



DCDC 2006-2007
Annual Progress Report

Decision Center for a Desert City
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DCDC 2007
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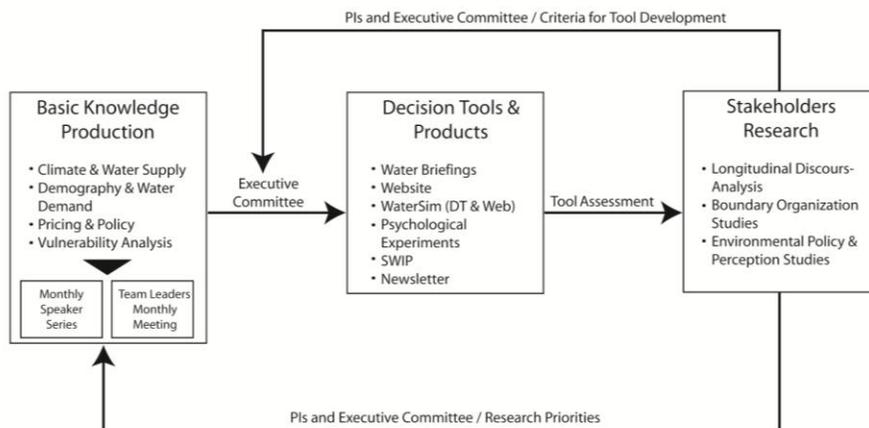


I. Introduction to DCDC

The Decision Center for a Desert City (DCDC) is one of five research projects funded by the NSF's Decision Making Under Uncertainty (DMUU) initiative. Now in its third year, DCDC's research, education, and outreach activities are focused on water resource decision making in central Arizona in the face of growing climatic uncertainty, rapid urbanization, and political and economic institutions designed for the past century's climatic and growth conditions.

Year 3 activities continued research that contributes to our model-building efforts. They further our basic understanding of the physical and social determinants of water supply and demand; of the social, economic, and political processes that govern water resource management at the community and regional scale; and of human adaptation and response to vulnerability from water shortage. In response to our midterm review, we have a refined conceptual framework that emphasizes integration and evaluation.

DCDC Research and Tool Development Conceptual Framework



This framework, which replaces the DCDC water model presented in earlier years' reports, incorporates formal and informal mechanisms for integration, evaluation, and planning (Fig. 1). The figure shows three types of activities crucial to DCDC's efforts. (1) Basic knowledge production includes traditional NSF-funded research using, to the extent possible, established laws of climate variability and change, water resource management, pricing and policy, and human vulnerability. (2) Decision support tools and products include WaterSim (as featured in the Decision Theater and a new Web-based version), and Monthly Water/Climate Briefings highlighting speakers from the regional water management community. (3) Stakeholder research includes a set of ongoing studies about how water managers perceive and engage with scientists and science products; results will contribute to the empirical literature on the science-policy interface and decision making.

WaterSim

WaterSim integrates information about climate, land use, population growth, and water policy. Decision levers enable users to gauge water-shortage conditions in response to climate change, drought, population growth, technological innovation, as well as policy decisions about the nature of the region's built environment, landscaping practices, and recycled water. WaterSim is central to DCDC's mission in three ways. First, it is a vehicle for integrating interdisciplinary, multiscale research, providing a framework for linking the work of geographers, economists, anthropologists, mathematicians, and decision scientists. While some DCDC scientists work on individual, discipline-specific projects, others are devoted to studying relationships that link the submodels of WaterSim. The overall model provides DCDC participants with a common, regional perspective. A second function of WaterSim is as a 'boundary object' to communicate with regional decision makers. Cash (Cash et al. 2003. *Knowledge systems for sustainable development. Proceedings of the National Academy of Sciences* 100(14): 8086-8091) argued that boundary objects, which can take the form of co-produced models, simulations, visualizations, assessment reports, and datasets, are an effective method of linking science and policy. They claim that the process of creating a boundary object engages end-users in defining data needs at an early stage in the scientific process (saliency), brings a wider range of expertise to the table to solve what are inevitably complex social and environmental problems (credibility), and makes the scientific process more transparent to decision makers (legitimacy). The third and arguably most innovative aspect of WaterSim is as an experimental environment in which to study decision processes. In fall 2006 we presented WaterSim to 69 regional stakeholders and conducted the first phase of a longitudinal analysis of the model's saliency, credibility, and legitimacy, among other scientific issues.

Three avenues of DCDC research inform the water model: (1) the sources of regional climate variation and change and their effects on water supply and demand conditions; (2) the decisions that individual and institutional actors make about water; and (3) the factors that put individuals and communities at risk from water shortage.

Year 3 projects included the following:

WaterSim: WaterSim is an integrated collection of quantitative models that represent water consumption and availability in central Arizona under scenarios of population growth, climatic uncertainty, individual behavior, and policy choices. It was constructed using a systems dynamics framework in the software application PowerSIM. The main components of the model consist of supply- and demand-side modeling. Preliminary results have been displayed in the Decision Theater, where the model serves as a boundary object that can be used jointly by the scientific community and water managers for meaningful discourse about future water policy. A web version of WaterSim is now widely available to the public at <http://watersim.asu.edu:81>.

Climate and Human Activity Studies: Early in DCDC's development, climatologists studied the climate system, with little regard for the linkages between human activities and that system. In Year 3, we began to focus more explicitly on interrelationships among climate, water, and growth. The following papers are representative of these efforts:

- a) Balling and Gober's (2007) study of how varying temperature and precipitation conditions affect water use in Phoenix,

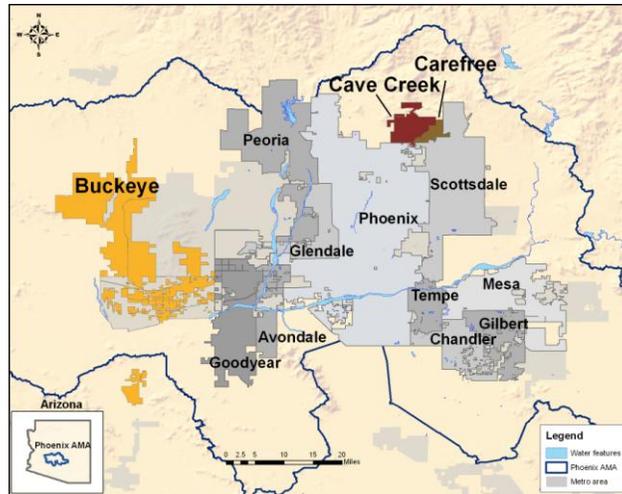
- b) Guhathakurta and Gober's (2007) study of how Phoenix's urban heat island affects water demand, and
- c) Brazel's et al. (2007) estimated effects of growth and housing construction on the urban heat island.

Decision Research: A range of individual and institutional actors make decisions about water in the Phoenix region. Individuals consume water directly in the form of indoor and outdoor uses (66% of the total water use in Phoenix is for exterior use) and indirectly through choices about the size of homes and lots, landscaping treatments, and pools. Municipalities manage supply portfolios, set water pricing schedules, and initiate conservation programs in the face of drought and climate change, but they also indirectly decide about water when they implement growth and zoning ordinances and choose the way they market themselves to developers and potential residents. DCDC's research deals with direct decisions about water (White et al. in press), indirect decisions (Gober 2006), and the relationship between the two (Wentz and Gober 2007).

