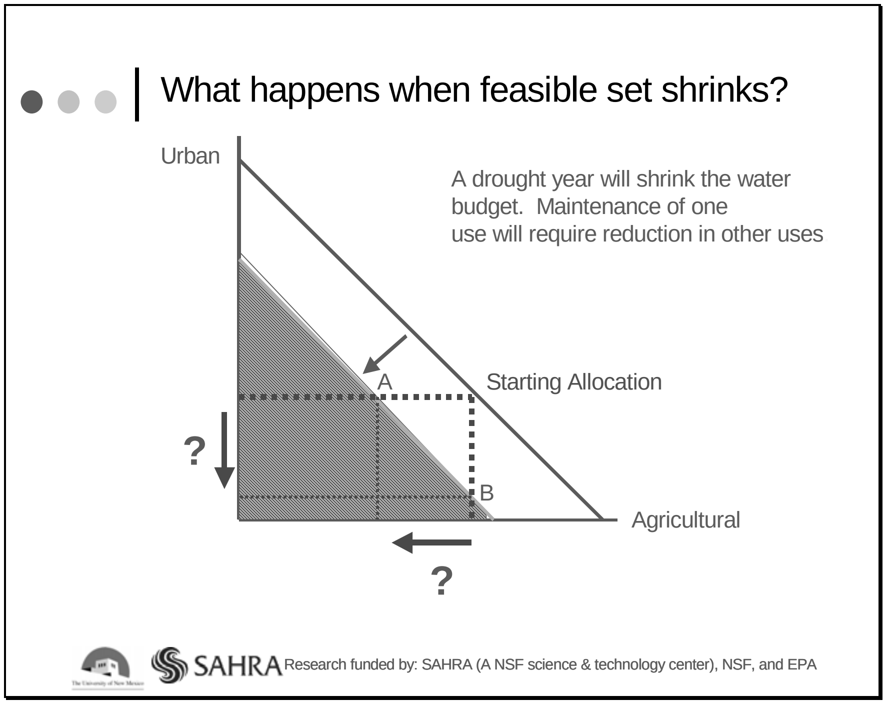
Existing studies of demand for water have not typically included an aggregate supply constraint: water allocated to one use, for example, urban users, is not available for competing uses, e.g., agriculture. This presentation describes a series of experiments designed to confront water demanders with the consequences of their allocation choices. We use a realistic model of surface water in the Middle Rio Grande Valley to compute the effects of different allocations under different climate scenarios, and we use GIS maps to illustrate those changes spatially. Economic models are used to calculate the dollar value of water in its various uses.



The current drought, together with population growth in the desert Southwest, highlights the finite nature of our water supply. Given this, it is imperative that policy makers understand the consequences arising from allocation of that scarce resource. Here we integrate a hydrological model of the valley with economic models of the value of water to users in the valley to understand these consequences. To enhance the users' appreciation of those consequences, we use GIS-generated maps of the valley to provide feedback to experiment participants. Thus this project is truly interdisciplinary and takes advantage of current technology.



A simple model of tradeoffs between two water users is shown, illustrating all feasible allocations with a given quantity of the resource. Efficient allocation (i.e., allocation that does not entail waste) occurs along the linear negatively sloped boundary of the feasible set. This model makes it clear that, under conditions of efficiency, increasing use by one user requires decreasing use by the other user.



When the available supply of water shrinks, here due to a drought, the starting allocation is no longer feasible. A new allocation at Point A would be one in which urban users maintained the same level of water consumption as before, but agricultural users reduced their consumption substantially. Similarly, Point B illustrates a new allocation in which agricultural water use is maintained, but very little water is allocated to urban users. The most likely reallocation of water would occur along line segment AB, but it is not clear exactly where along this line segment the allocation should – or will – ultimately lie.

