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TITLE OF PROPOSED PROJECT **iUTAH-innovative Urban Transitions and Aridregion Hydro-sustainability**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 20,000,000	60 months	08/01/12	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
- ☐ BEGINNING INVESTIGATOR (GPG I.G.2)
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
- ☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
- ☐ HISTORIC PLACES (GPG II.C.2.j)
- ☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
- ☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date ________ PHS Animal Welfare Assurance Number ________
- ☒ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number pending Exemption Subsection ________ or IRB App. Date Pending
- ☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j) ________
- ☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)

PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
Watershed Sciences	5210 University Boulevard Logan, UT 843225210 United States
PI/PD FAX NUMBER: 435-797-3872	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME: Todd A Crowl	PhD	1989	435-797-2498	todd.crowl@usu.edu
CO-PI/PD: Michelle A Baker	PhD	1998	435-797-7131	michelle.baker@usu.edu
CO-PI/PD: James R Ehleringer	PhD	1977	801-581-7623	jim.ehleringer@utah.edu
CO-PI/PD: Douglas Jackson-Smith	PhD	1995	435-797-0582	doug.jackson-smith@usu.edu
CO-PI/PD: Diane E Pataki	PhD	1998	949-824-9411	dpataki@uci.edu

Electronic Signature

iUTAH – *innovative* **U**rban **T**ransitions and **A**ridregion **H**ydro-sustainability

Water is critical to sustainable economic development in Utah and to the sustainability of our urban and natural ecosystems. Freshwater resources are facing immediate and long-term challenges due to population pressure and predicted changes in the amount and timing of precipitation. Utah's population will at least double in the next two decades, with most of this growth occurring along the narrow Wasatch Range Metropolitan Area (WRMA). Growth is expected to generate a significant increase in water demand that will need to be addressed through water transfers, infrastructure investments, and efficiency programs. The overarching goal for UT EPSCoR is to enhance Utah's research competitiveness and sustainable water decision-making through strategic investments in the state's physical, human and cyber-science infrastructure. We will form transdisciplinary teams of natural and social scientists to carry out hypothesis-driven research on hydroclimatic sustainability in the WRMA, a coupled human-natural system that is changing as a consequence of climate change and rapid urbanization. An improved understanding of this complex system and the development and implementation of innovative solutions require better integration of social, hydroclimate, ecological, and engineering knowledge, and closer links between the academic community and local water management institutions. The theme of Utah EPSCoR is directly aligned with our S&T plan; it builds on our considerable existing strengths in water, urban and ecological sciences while expanding relevant expertise in the social sciences needed to understand complex, human-dominated systems. Our infrastructure investments will provide a common research platform and facilitate statewide science collaboration to enhance our ability to compete for interdisciplinary NSF opportunities including CNH, CZO, ULTRA, LTER, REU, etc.

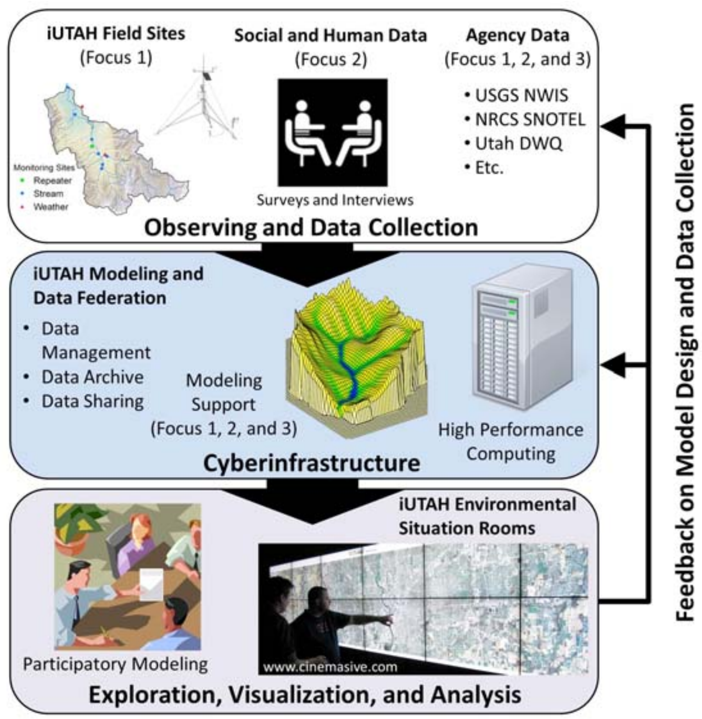
*The **innovative and transformational activities** in this proposal include: the development of fully integrated hydrologic and social sciences observatories that encompass whole watersheds along an urbanizing land use gradient; strategic activities designed to build a community of scholars across the state capable of addressing hydro-sustainability as a coupled human-natural system; and integrated education and outreach activities, such as participatory and collaborative modeling efforts, to ensure our research directly addresses societal needs and will translate and communicate our scientific findings to stakeholders, policy makers, and the general public.*