Water Pricing and Demand Modeling: We have begun to synthesize ongoing studies of water pricing and demand modeling with an eye toward developing a policy submodel for WaterSim 3.0. These studies include economist Kerry Smith's research into the price elasticity of water demand and the design of more efficient and conservation-based price schedules, geographer Elizabeth Wentz's and mathematician Pricilla Greenwood's spatial studies of water demand, and policy analyst Heather Campbell's work on the responsiveness of consumers to various water conservation policies. Results of their joint efforts enable us to model the spatial effects of potential demand reduction programs of the City (e.g. block pricing, incentives to remove turf, and water education campaigns). This synergistic approach allows DCDC to add value to the knowledge production process by fusing existing projects, transforming them into support tools, and working with a valued community partner (City of Phoenix) in the process.

Vulnerability Studies: Our vulnerability studies ask the important "so-what" questions: what are the consequences of water resource decision making for people and communities, and what are the risks of maintaining the status quo? Vulnerability refers to the characteristics that determine which individuals or groups are capable of anticipating, coping with, and recovering from natural hazards. Vulnerability analysis is both inductive and deductive. It is inductive in that it identifies historical, geographical, and institutional factors that affect resource use and shortage conditions. It is deductive in that it relies heavily upon a political-economy perspective.

The structure of societal arrangements renders certain people and places less secure than others in the face of environmental threat. This structural perspective informed Year 1 case studies of water conflicts in peri-urban communities in upland watersheds surrounding Phoenix (Collins and Bolin, submitted). Subsequent research has moved to case studies of urban-fringe communities where the preconditions for water shortage are in full force. These studies focus on the institutional arrangements that create vulnerability in the Phoenix area: (1) Cave Creek, an urban-fringe community, is experiencing periodic water shortages which leave 200 households without running water in the morning hours, and (2) the Gila River Indian Community (GRIC), which recently won a water rights settlement case, seeks to restore its traditional culture of irrigation agriculture in the midst of one of the nation's fastest-growing metropolitan areas.



These case studies have drawn from a geographic political-economy perspective (Harvey, D. 2006. *The Limits to Capital*. London: Verso) wherein the process of capital accumulation differentially allocates risks and resources across space, creating unequal landscapes of vulnerability. In a rapidly growing city like Phoenix, capital accumulation is strongly dependent on residential growth, producing a sociospatial dynamic which both increases the overall risk of water shortage and distributes that risk over a landscape of unequal physical, institutional, and social vulnerabilities.

Case studies have underscored the importance of institutions and regulatory frameworks in amplifying or mitigating risk. In summer 2007, we will produce a GIS-based vulnerability assessment of the Phoenix metropolitan area identifying the differential allocation of risks and resources across space as mediated by these institutional and regulatory forces. Vulnerability maps generated by this analysis will be integrated into the next version of WaterSim as we relate water shortage conditions due to drought and climate change to the water portfolios of municipal providers and place-specific vulnerability conditions. Results will show not only the heightened regional risk from climate change, but also the unequal landscape of risk depending upon local physical, institutional, and social conditions.

Education

Graduate Education: To date, 26 graduate students from the School of Life Sciences, the Center for Science, Policy and Outcomes, and the Departments of Geography, History, Political Science, Psychology, and Communications have participated in DCDC projects. To facilitate greater collaboration among graduate students working on DCDC projects, we require all research assistants to participate in a one-credit graduate seminar, *Community of Graduate Scholars*. The seminar brings together graduate students working on sustainability and water issues to build cross-disciplinary dialogues and interdisciplinary perspectives.

Undergraduate Education: In 2006-07, DCDC funded one REU student who participated in the University's Community of Undergraduate Research Scholars (COURS) program sponsored by the ASU Barrett Honors College. Facilitated by DCDC investigator and Barrett Honors College Associate Dean Margaret Nelson, COURS includes students from DCDC, the Southwest

Consortium for Environmental Research and Policy (SCERP), the Urban Ecology Integrative Graduate Education and Research Training (IGERT) program, the Biocomplexity project and other NSF-sponsored projects. The COURS students meet weekly for multidisciplinary discussions of research, participate in a range of research activities related to their respective projects, and prepared research posters for presentation at a culminating event hosted by DCDC, held this year on May 2, 2007. The COURS program epitomizes DCDC's goal of linking undergraduate education to research and decision making in a collaborative and interdisciplinary environment.

The education team designed and piloted an internship program in Year 3 to provide two undergraduate students with research and work experience opportunities with DCDC community partners. Interns also enrolled in an academic-year internship seminar led by Monica Elser. The program included weekly discussions of water and sustainability-related papers and students' reflections on their work experiences. The interns created posters to share at the Community of Undergraduate Research Scholars Poster Session on May 2, 2007.

K-12 Education and Outreach

On July 17-19, 2006, we hosted an Advanced Water Educators Workshop where 29 participants discussed issues related to the urban heat island, drought, and water management. Experts presented ideas on each topic and then engaged participants in discussions. The workshop had four goals: (1) enhance the participants' knowledge of water in Arizona, (2) describe the complexity of the impact of growth in water demand, (3) provide baseline knowledge on the urban heat island, drought, and water management, and (4) design opportunities to educate the public about current water issues. Pre- and post-workshop surveys were used to evaluate these goals.

Based on the success of the first Advanced Water Educators Workshop, DCDC will host a second Advanced Water Educators Workshop for approximately 30 formal and non-formal educators on July 31 to August 1, 2007. The goal is to create materials that enhance learning about climate change and decision making. The University of Arizona's Water Resources Research Center and Project Wet will co-sponsor this workshop. A similar workshop sponsored by the ASU Geographical Science department and comprised of high school geography teachers will be held on at DCDC on June 19, 2007.

The education team developed and pilot-tested an urban heat island module with a group of inner-city middle school children. The team also is working with a team of AP human geography teachers and community college geography professors to develop an urban sustainability learning module using WaterSim for incorporation into AP human geography courses.

II. Findings of Research Activities

Findings from Research Activities

Climate Change: Andrew Ellis, Timothy Hawkins, Robert Balling, and Patricia Gober developed a water-budget model of upstream watersheds of the Salt and Verde Rivers and ran the model using general circulation models (GCMs) to represent popular greenhouse gas and population and economic growth scenarios. They found that runoff is sensitive to changes in both temperature and precipitation, although the models produce more divergent results for

precipitation than for temperature. Of the 20 model-scenario combinations tested, 16 predicted a decrease in runoff and hence a structural reduction in the region's water supply. The mean runoff for all simulations is 77% of historical runoff levels. These studies are the first systematic assessments of possible effects of climate change on the water supply of central Arizona. Results have been submitted for publication to *Climate Research*.

Urban Heat Island: To link local climatic conditions to population growth and urbanization, Brazel et al. (2007) investigated the spatiotemporal variation in nighttime temperatures in and around Phoenix from 1990 to 2004. Findings revealed that the agricultural fringe adds 0.1 degree C from exurban sites, the desert fringe adds 0.5 degree C, and urban infill locations add 1.0 degree C. The urban core is 2.2 degrees C warmer than the surrounding rural countryside. Results of this study provide planners and city officials with a tool to estimate the temperature effects of population growth and new home construction. This tool is particularly important given the growth conditions of the region, where an estimated 646,329 new residents were added between 2000 and 2005, growing from 3.25 million to 3.90 million. Coupled with the results of Guhathakurta and Gober (2007), which demonstrated a relationship between rising nighttime temperatures and increased water demand, we can forecast more accurately the effects of future urban growth on water demand.