Modeling Objectives

- Simultaneously consider hydrologic and economic theory in a water allocation model
- Use the models to simulate alternative scenarios and to generate meaningful information, feedback for stakeholder decision-making
- Observe stakeholder choices when tradeoffs are required
- Provide policy analysis tool to assess resource management schemes

Our primary objective in developing this model was to provide a way to observe the physical and economic consequences of alternative water allocation combinations. However, for this tool to be effective, the results had to be presented in a way that stakeholders in the valley could use and interpret. Therefore, we designed the feedback pages to provide information three ways: numerically, using bar graphs, and spatially using maps. By asking stakeholders to make decisions about water allocation with this information available, we could observe the ways in which their decisions changed in response to the consequences of prior decisions.

The Experimental Approach

- Controlled decision-making environment
  Choice variables; parameterized scenarios
- Specific Institutions
  Aggregation of stakeholder decisions
- Provision of information; observation of response
- Salient consequences

Economic experiments are used when real-world data are not available. It would be impossible to investigate the effects of several different allocation schemes, and it would be extremely costly, both in terms of time and money, to wait for actual allocations to unfold. Furthermore, by anticipating possible consequences of alternative allocations, policy makers can avoid costly mistakes. Economic experiments rely on salience: we believe that answers to hypothetical questions may not reveal true preferences, but that responses that entail real financial rewards and costs are more likely to be accurate. Therefore, participants in these experiments were paid for their participation on the basis of how well, economically, their particular sector fared in the reallocations.

Integrated Tradeoff Experiments

- Spatial hydrologic modeling provides supply constraint
- Economic modeling provides tradeoff mechanisms and economic consequences
- GIS provides visual presentation of allocation choices and consequences
- POWERSIM provides computational environment

The experiments brought together models from several disciplines. Each stakeholder was seated at a computer on which the information was presented. Stakeholders entered choices about water allocation, and those choices were aggregated and sent to a server on which the integrated hydrological/economic model was running. The model then delivered the results back to the stakeholders' computer screens.

Stakeholder Participants

- Stakeholders drawn from lists provided by
  - MRG Water Assembly
  - Greater Albuquerque Chamber of Commerce
- 73 Participants in six sessions
  - Self-identification of participants:

    20% identified with environmental and habitat interests,
    38% with urban,
    33% with agriculture, and
    8% with some combination of the three.

In recruiting participants, we strove to have a cross-section of stakeholders from the Middle Rio Grande Valley. To do this, we sent letters to members of the Middle Rio Grande Water Assembly and the Albuquerque Chamber of Commerce. Survey results indicate that our participants were relatively representative: almost 40% of them indicated that they were urban users, and one-third indicated that they were agricultural users.

Basic Design

- GIS-generated maps illustrate land use patterns and water availability
- Participants enter allocation decisions that are then reflected in map changes and sector economic changes
- Consequences (payoff reduction) imposed if water budget is exceeded

The experiment design required that stakeholders make decisions in multiple rounds, representing several consecutive years. As the rounds progressed, earlier decisions affected the stored water available for subsequent years, using a simulated reservoir embedded in the hydrologic model. If too much water was allocated by participants in any given round, a cost was imposed. This was done by reducing participant payoffs for that round.

Protocol, Parameters & Mechanism

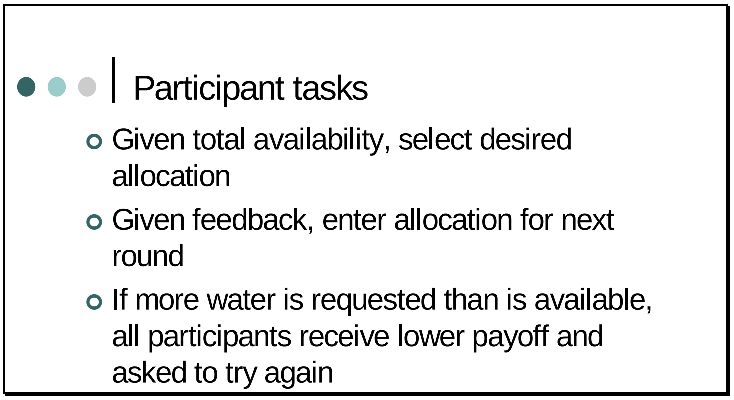
- Participants represent one of 3 Sectors:
  Agricultural Urban Bosque
- Two Treatments: Known sector; Unknown
- Climate condition data: Current; conditions from 1950s (under current land use patterns)
- Allocation decisions processed and returned by POWERSIM
- Multiple rounds: allows storage to fluctuate