Intellectual Merit. We propose three interdisciplinary focus areas to advance the infrastructure, research, and human capital capacity of the Utah science community. Activities in all focus areas will be synthesized through a central cyberinfrastructure (CI) that will provide an integrated data system for storing, sharing, and publishing observations and outcomes. The coordinated CI system will provide direct linkages between research, education, outreach, and application.

Focus Area 1 (Eco-hydrology) expands our capacity in the natural sciences through instrumentation of three watersheds distributed across an urbanization gradient. We will quantify the water balance and water quality of forested, urban, exurban, and agricultural lands covers; and evaluate the sustainability of water quality and quantity in light of future changes to climate and land use. We will monitor the ecologic/climate/hydrologic system in the WRMA to better understand biophysical and hydrologic processes, test models of ecosystem processes, assess dynamics and availability of future water resources, and provide baseline data as a foundation for future interdisciplinary projects. ***Facility: Integrated hydrologic and social science watershed observatories*** located along an urbanization gradient that will form the backbone of our integrated research, education, and outreach programs.

Focus Area 2 (Social and Engineered Eco-hydro System) expands our capacity to understand the interactions among built water infrastructure, water decision-making, and urban form. We will integrate urban processes with our understanding of biophysical climate and ecohydrology from Focus Area 1, and assess the potential role of green infrastructure in reducing water consumption and improving water quality. General questions include: (a) What are the current structures and drivers of water and land use management in the region; (b) How does urban form interact with water availability; and (c) How can we design our built systems to enhance sustainability? ***Facility: A green-infrastructure research facility*** consisting of controlled experimental gardens and buildings to test engineering innovations designed to improve runoff and water quality in the urban environment.

Focus Area 3 (Interdisciplinary Modeling and Visualization) will develop interdisciplinary models of coupled socio-eco-hydrological systems that incorporate natural, rural, and urban ecosystem structure and function, and determine how changes in water availability, water use, and social drivers alter water quantity and quality in the WRMA. We will bring together the data generated in Focus Areas 1 and 2, and facilitate the development of innovative new modeling platforms that integrate human, hydrologic, and ecological components. These models will be used to collaborate with stakeholders to explore the implications of future patterns of urbanization and alternative water management scenarios. ***Facility: Two linked "Environmental Situation Rooms" (ESRs)*** will be built to explore, visualize, and analyze data and model simulations from all three Focus Areas. The ESRs will enable project faculty and students to engage with diverse groups to explore dynamics of WRMA water systems and impacts of climate change, alternative infrastructure investments, and policy scenarios on water sustainability. They will be located at the Natural History Museum of Utah (NHMU) and the Logan USTAR campus to increase communication among faculty, students, stakeholders, and water managers; enhance training and outreach activities; share data with stakeholders interested in exploring alternative water management futures; and display complex data and modeling results in visual platforms that facilitate understanding.



Centralized CI Synthesis Facility will link data resources, modeling activities, and participatory engagement. This facility will build on the distributed fiber and satellite-based capacities provided by the Utah Education Network (UEN), and will integrate data on hydrologic, ecological, engineering, and social systems collected through our observatories. The CI servers will host the iUTAH website with portals for access to water system data at different temporal and spatial scales. The CI facility will provide a nexus for development of coupled human-natural system models and support visualization and engagement activities.