Decision Theater Experiment: Timothy Lant, Amber Wutich, Dave White, and Susan Ledlow brought 69 stakeholders to the Decision Theater to view WaterSim and studied their reactions to the presentation using text and interaction analyses of individual and group reactions. Preliminary results from coded interviews and transcripts indicate that legitimacy was not as important as credibility and saliency as a criterion for model evaluation. An obvious next step is to examine whether legitimacy becomes more important as DCDC tackles the more controversial topics of growth management and water markets. In subsequent waves of this longitudinal analysis, we will assess how stakeholder perceptions of science and WaterSim change as a result of exposure to and involvement with scientific information. In addition, the Web-based platform will enable us to investigate how participants use the model for background research, discussion, and decision making.

Risk Perception and Visualization: In a second Decision Theater experiment, Edsall and Larson (2006) compared the Decision Theater's 3-D environment relative to a standard PowerPoint classroom presentation as tools to increase scientific understanding of environmental problems. In a pilot project including students and experts, they found that students experienced a greater increase in awareness of Phoenix's urban heat island and groundwater overdraft than experts. Participants reported increased knowledge of the urban heat island, but decreased knowledge of global warming as a result of exposure to visualization.

Data Uncertainty: Lee et al. (in revision) used Bayesian Maximum Entropy (BME) to account for data uncertainty in measurements of the urban heat island in Phoenix. Use of BME increased mapping accuracy by more than 35% over standard linear kriging techniques. A further synthetic study showed the benefits of BME over simple kriging methods as the number of missing and incomplete data records increases.

Water Demand: Wentz and Gober (2007) investigated the determinants of water consumption for detached single-family residential units using ordinary least squares (OLS) regression and geographically weighted regression (GWR). Results confirm the statistical significance of

household size, the presence of a pool, landscaping practices (how much turf versus natural desert vegetation), and lot size. Improvement of the GWR over the OLS model suggests that there are spatial effects above and beyond the effects of the individual variables. Census tracts display consumption patterns similar to their neighbors, *ceteris paribus*. Model parameters are used by WaterSim to estimate the effects of trends in policies with respect to pools, landscaping, and lot size.

Boundary Science: White et al. (in press) investigated how 12 DCDC stakeholders perceive and negotiate the boundary between science and policy and how they represent, communicate, and manage uncertainty. Some respondents represented the science-policy interface as a linear process with scientists as neutral producers of knowledge and themselves as downstream users adjudicating the political process to make decisions. Others expressed a view of a more integrated, recursive process in which knowledge is co-produced by scientists and decision makers.

Decision Research Cluster: Three projects, independently conceived and executed, articulate different stages by which water messages are disseminated and internalized. Together, they will allow us to predict the spatial effects of different types of water policy. Bethany Cutts and Ann Kinzig's (School of Life Sciences) project deals with the social construction of water information. Their work introduced a new set of institutional water actors – the people designated by provider organizations to disseminate conservation messages – and mapped the intensity and type of their water education messages. Decision analysts Craig Kirkwood (Supply Chain Management) and Robin Keller (University of California at Irvine Paul Merage School of Business) investigated the values, tradeoffs, and decision metrics of water stakeholders and found, not surprisingly, that municipalities prize water sufficiency more highly than do environmental groups who place more weight on natural habitats and biophysical conditions. Elizabeth Wentz (Geography) and Priscilla Greenwood (Mathematics) modeled the sensitivity of households to water-conservation policies – specifically pricing schedules designed to reduce non-essential consumption.

Findings from Educational Activities

Advanced Water Education Workshop: On July 17-19, 2006, DCDC hosted an Advanced Water Educators Workshop where 29 participants discussed the urban heat island, drought, and water management. Experts presented materials on each topic and then engaged the participants in discussions. The workshop had four goals: (1) enhance the participants' knowledge of water in Arizona, (2) describe the complexity of the impact of growth in water demand, (3) provide baseline knowledge on the urban heat island, drought, and water management, and (4) design opportunities to educate the public about current water issues. Pre- and post-workshop assessment surveys show that all goals were met. Other education activities started in year 3 include the development of (1) urban heat island modules (tested in an inner city, Hispanic (95%) middle school, and (2) water-related modules (WaterSim & SWIP) for AP and junior college use.

Community of Undergraduate Research Scholars: ASU's Community of Undergraduate Research Scholars (COURS) Program has included a total of five REUs funded by DCDC. One of the goals of COURS is to build student ability to think across disciplines and to consider the broader impacts of research. Success is gauged in two ways: (1) comparison of a pre-test to two

mid-year assignments, and (2) comparison of the pre-test to a post-test. Results of these comparisons reveal that COURS students improved their understanding of how their research is relevant to other disciplines and to broader public and theoretical issues. Students also improved their understanding of the broader impact of research outside their field of expertise. The success of this program is illustrated in the fact that 78% of COURS undergraduates presented research at a national, professional meeting of which half were interdisciplinary meetings. In addition, 60% of those who have not yet graduated have continued to be involved in interdisciplinary collaborations after COURS.

III. Research Findings: Training & Development

Undergraduate: In Year 3, DCDC funded one undergraduate student to participate in the Community of Undergraduate Research Scholars (COURS) program as well as two undergraduate internships.

COURS is an interdisciplinary program, co-sponsored by the Barrett Honors College and the Global Institute of Sustainability (GIOS), and supervised by Barrett Honors College Associate Dean Margaret C. Nelson. COURS integrates undergraduate students into ongoing research projects, provides an interdisciplinary environment that enhances cross-disciplinary communication and appreciation for the broader impacts of scientific work, and results in concrete research products.

All COURS students prepared research posters for presentation at a capstone event on May 2, 2007, featuring an outside speaker and widespread participation from DCDC, CAP LTER, and IGERT faculty.

The DCDC internship program began in Year 3 and provides research and work experience opportunities with DCDC community partners. Interns also enrolled in an academic year internship seminar led by GIOS Education Liaison Monica Elser. This year's internship included weekly reflections by the interns and discussions of water and sustainability-related papers. DCDC's interns created posters of their experience to share at the Community of Undergraduate Research Scholars poster session.



The titles of the DCDC-related COURS poster presentations are listed below:

- “What difference does it make? Quantifying water conservation in Tempe, AZ,” Andrew Knochel²
- “Are apartment renters in the Phoenix metro area well informed about local water issues?” Nicholas Moore¹

- “Accounting and accountability: Groundwater management in the East Valley,” Caroline Newcome²

¹DCDC REU (COURS) students, ²DCDC Interns

Graduate: To date, 26 graduate students from the School of Life Sciences, the Center for Science, Policy and Outcomes, School of Social and Family Dynamics, School of Human Evolution and Social Change, School of Sustainability, School of Geographical Sciences, School of Earth and Space Exploration and the Departments of History, Political Science, Psychology, and Communications have participated in DCDC projects. To facilitate greater collaboration among graduate students working on DCDC projects, we have begun in year three and will continue to require all research assistants to participate in a one-credit graduate seminar, Community of Graduate Scholars.