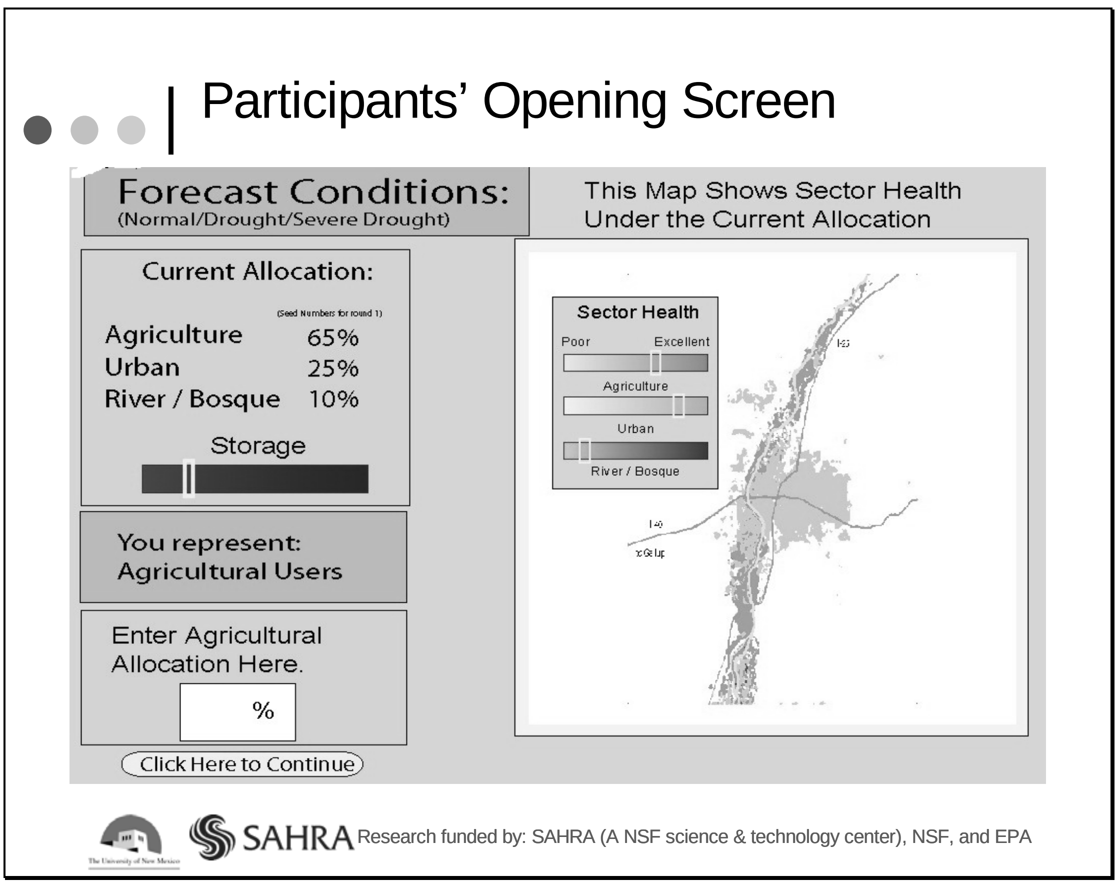
Each participant was assigned to one of three types of water user in the valley: agricultural, urban, or bosque/habitat protection. In some of the rounds, each participant knew the sector to which he or she was assigned. The participants' task in these rounds was to state how much water should be allocated to their own sector. In other rounds, the participants were not told their assigned sector, but were asked to suggest the appropriate allocation for all three types. Two series of water supply data were used for the simulations: current conditions and a set of years from the 1950s drought period.