Broader Impacts. iUTAH will enhance the STEM **Workforce Development** in Utah through formal science education activities that span the entire range of the STEM education enterprise and directly integrate with the proposed research foci. Research and education activities are planned for state-wide K-12 students and teachers; undergraduates and faculty at community colleges and primarily undergraduate institutions (PUIs); and undergraduates, graduate students, postdoctoral fellows, early career faculty, and faculty at Utah's main research universities. The three, instrumented watersheds will serve as 'living labs' that will involve statewide iUTAH partners in place-based research, and provide data for interdisciplinary modeling and urban scenario planning. iUTAH funds will support: research fellowships for faculty at PUIs; research grants for middle school and high school teachers; collaborative research opportunities for undergraduate and graduate students; interdisciplinary postdoctoral fellowships; and summer research institutes for teams of K-12 students and teachers, undergraduate and graduate students, and science educators to get experience doing research and to develop innovative new curricula.

External Engagement plan focuses on participatory research, outreach, communication, and dissemination activities to engage stakeholders and the general public. Together with the NHMU, UEN, and the Genetics Learning Center, we will develop research-based resources, websites, curricula, traveling exhibits, and other visual displays to communicate iUTAH research results with K-12 audiences and the public. Our ESRs provide an ideal location to bring together researchers, educators, students, stakeholders and policy makers, to help participants increase their understanding of complex problems, apply data, and incorporate uncertainty in their learning and planning processes.

Diversity Team will be actively involved with all research, education and outreach activities to ensure we recruit and retain participation from a diverse group of institutions, disciplines, locations, and individuals statewide. iUTAH activities will specifically target women, Native Americans, Hispanic Americans and rural audiences. We are partnering with colleges and high schools in the Four-Corners area that specialize in education and engagement with Native Americans. Our 'watershed observatories' will allow hands-on learning and engagement with diverse populations.

CI Plan is driven by the immense storage and computing power needed to collect, store and collate large, real-time data sets and models. These needs are parallel to those required by NM and WY; we are partnering with both of these EPSCoR programs through shared supercomputer access as well as data and modeling capabilities associated with Data-One activities. Data collected in the course of UT and WY Track I proposals will be archived in the data storage facility currently being constructed by the joint CI-WATER effort. These data will be available to scientists on both the Track I and II efforts as they research the fate and transport of water at a range of scales.

Synergy among EPSCoR Jurisdictions. We will also collaborate with Alaska on their social-ecological-systems (SES) project titled "Alaska Adapting to Changing Environments". The Utah-Alaska linkage represents a unique opportunity to address related sustainability issues, but in geographical regions expected to have contrasting changes over the next several decades. We will initiate interactions with workshops in years 1 and 2. These interactions will expand to include graduate student exchanges thereafter. Ultimately, we expect to identify research themes where principles and methodologies in our contrasting regions lead to common principles with broad applicability.

Program Goals, Strategies and Timelines

GOAL	STRATEGY	YR
Creation of common Research Platform required to enhance interdisciplinary excellence in water and urban science	• **Create integrated, instrumented watershed observtories across urbanization gradient** • **Create integrated, multi-institutional research teams** • **Engage existing, and target new, expertise in social sciences with an emphasis on maximizing interdisciplinary collaboration** • **Create an urban green infrastrucutre facility to test engineering solutions to water quality and quantity issues**	**1-2** **1-3** **2-4** **3-5**
Promote excellence and innovation in integrated modeling of coupled human-natural systems	• **Create a highly integrated CI data storage and modeling network in UT, and in collaboration with WY and NM, that will provide state-of-the-art data storage and high throughput modeling capabilities**	**1-5**
Enhance UT economy and workforce	• **Partner with private industry through sensor system design, development and deployment** • **Partner with private industry and government agencies through student internship and exchange programs**	**1-4** **1-5**
Enhance the diversity of UT's workforce	• **Engage women and underrepresented groups in STEM** • **Partner with statewide experts on recruitment and retention of diverse communities**	**1-5** **1-5**
Grow a STEM-informed citizenry	• **Partner with museums, K-12 schools and statewide citizen science programs** • **Engage diverse audiences in STEM**	**2-5** **2-5**
Integrate research, education and decision-making	• **Create 'Environmental Situation Rooms' for data visualization that will bring researchers, educators and decision-makers together in a participatory modeling environment** • **Enhance STEM pipeline with an emphasis on women, Hispanic, Native American and rural students**	**3-5** **1-5**

Evaluation and Assessment plan involves review and evaluation by a diverse group of independent, external experts, including a unique 'scientometric' assessment of iUTAH's enhancement of collaboration and networking statewide. Recommendations from the evaluation teams will be used to inform plans for subsequent years. **Sustainability Plan** includes seed funding research opportunities, a high percentage of junior faculty on our teams (over 66% of total), and targeted strategic hires. **Management Structure** integrates all research focus areas with the diversity, workforce development, and external engagement activities. EPSCoR Management Team (EMT, Fig. 5), which includes the research team leads, representatives from education and outreach teams, and faculty from the research universities and the primarily undergraduate institutions statewide, will meet bi-weekly to ensure successful integration, coordination, and implementation of al iUTAH activities.