The Community of Graduate Scholars seminar is modeled on the COURS program. The seminar integrates graduate students into ongoing DCDC research projects, provides an interdisciplinary environment that enhances cross-disciplinary communication and appreciation for the broader impacts of scientific work, and results in concrete research products. DCDC graduate students participated in the Central Arizona Project Long Term Ecological Research (CAP LTER) 2007 poster symposium in January 2007 in Tempe. They also organized a poster session for students across all DMUU units at the AAAS meetings in February 2007 in San Francisco. Poster titles and authors are listed below:

CAP LTER

- “Decision Making Under Uncertainty: Ranking of Multiple Stressors on Central Arizona Water Resources,” Netra Chhetri, Lori Hiding, Mark Neff¹, Megan O'Shea, Alyia Buttar, and Uven Chong
- “Water Landscapes: Representing the Effort Distribution Multiple Outreach Organizations,” Bethany Cutts¹
- “WaterSim: A Study of Water-Related Decision-making under Uncertainty,” Meredith Gartin¹, Tim Lant, Amber Wutich, Dave White, Susan Ledlow, and Pat Gober
- “The Impact of Housing Characteristics and Surface Heat Islands on Water Use in Single Family Residences: The Case of Phoenix Metropolitan Area ,” Subhrajit Guhathakurta, Patricia Gober, and Jamie Patterson¹
- “Water Conservation Policy in an Arid Metropolitan Region: A Historical and Geographical Assessment of Phoenix, Arizona,” Annie Gustafson¹, Kelli Larson, Paul Hirt, and Jagadeesh Chirumamilla¹
- “Water Vulnerability on the Urban Periphery: Buckeye, Carefree and Cave Creek, Arizona,” Claire Smith¹, Lilah Zautner¹, Kelli Larson , and Bob Bolin

AAAS

- "Uncertainty in Mapping: Water Education Effort," Bethany Cutts¹
- "Examining the Interface between Policy Makers and Scientists," Meredith Gartin¹ and Tim Lant

- "Water Conservation Policy in an Arid Metropolitan Region: A Historical and Geographical Assessment of Phoenix, Arizona," Annie Gustafson¹, Kelli Larson, Paul Hirt, and Jagadeesh B. Chirumamilla¹
- "Arbitrary Impacts and Unknown Futures: the shortcomings of climate impact model," Ryan Meyer¹
- "Will Phoenix Have Sufficient Water? A Workshop to Assess Stressors to an Urban Water System," Mark Neff¹, Netra Chhetri, Dan Sarewitz, Lori Hidinger, Megan O'Shea¹, Aliya Buttar, Uven Chong¹
- "The Impact of Housing Characteristics and Surface Heat Islands on Water Use in Single Family Residences: The Case of the Phoenix Metropolitan Area," Jamie Patterson¹, Subhrajit Guhathakurta, and Patricia Gober
- "Phoenix as a Human Habitat in Summer: Exposure and Resources to Cope with Extreme Heat," Darren Ruddell¹ and Sharon Harlan
- "Water Vulnerability on the Urban Periphery: The Case of Metropolitan Phoenix, Arizona," Claire Smith¹, Lilah Zautner¹, Kelli Larson, and Bob Bolin

¹DCDC Graduate students

Postdoctoral: DCDC has two post-doctoral fellows associated with research projects.

Mohan Seetharam, a recent Ph.D. recipient from Clark University's Graduate School of Geography, specializes in GIS and vulnerability mapping.

Seung-Jae Lee, a Ph.D. from the Department of Environmental Sciences and Engineering at the University of North Carolina, specializes in environmental modeling, geostatistics, and data uncertainty.

IV. Education and Outreach

DCDC's water/climate briefings continue to draw participants from the academic and practitioner communities. Speakers in Year 3 included community partners and academic colleagues whose topics served to increase the understanding of decision making processes in water resources management. Five briefings were held in Year 3 with total attendance of nearly 300 individuals.

- *The Next Bucket of Water* was presented May 2, 2007, by Steve Olson, Executive Director of Arizona Municipal Water Users Association. Olson discussed the current issues in supplying water for Arizona's growth.
- *Water in the Arid West: Moving from Mark Twain to the Realities of Climate Change* was presented April 4, 2007, by Patricia Mulroy, General Manager, Las Vegas Valley Water District and Southern Nevada Water Authority. Mulroy discussed how relationships between neighbors and neighboring states in the arid west are evolving in response to climate change and reduced flow in the Colorado River basin.
- *Inflow and Outflow, Flycatchers and Chubs* was presented February 7, 2007, by John Keane, Senior Environmental Scientist at SRP, Ruth Valencia, Senior Environmental

Scientist at SRP and Charles Paradizick, Senior Ecologist at SRP. The speakers discussed reservoir operations and the endangered species act on the Salt and Verde Rivers.

- *Water Implications of the Superstition Vistas Project* was presented October 4, 2006, by Grady Gammage, Jr., Senior Research Fellow, Morrison Institute for Public Policy. Gammage discussed future water resources for Superstition Vistas and whether or not water will be a constraint on the project.
- *The Impact of Climate on Water Supply Reliability* was presented September 6, 2006 by two groups. (1) Katharine L. Jacobs, Executive Director of Arizona Water Institute, and Deputy Director of the NSF Center for Sustainability of Arid Region Hydrology and Riparian Areas at University of Arizona. Project Team: Dr. David Meko, Associate Research Professor, University of Arizona, and Dr. Bonnie Colby Professor for Department of Agricultural, University of Arizona. Students: Laura Lindenmayer and Dustin Garrick. This group discussed enhancing water supply reliability through climate information. (2) Dr. Robert C. Balling, Jr., Professor, School of Geographical Sciences, ASU, and Dr. Andrew W. Ellis, Associate Professor, School of Geographical Sciences, ASU, discussed simulating the potential impacts of regional climate change on water supply from the Salt and Verde watersheds.

DCDC also sponsored or co-sponsored several lectures. These lectures brought together individuals from industry and multiple academic disciplines to explore and discuss topics such as robust decision making, historic perspectives of water in societies, visualization in environmental policy, and climate change in human-dominated systems. Titles of the lectures are listed below:

- *Does experience make a difference? Alaskan risk perceptions of climate change* was presented November 21, 2006, by Anthony Leiserowitz, Principal Investigator, Center for Research on Environmental Decisions, Columbia University. Leiserowitz discussed Alaskans' perception of climate change, and what mitigation and adaptation measures they prefer.
- *Water (Re) Allocation and Management in a Time of Scarcity, Competition and Climate Change* was presented November 14, 2006 by Rosalind Bark, Doctoral Candidate, University of Arizona Arid Lands Research Science. Bark presented three case studies in Arizona that describe other challenges to water sustainability goals: the competing water needs of the environment, the threat of climate change on winter-based recreation, and water reallocation to Indian tribes.
- *Social Vulnerability, Climate Change, and Economic Development on the Deccan Plateau* was presented November 8, 2006, by Mohan Seetharam, Doctoral Candidate, Clark University Graduate School of Geography. Seetharam discussed the relationship between long-term drought exposure, adaptive capacity, and the geographical distribution of vulnerability using a meso-scale, GIS-based vulnerability model.
- *Freshwater Ecology Roundtable* was presented August 8, 2006, by Dr. Jackie King, Principal Freshwater Research Officer at University of Cape Town, South Africa. King led a science roundtable featuring a discussion of possible collaborative opportunities.

Presenters included Dr. King, ASU VP for Research and Economic Affairs Jonathan Fink, Grady Gammage of the Morrison Institute for Public Policy, Rita Maguire of Think AZ, DCDC Co-director Pat Gober, and DCDC scientist Tim Lant. Discussants included numerous DCDC scientists, representatives from the University of Arizona, and visitors from many other public and private Arizona institutions. King's visit to Arizona was the last of a series that included stops in Costa Rica and Guatemala as part of an effort to raise public awareness of the diverse set of approaches that different countries are taking to address increasing water scarcity and growing human populations.