Payment for participation: Goal of Salience

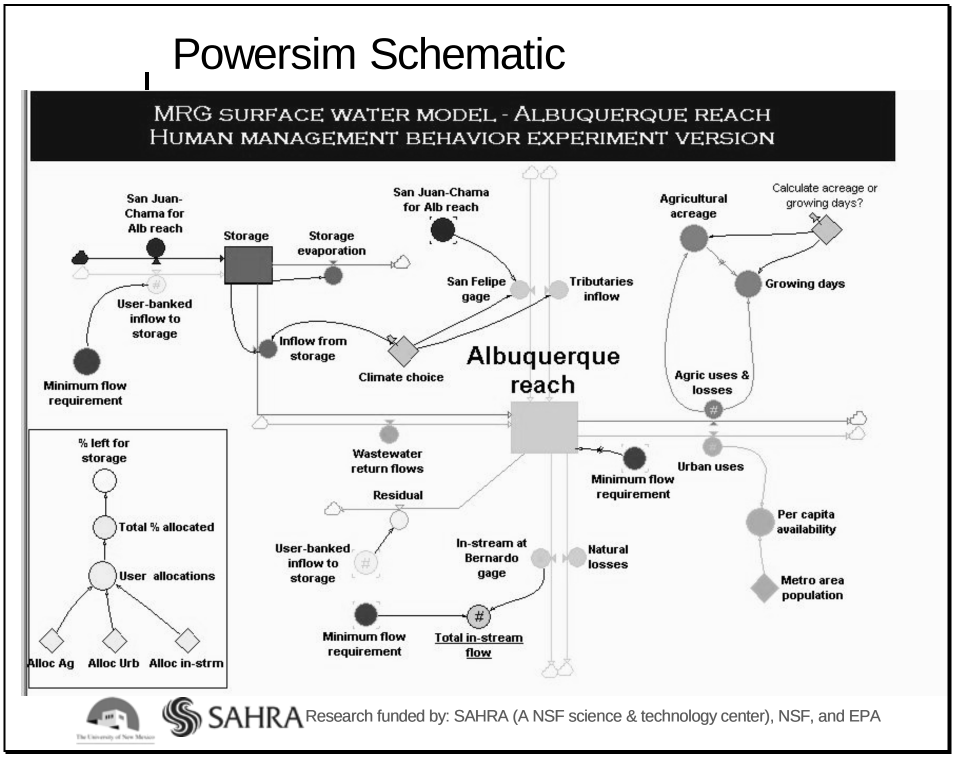
- Change in sector wealth resulting from reallocation
  - Agriculture: Return calculated on the basis of existing crop yield patterns.
  - Urban: Return derived from current consumption, population and consumer surplus based on demand estimates.
  - Bosque: Return derived from survey WTP values.
- Payment reductions for over-allocation (multiple iterations)

Different allocations of water have economic consequences. Too little irrigation will reduce an agricultural user's wealth, and too little urban water will have adverse effects for urban users. We modeled the economic effects of water use for the three different user types using three user-specific models. Participants were paid on the basis of these economic effects. In addition, we included a penalty for failure to allocate.