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For font size and page formatting specifications, see GPG section II.B.2.

Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

4.1 Status and Overview

Our goals are to improve the human, facility, and cyberinfrastructure (CI) necessary to enhance our ability to conduct research and education at scales relevant to Utah's economic well-being. We will accomplish this by increasing the number of institutions and individuals engaged in research; strengthening our ability to compete for large, interdisciplinary grants; increasing the size and diversity of the STEM workforce; and enhancing discovery and innovation in science, education, and engineering.

Utah's sustainability challenge: As the nation's third driest state (356 mm annual average rainfall), water is critical to Utah's continued growth and economic development. The delivery of freshwater resources is in jeopardy both in the immediate future and in the long-term. Utah's population will double over the next three decades, increasing demand for water resources. At the same time, climate change, water rights issues, and regional water compacts will exacerbate water shortages. Assessing the impact of these factors on Utah's economic well-being requires transdisciplinary solutions that combine biophysical and social science research. Accordingly, Utah's EPSCoR RII theme is **iUTAH**: innovative Urban Transformations and Aridregion Hydro-sustainability. iUTAH will invigorate statewide research productivity through an integrated program that enhances research, human, and CI capacities related to understanding **how population pressure coupled with a changing climate and altered land use affect water resources and the sustainability of urban and natural systems**. iUTAH will build transdisciplinary teams of natural and social scientists that focus on hypothesis-driven research on sustainability of coupled human-natural systems in the Wasatch Range Metropolitan Area (WRMA), where 85% percent of Utah's citizens live and most future growth will occur (Fig. 1).

iUTAH vision: iUTAH will build critical observatory and modeling facilities across watersheds; create transdisciplinary research teams from many Utah institutions, government agencies, and the private sector; and enhance expertise and diversity through strategic recruitment of faculty and students. The **novel and transformational activities** of iUTAH include: the development of fully integrated hydrologic and social sciences observatories that encompass whole watersheds along an urbanization gradient; collaborative activities to create a community of scholars across the state to address sustainability of coupled human-natural systems; and integrated education and outreach activities such as participatory and collaborative modeling efforts to communicate and collaborate with stakeholders and policy makers.

Fig. 1 – Wasatch Range Metropolitan Area (WRMA)

4.1.1 Status of Utah's R&D Enterprise

Utah's growth in NSF-funded research (35%) was much less than that of the NSF budget (58%) over the last decade (Table 1) and Utah's average success rate dropped from 28% early in the decade to 22.8% over the last 5 years. Utah's NSF funding has slipped nationally (BYU 153rd to 174th, USU 144th to 161st, UU 52nd to 59th). Other major sources of research funding are DOE (BYU, UU), NASA (USU), and NIH (BYU, USU, UU).

Utah schools	2007 - 2010	2000 - 2002
BYU	$4.99	$3.90
SLCC	$0.45	$0.15
USU	$6.55	$4.36
UU	$25.57	$19.28
UVU	$0.40	$0.03
Westminster	$0.03	$0.50
WSU	$0.24	$0.00

Table 1 - NSF-funded research in millions of dollars at Utah colleges and universities

Utah has two public PhD-granting research universities: University of Utah (UU) and Utah State University (USU); metro-regional universities (Utah Valley University, Southern Utah University, Weber State University, Dixie State College); Snow and Salt Lake Community Colleges; and USU regional campuses Roosevelt, Vernal, Tooele, Brigham City, USU Eastern-Price, USU Eastern-Blanding). Brigham Young University (BYU) is the state's only private, PhD-granting university and Westminster College is the only private liberal arts college (Fig. 2). Student growth has been largely at regional universities and community colleges; this growth has not translated into increased STEM graduate education.