DCDC has launched two decision support tools on the Web: (1) SWIP (Southwest Water Information Project) is an online, interactive atlas released in mid-summer 2006 (<http://dcdc.asu.edu/swipatlas/>). SWIP began as a collaborative effort with the University of Arizona's SAHRA program as a regional water information system for cross-city analyses of water issues in Phoenix and Tucson. The online atlas identifies the spatial characteristics of water consumption along with climatic conditions, demographics, and temporal land use changes. (2) WaterSim, launched in summer 2007 (<http://watersim.asu.edu:81>), is an on-line interactive systems dynamic model that integrates information about climate, land use, population growth, and water policy. Decision levers enable users to gauge water-shortage conditions in response to climate change, drought, population growth, technological innovation, as well as policy decisions about the nature of the region's built environment, landscaping practices, and recycled water.

Community Outreach Presentations and Miscellaneous Activities

Research findings are regularly presented to the local community, as well as to the international academic community. DCDC researchers regularly present DCDC research goals and results to community groups, students and other academic institutions.

Presentations 2007

Balling, Jr. R.C. and A.W. Ellis. 2007. Climate Change 2050: Impacts on the Salt and Verde Watersheds. Family Farm Alliance Annual Meeting, Las Vegas, Nevada, February, 2007.

Balling, Jr. R.C., A.W. Ellis, T. Hawkins, and P. Gober. 2007. Impacts of Potential Climate Change on the Phoenix, Arizona Water Supply. Annual Meeting of the Association of American Geographers, San Francisco, California, April, 2007.

Bolin, B., T. Collins, and K. Darby. 2007. Pumping Groundwater, Draining Rivers: The Political Ecology of Water and Development in Rural Arizona. Paper Presented at the Annual Meetings of the Association of American Geographers. San Francisco, California. April 2007.

Edsall, R.M. and K.L. Larson. 2007. Testing Usability of Visualization in a Semi-immersive Virtual Environment for Decision-Making. Annual Conference of Association of American Geographers in San Francisco, California , April 2007.

Gartin, M. and A. Wutich. 2007. The Social Dynamics of Policymaker Collaboration. The Society for Applied Anthropology, Tampa, Florida, March 27-31, 2007.

Gober, P. 2007. The Role of Population in Integrated Environmental Modeling and Decision Support. Ohio State University, Initiative in Population Research, Columbus, Ohio, April 10, 2007.

Gober, P. 2007. Pasteur's Quadrant: The Challenges and Opportunities of Boundary Science (Discussant). Annual Meeting of the Association of American Geographers, San Francisco, California, April 18, 2007.

Gober, P. and C. Redman. 2007. Decision Making Under Uncertainty: The Challenge of Sustainable Well-Being. Annual Meeting of the American Association for the Advancement of Science, San Francisco, California, February 17, 2007.

Keller, L.R. and C. Kirkwood. 2007. Preference Functions for Decisions with Geographically-Varying Attributes. Merage School of Business, University of California, Irvine, California, Lunch Seminar Series presentation, April 19, 2007.

Larson, K.L. 2007. Residential Landscaping Patterns and Practices in Metropolitan Neighborhoods of Phoenix, Arizona. Annual Conference of Association of American Geographers in San Francisco, California, April 2007.

Redman, C.L. 2007. Chinese Academy of Sciences (CAS) delegation visit. Presented material to CAS which resulted in a Memorandum of Understanding on joint ventures and areas of potential collaboration. Tempe, Arizona. April 24-25, 2007.

Presentations 2006

Balling, Jr., R.C. 2006. Analysis of Drought Determinants for the Colorado River Basin. Association of Pacific Coast Geographers. Eugene, Oregon. September, 2006.

Balling, Jr., R.C. and A.W. Ellis. 2006. Simulating the Potential Impacts of Regional Climate Change on Water Supply from the Salt and Verde Watersheds. DCDC Symposium on “The Impact of Climate on Water Supply Reliability”, Tempe, Arizona, September 6, 2006.

Balling, Jr., R.C. and A.W. Ellis. 2006. Climate Change 2050: Impacts on the Salt and Verde Watersheds. Colorado River Water User’s Association, Las Vegas, Nevada, December 13-15, 2006.

Brazel, A.J. and N.J. Selover. 2006. Diurnal Regimes of Evaporation at Tempe Town Lake, Arizona. Association of Pacific Coast Geographers. Eugene, Oregon. September, 2006.

Chhetri, N., L. Hidinger, M. Neff, M. O Shea, A. Buttar, and U. Chong. 2006. Decision Making Under Uncertainty: Ranking of Multiple Stressors on Central Arizona Water Resources. Paper presented at the workshop on Water Stressor Ranking, Arizona State University, Tempe, Arizona. 2-3 November 2006.

Ellis, A.W. 2006. Potential Impacts of Climate Change on Central Arizona Watersheds. Association of Pacific Coast Geographers. Eugene, Oregon. September, 2006.

Ellis, A.W. 2006. Is there Enough Water?. Camelback Kiwanis Club. Phoenix, Arizona.

Ellis, A.W. and R.C. Balling. 2006. The Potential Impacts of Climate Change on Arizona Watersheds. Geological Society of America Specialty Meeting “Managing Drought and Water Scarcity in Vulnerable Environments: Creating a Roadmap for Change in the United States”, Boulder/Longmont, Colorado, September 18-20, 2006.

Feng, T., L.R. Keller, L. Kessel, C. Kirkwood, N. Jones, and J. Simon. 2006. A Multiple-objective, Multiple-stakeholder Decision Analysis Approach for Water Resources Planning. The Institute for Operations Research and the Management Sciences (INFORMS), International Meeting, Hong Kong, June 26, 2006.

Garfin, G. 2006. Observed and Projected Climate Change in Arizona. Climate Change and Drought Workshop, for county and municipal managers and water providers. Arizona Hydrological Society Symposium, Glendale, Arizona, September 13, 2006.

Gober, P. and T. Lant. 2006. Does Phoenix Have Enough Water to Grow? Association of Pacific Coast Geographers. Eugene, Oregon. September, 2006.

Goodrich, G.B. and A.W. Ellis. 2006. Climatological Drought in Arizona: An Analysis of Indicators for Guiding the Governor's Drought Task Force. Geological Society of America Specialty Meeting: Managing Drought and Water Scarcity in Vulnerable Environments – Creating a Roadmap for Change in the United States. Boulder, Colorado.

Grossman-Clarke, S. and J.A. Zehnder. 2006. Urban induced mesoscale circulations in an arid region. International Conference on Urban Climate, Goeteborg, Sweden, June 12-16, 2006.

Keller, L.R. and C. Kirkwood. 2006. Preference Functions for Decisions with Geographically Varying Attributes. The Institute for Operations Research and Management Sciences (INFORMS), Pittsburgh, Pennsylvania. November 5, 2006.

Larson, K.L. 2006. Pilot Project: Awareness and Perceptions of Rising Temperatures in Metropolitan Phoenix. City of Phoenix Urban Heat Island Task Force. Tempe, Arizona. September, 2006.

Larson, K.L., R. Edsall, and J. Block. 2006. The Effects of Visual Information on Environmental Understanding: Awareness and Perceptions of Water and Heat Problems in Metropolitan Arizona. Association of Pacific Coast Geographers. Eugene, Oregon. September, 2006.