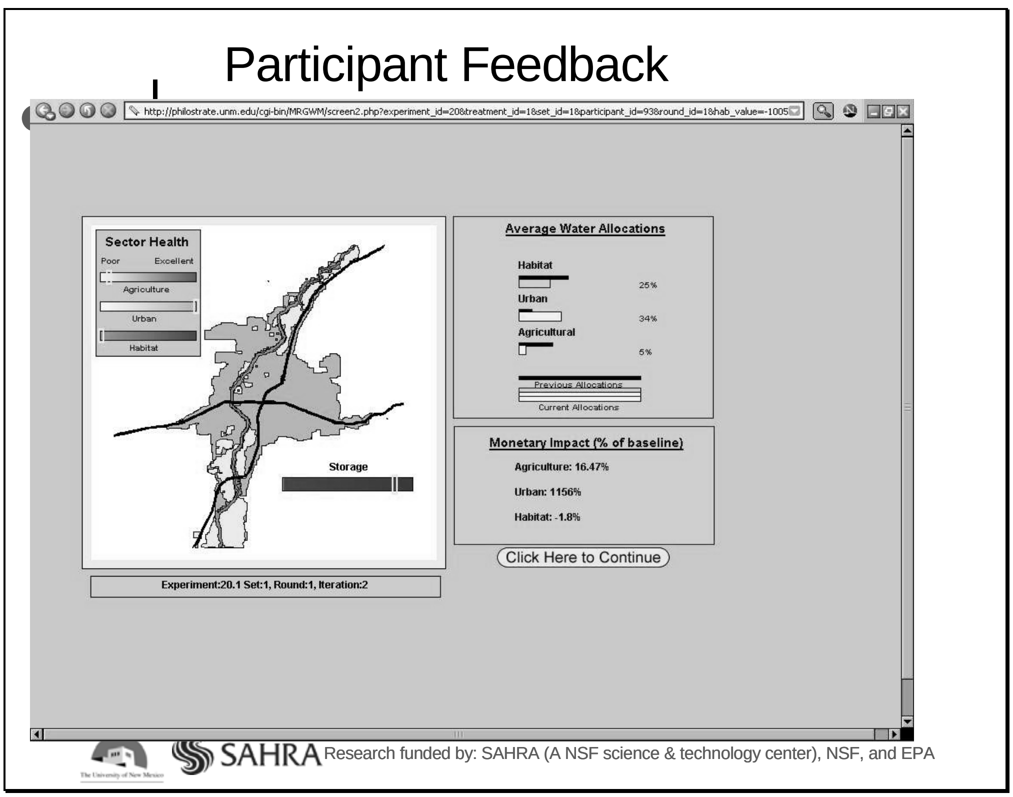




The first screen seen by the participants looked like this one. Color intensity on the map corresponds to color intensity in the bars that indicate sector health. Darker colors indicate sufficient water to support that use; lighter colors indicate less-than-optimal water availability. Additional information is provided regarding starting use, storage level, and climate condition. The participants were asked to enter the percentage that they thought should be allocated to their own sector's use (in the known treatment shown). In some treatments, three boxes were shown, and the participants were asked to allocate 100% of the water among the three competing uses.



Allocation requests from each of the three user-types were averaged and then sent to a PowerSim model of the valley. This model accounted for inflows, natural losses, and other effects on the supply of surface water to the valley. The resulting available water was then used to calculate economic benefits for each sector.

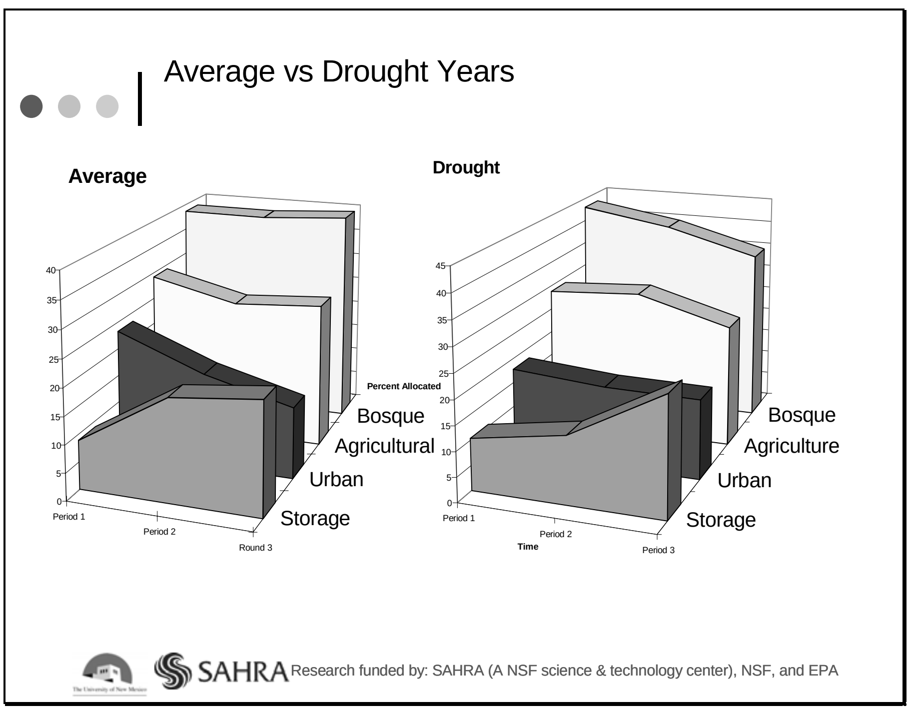


If the allocation requests did not exceed water availability, the participants would see this screen. (The schematic on the prior slide was not shown to the participants.) This provides information about the new sector health, storage, and economic, or monetary, impact of the allocation.