4.1.2 Strengths, Barriers, and Opportunities

Strengths: Utah's foundation for economic development is based in science, engineering, and innovation. Ecology, engineering, earth sciences, water resources, and urban planning research programs are strong at Utah's universities [see Utah's Science and Technology (S&T) Plan]. CI is well established and the Utah Education Network (UEN) has established unprecedented networking among all higher institutions and K-12 districts statewide. Utah has a growing population: the average Utahn is 28.8 years old, the youngest in the nation and 8 years younger than the national average (U.S. Census Bureau). Utah's commitment to research as a basis for economic development is exemplified by USTAR (Utah Science Technology and Research Initiative), which has $160M in State funds for new research facilities and $15M/year to recruit new research teams.

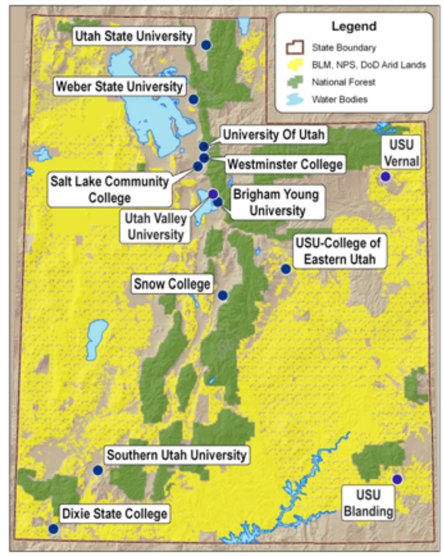

Fig. 2 – Institutions of Higher Education

Barriers and opportunities: Utah is less competitive for NSF funding, especially in interdisciplinary programs such as Dynamics of Coupled Natural and Human Systems (CNH); Water Sustainability and Climate (WSC); Urban Long-Term Research Area (ULTRA); Long Term Ecological Research (LTER); and the newly created Science, Engineering, and Education for Sustainability (SEES) programs. Our S&T plan has identified issues limiting our competitiveness:

Weak STEM pipeline – Utah ranks 50th in per capita K-12 education expenditures and ~20th in student achievement. Also, approximately 35% of Utah's math/science teachers do not have primary certification in STEM fields. Utah ranks last in the percentage of women that complete an undergraduate degree.

Inadequate institutional partnerships – Utah has significant research capability and potential at its universities; however, there have been very few inter-institutional research or education programs. There has also been limited collaboration among universities, with STEM education programs, or K-12 schools.

Lack of core multi-user research facilities – Modern equipment is essential for research and infrastructure improvement. Utah does not have integrated, environmental research facilities. We do not have shared, multi-PI research areas or infrastructure across the PhD-granting institutions, let alone statewide. Key investments would have broad and high-impact benefits, provide fertile training opportunities, and enhance statewide competitiveness for multi-investigator and interdisciplinary grants.

Limited interdisciplinary research – While we have many faculty with expertise in specific areas of ecology, hydrology, atmospheric science, urban studies, engineering, etc., there is limited integration across these disciplines. There is considerable expertise in environmental social sciences and natural resource management across institutions, including USU, UU, BYU, WSU, SLCC, and UVU, but there has been a lack of critical mass at any single institution to fully develop research programs in coupled human-natural systems. iUTAH proposes related research and training programs, facilities, and bridging activities to increase communication and collaboration across the disciplines and campuses.

4.1.3 Strategic Selection of Utah's Research Focus Areas

Using funds from the EPSCoR Planning Grant, the EPSCoR State Committee Director's Office and the Utah System of Higher Education (USHE) have worked with Battelle Memorial Institute to conduct a comprehensive analysis of the state's core strengths and to develop Utah's S&T plan (see Supplemental Document). The plan identifies resource sustainability for natural and economic benefits as a high priority, especially with respect to water resources. The environmental sector was formally analyzed in the S&T Plan because of its role in Utah's ability to grow and provide quality of life, infrastructure, resources, and jobs. The S&T plan recognizes core statewide competencies in ecology, engineering, and water resources. iUTAH will build on those strengths, as well as enhance statewide linkages between the research community and urban planners, regulators, businesses, and policy makers. We will emphasize the integration of the social sciences into these core natural science strengths through a transdisciplinary understanding of the WRMA as a coupled human-natural system. These fundamental studies are imperative to address the projected population growth, constraints on water rights and water compacts, and impacts on the well-being of future generations. The S&T plan also highlights Utah's critical challenges in developing its workforce of the future:

1. Utah is experiencing a generational shift in its ethnic and racial makeup. By 2050, nearly one-third of Utah's population will be comprised of racial and ethnic minorities; however, there is a growing disparity between the number of white versus minority children that graduate from high school.
2. Utah test scores fall below our peer states. A landmark study [1] showed that Utah's math, reading, and science scores over the past two decades have been lower than states with similar demographics.
3. Utah's workforce will be unprepared to meet the demands of skilled jobs that require either a degree or certificate unless these trends change. Between 2008-2018, Utah's new jobs requiring post-secondary education and training will grow by 202,000 [2], while jobs for high school graduates and dropouts will grow by only 97,000. During the same period, Utah will create 477,000 job vacancies due to retirement,with 308,000 projected to require postsecondary credentials.

To meet these challenges, Utah has embarked on a long-term effort that lays out broad guiding principles and key goals that will help increase the number of degreed individuals. The S&T plan views Utah's colleges and universities as economic engines that must be leveraged to provide high-paying jobs and solve community problems. Working closely with USTAR and other statewide initiatives, including the S&T plan, the State is developing an integrated, focused, and actionable plan to address research, commercialization, and workforce improvements needed to create and sustain a vibrant economy.

4.1.4 Synergy with other EPSCoR jurisdictions

Alaska – The intersections of social sciences, natural sciences, and engineering to address sustainability provide transformational opportunities for our jurisdiction. The breadth of interactions, workforce development, and research impacts would be greatly stimulated through linkages with another jurisdiction also working on a similar but contrasting coupled human-natural system. As part of iUTAH, we will collaborate with Alaska, a jurisdiction proposing a social-ecological-systems (SES) project titled "Alaska Adapting to Changing Environments (Alaska ACE)". The Utah-Alaska linkage represents a unique opportunity to address related sustainability issues, but in geographical regions expected to have contrasting changes over the next several decades: (a) limited *versus* abundant moisture availability; (b) large *versus* modest temperature changes; and (c) densely urbanized *versus* rural settlement patterns. We will initiate interactions with workshops in years 1 and 2. These interactions will expand to include graduate student exchanges thereafter. Ultimately, we expect to identify research themes where principles and methodologies in our contrasting regions lead to common principles with broad applicability.

Wyoming – Data collected in the course of UT and WY Track I proposals will be archived in the data storage facility currently being constructed by the joint Utah-Wyoming CI-WATER effort. These data will be used to support research by both States in their efforts to understand the fate and transport of water at a range of scales, and would be available to scientists in both Track I and Track II. In this way, the efforts in both states will be magnified through data sharing and leveraging of resources. In addition, we will hold a joint strategic planning meeting in year 1 which will include formalizing data and model sharing as well as developing a program for graduate student and post-doctoral exchange.

4.2 Results from Relevant Prior NSF Research

4.2.1 Utah EPSCoR Planning Grant **(9/2009-8/2010; OIA-0940499).** From this award, we developed approaches to eliminate barriers to collaboration; identified leadership and theme areas for focused investment; raised faculty awareness in areas of common interest; contracted Battelle to produce a State Science and Technology Plan; and produced a long range EPSCoR plan aligned with Utah's S&T plan.

4.2.2 Extending Campus Networks and Research@UEN Optical Network in Support of the Utah EPSCoR Initiative **(9/2010-8/2012; EPS-1007027).** This RII Cyber Connectivity (RII C2) award is leveraging the facilities and statewide reach of the Utah Education Network (UEN) to expand optical networking capabilities of the research and education communities, engage faculty and students more effectively across Utah in STEM fields, and serve as a platform to support field science in Utah. *Research@UEN's* Phase 1 development includes a Salt Lake City metropolitan optical network and a fiber-based spur to Logan in support of UU and USU, respectively. Combined with a southward extension to Provo for BYU, these advances will enhance the level of collaboration and computational engagement among the three research institutions and greatly expand their capabilities to collaborate nationally and internationally. The RII C2 award significantly improves the bandwidth capacity for UU, USU and BYU, which underlies all collaborative activities in this proposal.