Redman, C.L. 2006. Meeting with Federico Graeff, Director, Center for Scientific Research & Higher Education of Ensenada (CICESE), Mexico. Discussed areas of collaboration between Global Institute of Sustainability and CICESE. Ensenada, Mexico. May 12, 2006.

Redman, C.L. 2006. Met with Dr. Sergio Revah and Dr. Rodolfo Quintero, Universidad Autonoma Metropolitan, Cuajimalpa, Mexico to share information about the Global Institute of Sustainability and the Department of Processes and Technology at the Universidad Autonoma Metropolitana. Cuajimalpa, Mexico. May 16, 2006.

Redman, C.L. 2006. Met with Lisa Shafer, Assistant Director, Program Development and International Relations at the Scripps Institution of Oceanography at the University of California at San Diego to discuss sustainability initiatives at the Global Institute of Sustainability. San Diego, California. May 18, 2006.

Redman, C.L. 2006. Meeting with Rohan Nelson, a resource economist at CSIRO Sustainable Systems in Australia to discuss ASU's approach to inter-disciplinary and multi-disciplinary research and education. Australia. July 6, 2006.

Redman, C.L. 2006. Met with Francois Bousquet, Director of CIRAD, a French agricultural research centre working for international development, to discuss sustainability initiatives at ASU and the Global Institute of Sustainability. Tempe, Arizona. July 17, 2006.

Redman, C.L. 2006. Met with Andreas Rechkemmer, Executive Director, International Human Dimensions Programme on Global Environmental change (IHDP) to discuss the future

Urbanization and Global Environmental Change (UGEC) International Project Office which is located at the Global Institute of Sustainability. Tempe, Arizona. September 12-13, 2006.

Redman, C.L. 2006. Met with President Becker of the University of Dortmund, Germany to discuss environmental and sustainability initiatives at ASU and the Global Institute of Sustainability. Discussed areas of potential collaboration. Tempe, Arizona. September 14, 2006.

Redman, C.L. 2006. Long-term Ecological Research All Scientists Meeting held in Estes Park, Colorado. Purpose of the summit was to explore potential synergies between CAP LTER and DCDC researchers toward a goal of producing joint projects and advancing conceptual understanding. Estes Park, Colorado. September 22, 2006.

Redman, C.L. 2006. Met with Rob & Melani Walton and Andy Ruben of Wal-Mart to discuss ASU's global role in sustainability. Tempe, Arizona. October 16, 2006.

Schmidt, S.K., W.A. Griffin, and O. Kornienko. 2006. DesertWater - An ABM of Household Water Use in the Southwestern United States. The First World Congress on Social Simulation. Kyoto, Japan. August, 2006.

Serre, M.L. and S.J. Lee. 2006. Risk Mapping of Subsurface Arsenic in New England Using Measurement Error Model and Secondary Soil-pH Data. International Association for Mathematical Geology, XI International Conference. Universite de Liege, Belgium. September 3-8, 2006.

Serre, M.L., S.J. Lee, and K. Yeatts. 2006. Accounting for the Observation Scale of Confidential Health Data to Study the Spatial Association between Childhood Asthma Prevalence and Air Pollutants in North Carolina. International Conference on Environmental Epidemiology & Exposure, Paris, France, September 2-6, 2006.

V. Contributions

Contributions within Discipline:

Systems Dynamics Modeling: WaterSim is an integrated collection of quantitative models that represent water consumption and availability in Central Arizona under scenarios of population growth, climatic uncertainty, individual behavior, and policy choices. WaterSim serves as a 'boundary object' that can be used jointly by the scientific community and water managers for meaningful discourse about future water policy.

Boundary Science: DCDC has linked geography more explicitly to the growing literature on boundary science in science and technology policy. Gober organized two sessions at the 2007 AAG meetings to showcase the application of boundary science in geography. The first

highlighted research that influences energy and environmental policy, and the second was a panel discussion dealing with the challenges of and opportunities for geographers working in policy-oriented fields.

Human-natural Coupled Systems: DCDC has produced a critical mass of urban environmental research that links physical and human side geography. Although the discipline includes scientists, social scientists, and humanists, few projects provide the relevant research questions and social networks for actual collaboration across the subdisciplines. DCDC's efforts to interrelate climatic uncertainty, water resource management, and human vulnerability have created opportunities for geographers to ask more complex questions and cross over into new subfields. Examples of this work are a recent study that links City of Phoenix water use with temperature and precipitation conditions (Balling and Gober, 2007), an article that relates Phoenix's urban heat island to residential growth patterns (Brazel et al., 2007), and a third paper that relates the urban heat island to residential water use (Guhathakurta and Gober, in press).

Data Uncertainty: A team of DCDC scientists used Bayesian Maximum Entropy (BME) to characterize Phoenix's urban heat island and to demonstrate the utility of this technique for common geographic problems plagued by data uncertainty. Results demonstrate that the use of BME increases mapping accuracy up to 35.3% over traditional linear kriging analysis. A subsequent synthetic case study confirms that the increase in mapping accuracy occurs when there are many cases missing or uncertain data.

Education: DCDC has launched a project to develop new learning materials related to urban sustainability for Advanced Placement Human Geography courses. This course provides collegiate instruction in geography to more than 20,000 high school students.

Contributions to Other Disciplines:

DCDC's mission as an interdisciplinary research center seeks to fuse traditional disciplinary knowledge to solve a complex societal problem, in this case, how to manage Central Arizona's water in a sustainable way. As such, the goal is not only to produce new disciplinary knowledge but to develop strategic connections among the disciplines that participate in our center. WaterSim has provided opportunities for disciplinary scientists to work on submodels and then to negotiate with colleagues regarding how those models are joined.

Another example of innovative linkage across the disciplines focuses on the social construction of water education knowledge, the social networks through which this knowledge is disseminated, the geographical properties of these networks, and their ultimate effects on water consumption. This collaborative project involves representatives from geography, mathematics, biology, and decision research. The ultimate aim is to model the effects of water conservation messages on the landscape of water demand.

Contributions to Human Resource Development:

DCDC provides a framework for training graduate students, nourishing interdisciplinary projects and contributing to the fields of geography, decision research, vulnerability analysis, and agent-based modeling. Our project is also committed to engaging undergraduate students and K-12 teachers, community organizations, government agencies, and the general public in our interdisciplinary investigation of climate change and human decision making. Graduate students

are drawn from a wide range of disciplines, including geography, geology, psychology, history, political science, family science, communications, plant biology, and microbiology.

Contributions to Resources for Research and Education:

DCDC's setting within a large public institution enhances its ability to leverage research and outreach programs for educational benefit. To date, 26 graduate students have been engaged in DCDC research programs. DCDC is a founding partner and collaborator in the university's Community of Undergraduate Research Scholars (COURS) program. Preparation of the DCDC proposal provided the initial impetus for this innovative program, which integrates undergraduate students into research. An internship program was initiated in 2006-07 that places undergraduates in research positions with local community partners.

DCDC's close collaboration with the Decision Theater (DT) offers myriad opportunities to link research and education. The DT is not only a setting to view visualizations but also a laboratory for studying and engaging decision makers. We anticipate examining the way research and educational infrastructure melds together in the DT.

Contributions Beyond Science and Engineering:

DCDC's core mission is to produce the scientific understanding and support tools that will lead to better water decision making and a more sustainable future for Phoenix, the fastest-growing large metropolitan area in the United States. Results and modeling products can be adapted to other regions experiencing rapid growth, water scarcity, and climatic uncertainty.