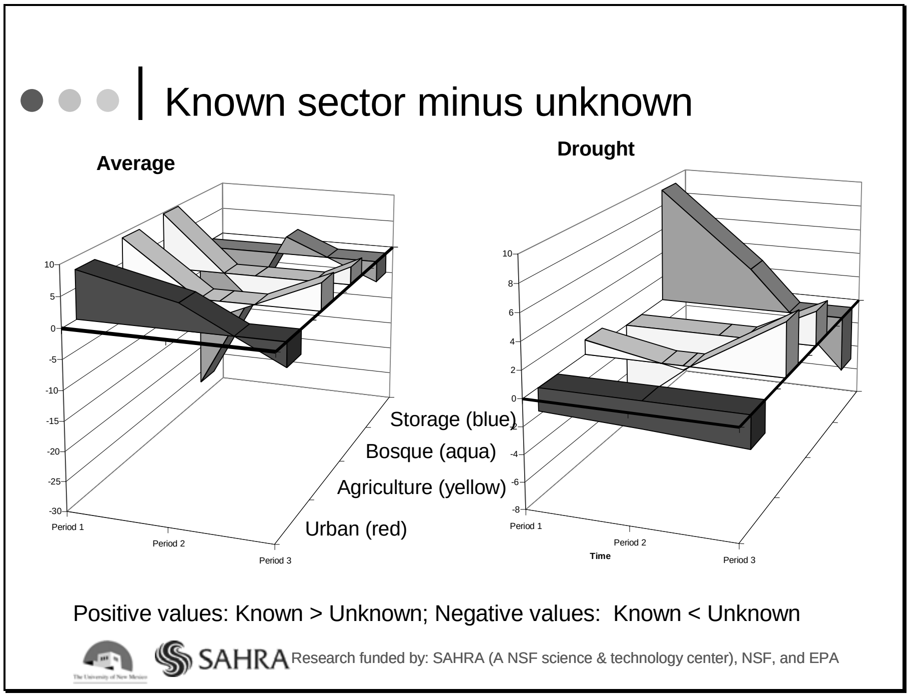
Specific Issues; Preliminary Results:

- Effects of treatments and parameters on decisions
  - Average rainfall vs Dry years?
  - Known type vs Unknown?
- What conditions tend to lead to multiple iterations?
- Do multiple iterations impact final allocation choices?
- Assigned group identity vs self-reported sympathies.

We were interested in comparing allocation requests under the various treatments. Specifically, we looked for differences in allocation between drought and non-drought years and for differences in allocations between the known and unknown treatments. The unknown sector treatments were included to capture participants' perceptions of equitable allocations. Since participants did not know the sector to which they were assigned, they did not have an incentive to ask for a large allocation for any single sector in hopes of a high payoff. We were also interested in identifying conditions under which participants were more likely to try to allocate too much water, leading to a failed round, and in the response of participants to a round in which they were penalized for over allocating. Finally, we were interested in the impact of role assignment. In some rounds, participants were assigned the sector to which they were naturally sympathetic; in some rounds the sector assignment was not aligned with the participant's true affinity.



A very preliminary look at the data suggests very little difference between average and drought years.