4.2.3 CI-WATER: Cyberinfrastructure to Advance High Performance Water Resource Modeling **(9/2011-8/2014; OCI-1135482).** This new award, in collaboration with Wyoming, will provide CI to support the development and use of large-scale, high-resolution computational water resource models to comprehensively examine integrated system behavior through physically-based, data-driven simulation. This CI will consist of integrated data services, modeling and visualization tools, and a comprehensive education and outreach program that will revolutionize how computer models are used to support water resources research in the Intermountain West and beyond. Successful integration requires data, software, hardware, models, visualization and dissemination tools, and outreach to engage stakeholders and translate science into policy, management, and decision-making.

4.3 Research Program

Many of Utah's challenges are similar to other states in the western U.S. where growing populations demand more water and energy resources [3, 4]. EPSCoR programs in Idaho, Montana, New Mexico, Nevada, and Wyoming also focus on water resources. Utah has one of the largest and most rapidly expanding metropolitan regions, with Utah's WRMA predicted to double within three decades, largely driven by a high fertility rate and migration from other states. Increasing societal demands for water will pose complex constraints and challenges [5-7]. Feedbacks, thresholds, and tipping points influence the sustainability of coupled human-natural systems [4, 6, 8-10]. **iUTAH's sustainability solutions will emerge through innovative interdisciplinary research and systems-level knowledge of the interactions among water, sustainability, and climate.** iUTAH will examine interactions and feedbacks among hydroclimate, ecological and human systems, and how these impact the sustainability in the WRMA. We will explore potential adaptive solutions that include alternative water management strategies, urban planning and design, and the use of green infrastructure to enhance and protect ecosystem services.

Proposed research facilities and activities will enhance strengths identified in the Utah S&T plan. These include active and growing research programs focused on hydrology, ecology, natural resource management, urban planning and design, and water resource engineering. They also fill critical gaps and bring new tools to Utah's colleges and universities necessary for water resources-related environmental sciences training. By employing a coupled human-natural systems approach, we will better establish a culture of statewide, inter-institutional, transdisciplinary research.

iUTAH will use the WRMA corridor as an outdoor 'living' laboratory to document the critical hydroclimate, ecological, and human processes required to better understand a complex coupled human-natural system. Our work is built on a **transdisciplinary** model – which not only encourages greater interdisciplinary research, but also facilitates institutional and organizational learning and adaptation through participatory research techniques and the innovative use of stakeholder engagement tools. Our vision involves enhancing the skills of our current college and university communities while engaging urban and rural students for a more robust and diverse statewide future for STEM. iUTAH will enhance other interdisciplinary, multi-institutional projects in the state and beyond because:

- A synergistic, transdisciplinary, multi-institutional research effort will be more effective for building research capacity than traditional discipline-focused and single-institution efforts.
- The establishment, enhancement, and cooperative sharing of state-of-the-art facilities will increase capacity for leveraging institutional resources and developing partnerships.
- Greater cooperation among academic, non-academic, and stakeholder communities builds partnerships that will have lasting impacts on STEM, human infrastructure, and research capacity.

iUTAH's Focus Areas and associated facilities concentrate on undergraduate, graduate, and post-doctoral training, on nurturing junior faculty who will receive research and graduate student support, and the engagement of senior faculty as role models and mentors. Involvement of faculty from metro/regional universities and community colleges traditionally focused on teaching will elevate the research capacity of those institutions. In anticipation of iUTAH, the UU hired three new faculty in the areas of urban systems, water, and climate to begin in 2012. iUTAH will support two new faculty members in support of this project (see **4.9**). The project will have broader impacts on research competitiveness and human infrastructure development, significantly enhancing the R&D capacity of Utah institutions. It will also enable us to successfully compete for interdisciplinary NSF programs such as WSC, ULTRA, CNH, Critical Zone Observatories (CZO), and Software Infrastructure for Sustained Innovation (SI^2).

4.3.1 The Research Problem

As described above, Utah faces severe water-limitations that will only worsen with climate change and population growth. Our ability to attract new economic development, sustain a high quality of life, and protect critical ecosystem services hinges on our ability to understand the fundamental interactions and dynamic feedbacks among hydroclimate, ecological, and human aspects of urban and montane landscapes (Fig. 3). Such understanding requires transdisciplinary studies of how different land use types are linked and influenced by water, ecological processes, and decision-making.