**DCDC 2005 Annual Report – Appendix A
Partner Organizations and DCD Participants**

Partner Organizations:

Salt River Project: Collaborative Research

(Ongoing) SRP delivers nearly one million acre-feet of water to a service area in central Arizona and operates an extensive water-delivery system that includes reservoirs, wells, canals, and irrigation laterals. SRP

has provided a wide range of information to DCDC scientists, including hydrological data, public attitude surveys that reveal household perception of drought and responsiveness to conservation messages, reports of water duties (usage rates) associated with different land uses, water delivery data, and irrigation coverage. SRP climatologists and water managers are among the most regular participants at the DCDC Climate/Water Briefings and SRP representatives gave presentations and sparked discussion at two monthly Water/Climate Briefings. SRP also partnered with DCDC and University of Arizona's Water Resources Research Center on a summer 2006 workshop for teachers held at DCDC.

City of Phoenix: Collaborative Research

(Ongoing) DCDC collaborates closely with the City of Phoenix's Water Services Department, sharing the results of different but complementary water modeling efforts. In addition, the City has provided an immensely useful data set that includes municipal water use by different types of users across census tracts between 1990 and 2005. City representatives presented two DCDC monthly Water/Climate Briefings.

East Valley Water Forum: Collaborative Research

(2004-05) The East Valley Water Forum consists of tribal, public, and private water agencies in the East Salt River Valley. They shared their groundwater-modeling output with DCDC so it could be integrated with agent-based models to produce visualizations for the Decision Theater.

Arizona Department of Water Resources: Collaborative Research

(2004-05) A DCDC-sponsored intern worked 20 hours per week at ADWR to retrieve data on the Phoenix area's water budget. The intern also developed metadata about how ADWR created the water budget.

INTEL: Collaborative Research

(2004-2005) The DCDC/Intel partnership pursued three areas of mutual interest: 1) sharing expertise and technology through education, training, seminars, and the Decision Theater; 2) working with industrial-sector water users to promote conservation measures and voluntary goals before mandatory water requirements take shape; and 3) researching the policy and technology driving water management.

University of Arizona: Collaborative Research

(Ongoing) DCDC collaborates with three University of Arizona (UA) research centers dedicated partly or wholly to water and climate research. Researchers from the Arizona Water Resources

Research Center (WRRC) participate in the Science and Technology Policy/Boundary Organization efforts, investigating public perception of drought and water management. DCDC also partners with Climate Assessment for the Southwest (CLIMAS), part of UA's Institute for the Study of Planet Earth on climate research. DCDC and UA's Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA) are developing an online digital water-information system. SAHRA's experience with a broad spectrum of stakeholders (both public agencies and private organizations) enhances the relevancy of the project to decision makers.

Lincoln Institute for Land Policy: Collaborative Research

(2004-05) DCDC partnered with the Lincoln Institute for Land Policy on a land-use workshop that developed three K-12 education modules: (1) long-term climate change in Phoenix, (2) GIS interfaces to explore the urban heat island, and (3) a thermal-mapping activity.

Northern Arizona University: Collaborative Research

(2005-06) DCDC co-sponsored the Arizona Water Summit, held at NAU in August 2005, with the Center for Sustainable Environments. This event brought together the state, local, and tribal water management communities to discuss relevant science and policy issues related to water resource management.

City of Mesa: Personnel Exchanges

(2006-07) Under DCDC auspices and supervision, the City of Mesa Utilities Department sponsored an internship for an undergraduate student. The intern worked with a water resource specialist in the Resources Division of the Utilities Department. The intern assisted in research focused on scenario assessment for Mesa's long-term groundwater management plan.

City of Tempe: Personnel Exchanges

(2006-07) City of Tempe supplies household-water-use data for DCDC analysis. Under DCDC's auspices and supervision, the Tempe Water Utilities Department sponsored an internship in 2006-07. The student investigated the potential water savings under various landscape water conservation scenarios.

Arizona Water Institute: Collaborative Research

(Ongoing) The Arizona Water Institute is a state-wide initiative to facilitate cross-university research about water resource management. Focus thus far is on developing the Arizona Hydrologic Information System.

Other collaborators:

Center for Science, Policy and Outcomes: (Ongoing) DCDC collaborates with ASU's Center for Science, Policy and Outcomes (CSPO), an internationally known organization involved in studying the linkages between science and technology and society. In fall 2006, CSPO convened a workshop of scientists actively studying water resource management in the Southwest with a goal of identifying the major stressors on the Phoenix metropolitan area water supply. Workshop

results were used to help DCDC develop research priorities and to provide regional water managers with information regarding potential vulnerabilities. In spring and summer of 2007, CSPO will expand the geographic scope of their 2006 research. Specifically, CSPO will perform background research to identify key areas of uncertainty about water supply and assess the comprehensive picture of demand in the region to include the entire lower Colorado River Basin. They will produce a draft paper covering the current knowledge of stressors on this region's water supply and predictions about future changes. This paper will also create a ranking of stressors on the system.

Global Institute of Sustainability: (Ongoing) DCDC is administered by and closely collaborates with ASU's Global Institute of Sustainability (GIOS). GIOS serves as the bridge to other relevant NSF-sponsored projects, especially the Central Arizona Phoenix Long-Term Ecological Research (CAP LTER) project, the Urban Ecology Integrative Graduate Education and Research Training (IGERT) program, the cross-site Biocomplexity in the Environment project on Agrarian Landscapes in Transition, and the Sustainability Partnership Enterprise. As GIOS expands, international researchers are being asked to participate in its programs, including DCDC.

Decision Theater: (Ongoing) Founded simultaneously with DCDC, the Decision Theater at Arizona State University is a learning and decision space in which the latest understanding of complex social, economic, and natural processes and their interactions are visualized. DCDC works closely with DT to translate DCDC science and modeling into visualizations applicable for the general public and decision makers. DCDC's WaterSim is presented in the Decision Theater, and DT was used as the setting for a project to evaluate WaterSim as a decision support tool.

Central Arizona – Phoenix Long Term Ecological Research: (Ongoing) DCDC and the CAP LTER partnered in the design and implementation of the second round of the Phoenix Area Social Survey (PASS), a survey of 800 randomly selected Phoenix-area households. The survey asks respondents about their knowledge of, attitudes toward, and behaviors about a set of locally-relevant environmental issues, including urban sprawl, air quality, the urban heat island, and water scarcity. Results will allow DCDC researchers to test hypotheses about the interrelationships among environmental knowledge, attitudes and value systems, and ultimate behavior regarding water use and conservation practices. Closer collaboration between DCDC and CAP

LTER, ASU's two large urban environmental research programs, offers the opportunity for integration of DCDC's inherently social science approach to urban modeling with CAP LTER's more ecological approach. A summer 2006 summit developed a research agenda to investigate human and ecological adaptations to future climate change. In 2007, DCDC and CAP LTER are expanding the PASS project to include GIOS scientists and public sector professionals.

University of California at Irvine Paul Merage School of Business: (Ongoing) Decision research at DCDC includes a partnership between L. Robin Keller (University of California at Irvine Paul Merage School of Business) and ASU faculty. The multi-objective decision analysis work performed in Year 1 is the foundation for developing decision-focused evaluation metrics for use with the models that are being developed within DCDC.

Community of Undergraduate Research Scholars: (Ongoing) ASU's Community of Undergraduate Research Scholars (COURS) provides opportunities for undergraduate students

enrolled in the Barrett Honors College to contribute to DCDC research. In 2007, DCDC hosted the second annual COURS poster session, highlighting the interdisciplinary work of more than a dozen students. Faculty associated with DCDC, IGERT, the Southwest Consortium for Environmental Research and Policy (SCERP), CAP LTER and other NSF-funded projects oversaw the research presented.