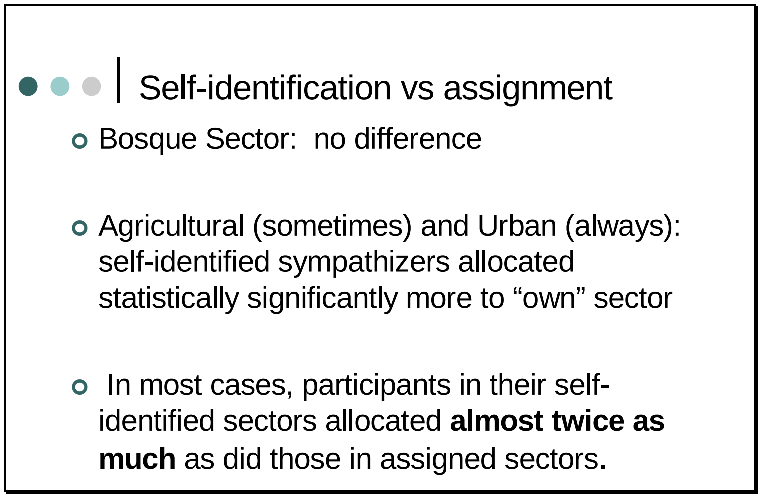


Some interesting patterns are revealed when comparing the known treatments with those in which sector assignment is unknown. In these figures, mass lying below the bolded zero axis indicates higher allocations when sector assignment is unknown. For example, during average years, unknown-sector treatments yielded high storage in the first round; just the opposite is true in drought years. There, knowing sector assignment led to higher storage early on. As for the three use types, during average years knowing the sector to which you belonged was most often associated with greater draws on the water supply, particularly in the earliest rounds. When type was unknown, during drought years significantly more was allocated to agriculture (in the early rounds).

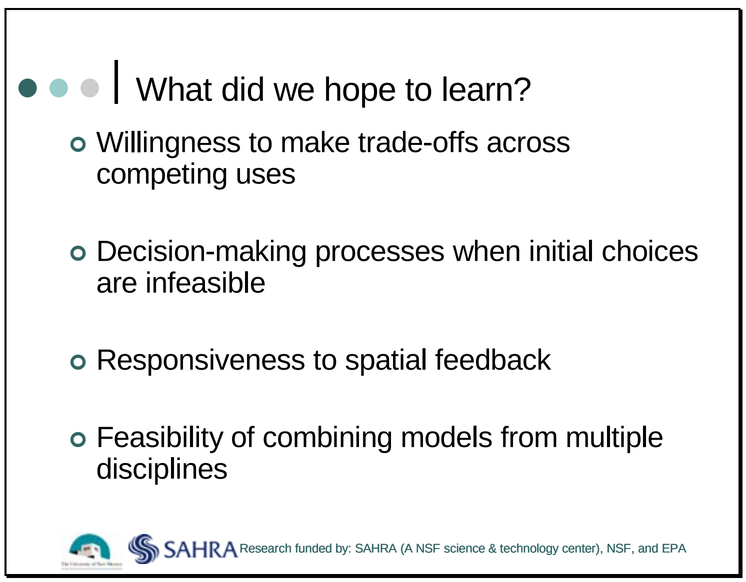
Multiple attempts (iterations)

- 39% of experiment sets resulted in over-allocation (multiple iterations)
- More occurred in drought/known sector scenarios than any other treatment combination.
- More occurred in later rounds within a set (as storage was drawn down)
- NO systematic difference in allocations when multiple iterations occurred.

If the sum of the participant allocations exceeded the water supply (including storage from earlier rounds), a monetary penalty was deducted from their earnings and the participants were asked to try again. Thus over allocations in a round led to multiple iterations in the same round. More than a third of the rounds resulted in over-allocations, forcing participants to try again. These most often occurred under drought conditions and, as seen in the prior slide, when participants knew the sector to which they had been assigned. The drought condition is associated with lower levels of water storage, and when that condition was in place participants tended to draw down what little storage existed. This led to over allocation in later rounds of drought sets. Contrary to our expectations, participants did not, as a rule, reduce allocation requests after a round in which over allocation led to failure.



Perhaps the most striking result revealed in our preliminary look at the data is that people played true to type. When participants were assigned to their own self-identified sector, they often requested more water. This was particularly true of the self-identified urban group: these participants always allocated more to the urban sector when they played that role.



The work presented here represents very preliminary analysis of the data generated by these experiments. Thus our biggest accomplishment to date is the development of the tool. We have shown that researchers from diverse disciplines can combine their models in ways that shed light on a very important issue: competing water demands in the desert Southwest.