Project Wet: (Ongoing) In 2006, DCDC partnered with University of Arizona's Project Wet and the Salt River Project to host a summer teacher training workshop, where 30 teachers from K-12 schools in the Phoenix Metropolitan area developed new learning materials based on local environmental issues such as water scarcity, water recycling, and the urban heat island. The new learning materials are based upon DCDC research, data sets, and outreach activities. A second 'Advanced Water Educator's Workshop' is scheduled for July 2007.

ASU President's Office: (2006-07) DCDC and other university constituents, under the guidance of the Office of the University President, partnered with the Arizona Republic to create the Metropolitan Phoenix Indicators Project, a set of data presented in an impartial manner to illuminate the current state of the economic, social and cultural life of our region.

Other ASU research and academic units: (Ongoing) DCDC regularly co-sponsors lectures and symposia with other ASU research and academic units. These events bring together individuals from industry and multiple academic disciplines to explore and discuss topics such as robust decision making, historic perspectives of water in societies, visualization in environmental policy, and climate change in human-dominated systems.

DCDC Participants:

Principal Investigators/Project Directors

Patricia Gober, School of Geographical Sciences

Charles L. Redman, Global Institute of Sustainability

Co-Principal Investigators

Bob Bolin, School of Human Evolution and Cultural Change

Grady Gammage, Jr., Morrison Institute for Public Policy

Thomas Taylor, Mathematics and Statistics

Senior Personnel: Core Scientists

John Anderies, School of Life Sciences

Brad Armendt, Philosophy

Richard Aspinall, School of Geographical Sciences

Robert Balling, School of Geographical Sciences

Anthony Brazel, School of Geographical Sciences

David Cassagrande, Global Institute of Sustainability

Netra Chhetri, School of Geographical Sciences and Center for Science, Policy and Outcomes

Elizabeth Corley, School of Public Affairs

John Crittenden, Civil & Environmental Engineering

Robert Edsall, School of Geographical Sciences

Michael Ellegood, Maricopa Flood Control District

Andrew Ellis, School of Geographical Sciences

Monica Elser, Global Institute of Sustainability

Gregg Garfin, CLIMAS, University of Arizona
Corinna Gries, Global Institute of Sustainability
Priscilla Greenwood, Department of Mathematics
William Griffin, Family & Human Development
Suzanne Grossman-Clarke, Global Institute of Sustainability
Subhrajit Guhathakurta, School of Planning
Ed Hackett, Anthropology
Sharon Harlan, Anthropology
James Holway, Global Institute of Sustainability
Kathy Jacobs, SAHRA, University of Arizona
Donald Keefer, Supply Chain Management
L. Robin Keller, UC-Irvine Graduate School of Management
Peter Killeen, Psychology
Ann Kinzig, School of Life Sciences
Craig Kirkwood, Supply Chain Management
Michael Kuby, School of Geographical Sciences
Tim Lant, Mathematics and Decision Theater
Kelli Larson, School of Geographical Sciences and Global Institute of Sustainability
Susan Ledlow, Global Institute of Sustainability
Peter McCartney, Global Institute of Sustainability
Joan McGregor, Philosophy
Rob Melnick, Morrison Institute for Public Policy
Margaret Nelson, Barrett Honors College
Ray Quay, City of Phoenix
Anshuman Razdan, Partnership for Research in Spatial Modeling
Jeremy Rowe, Information Technology
Charlene Saltz, Global Institute of Sustainability
Paul Torrens, School of Geographical Sciences
Barbara Trapido-Lurie, School of Geographical Sciences
William Verdini, College of Extended Education
Elizabeth Wentz, School of Geographical Sciences
Dave White, School of Community Resources and Development
Amber Wutich, School of Human Evolution and Social Change
Joseph Zehnder, School of Geographical Sciences

Senior Personnel: Managers

Bill Edwards, Executive Administrator

Postdoctoral Research Associates

David Casagrande, Global Institute of Sustainability
Timothy Collins, Decision Center for a Desert City
Seung-Jae Lee, Decision Center for a Desert City

Other Collaborators

Rimjhim Aggarwal, School of Sustainability
James Buizer, Office of Sustainability Initiatives
Michael Crow, President
Paul Hirt, Department of History

Chris Lukinbeal, School of Geographical Sciences
Chris Martin, Department of Applied Biological Sciences
Daniel Sarewitz, School of Life Sciences
Nancy Selover, School of Geographical Sciences
Kerry Smith, W.P Carey School of Business; Economics

Research Technical Personnel

Jessica Block, Decision Theater
Aashish Chaudhary, Decision Theater
Charlie Collins, Decision Theater
Deirdre Hahn, Decision Theater
Jiuxiang Hu, Decision Theater
Jana Hutchins, Global Institute of Sustainability
Kade Hutchinson, Decision Theater
Shea Lemar, Information Technology
Wayne Porter, Global Institute of Sustainability
Michael Zoldack, Global Institute of Sustainability

Public Outreach Personnel

Michelle Schwartz, Decision Center for a Desert City

Research Support Personnel

Nikol Grant, Global Institute of Sustainability
Karen Gronberg, Global Institute of Sustainability
Nancy Jones, Research Specialist
Lauren Kuby, Global Institute of Sustainability
Linda Newson, Decision Center for a Desert City
Michael Tschudi, Decision Center for a Desert City

Graduate Research Associates

Suresh Ayyalsamy, Family and Human Development
Neil Barton, Geography
Erin Comparri, Global Institute of Sustainability
Jagadeesh Chirumamilla, Global Institute of Sustainability
Bethany Cutts, School of Life Sciences
Stephanie Deitrick, Geography
Vanessa Escobar, Geology
Mededith Gartin, School of Human Evolution and Social Change
Chris Graham, Geography
Annie Gustafson, History
Shannon Gysberg, Geography
Brent Hedquist, Geography
Kim Michel, School of Life Sciences
Mark Neff, School of Life Sciences
Megan O'Shea, School Of Earth & Space Exploration; School of Geographical Sciences
Jamie Patterson, Geography
Shana Schmidt, Family and Human Development
Clea Senneville, School of Sustainability

Cheryl Sexton, Family and Human Development
Claire Smith, School of Human Evolution and Social Change
Subramanian Swaminathan, Geography
Margaret White, School of Life Sciences
Yolanda Youngs, Geography
Lilah Zautner, School of Geographical Sciences

Community of Undergraduate Research Scholars (COURS)

Malaya Fletcher, Global Institute of Sustainability
Peter Howe, Geography
Matt Kruger, Political Science
Nicholas Moore, School of Geographical Sciences
Arianne Peterson, School of Human Evolution and Social Change
Melanie Tluczek, School of Human Evolution and Social Change

Other Undergrads

Brian Keegan, Business
Andrew Knochel, Urban Planning
Adam McDaniel, Global Institute of Sustainability
Caroline Newcombe, Civil Engineering
Michelle Rupp, Political Science
Rosanne Servis, English
Uven Chong, Mechanical Engineering

Community Partners

Michael Ellegood, Maricopa Flood Control District
Mitchell Haws, Bureau of Reclamation
John Hetrick, Salt River Project
Ray Quay, City of Phoenix
Dallas Reigle, Salt River Project
Kerry Schwartz, University of Arizona, Water Resources Research Center