To address these challenges, the iUTAH research platform will address the following questions:

- ***What is the current water balance of the region, and how vulnerable are water resources to changing climate and urbanization?***
- ***What is the current structure of land use and water management, and how can these systems best adapt to future constraints on water resources?***
- ***What are the key linkages between the biophysical and human components of the water system, and how do these linkages structure adaptation to water resource changes?***
- ***How can we present and visualize our model and data products to enhance communication, learning, and experimentation among faculty, students and stakeholders?***

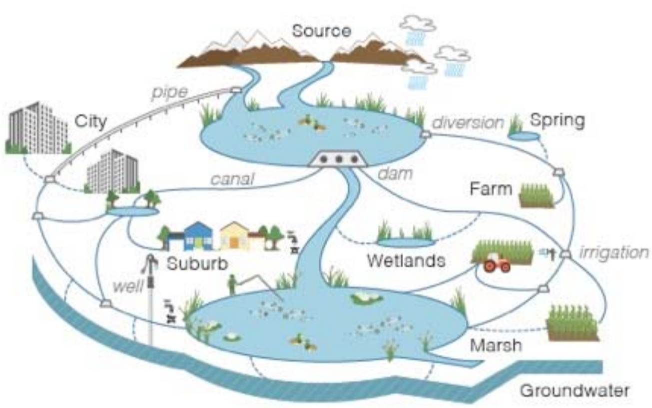

Fig. 3 – Connectivity between montane water sources, agriculture, suburban and urban use

The WRMA provides a wealth of research opportunities in these areas. It is a semi-arid landscape that nonetheless currently captures sufficient volumes of water to meet the needs of 2.5 million residents. Each year, 5.1–12.7 m of snowfall in the Wasatch Mountains is largely gravity fed to urban centers [11]. Many factors may alter the amount, timing, and quality of this resource in the future. Aside from climate changes, factors such as urban heat island effects and the transport and deposition of dust and pollutants may impact the timing and amount of snowmelt and the capacity of montane ecosystems to affect water balance and process nutrients. In addition, Utah's water infrastructure is aging and consumer demand is changing through public awareness programs. Additional changes in consumer water uses must occur under increased population pressures.

Utah's water cost of $0.00134 per gallon is 43% below the national average and the second lowest in the United States [12]. Water pricing, infrastructure, changing regulations, and urban and ex-urban development patterns will influence future water demands. We propose observational, experimental, and modeling infrastructure improvements to enhance our capacity to study both individual components of this system, as well as feedbacks and linkages. Research will focus on three principal basins that feed the WRMA: Bear, Red Butte, and Provo-Jordan. These watersheds represent stages along a land use gradient and provide resources to a population predicted to double to 5 million over the next 3 decades.

4.3.2 Research Focus Areas We propose three Focus Areas to organize our investments in the research and training capacity of Utah's higher education community:

1. ***Focus Area 1: the biophysical subsystem*** including ecohydrology, local and regional climate, atmospheric transport, and biogeochemistry.
2. ***Focus Area 2: The social and engineered subsystem*** including sociodemographic trends, local institutions, land and water use history and management, urban form, and new forms of green infrastructure.
3. ***Focus Area 3: The coupled human-natural system*** that brings together these two subsystems including new methods of model integration, informatics, and cross-disciplinary training programs.

4.3.2.1 iUTAH Focus Area 1 - The biophysical ecohydrologic system

Team (project leaders in bold): **Michelle Baker**, Diane Pataki, **Zach Aanderud**, **David Bowling**, **Scott Jones**, David Tarboton, Jiming Jin, Bethany Neilson, Courtenay Strong, Richard Gill, Sam St. Clair, Suzanne Walther; 3 technicians; 1 post-doc; 10 graduate students; 10-15 undergraduate students.

We will improve Utah's capacity to monitor the ecologic/climate/hydrologic system in the WRMA to better understand biophysical and hydrologic processes, test models of ecosystem processes, project dynamics and availability of future water resources, and provide baseline data to serve as a foundation for future interdisciplinary projects. The critical processes that influence local water quantity and quality include those factors that affect the timing and amount of snowpack, forest water balance, deposition and biogeochemical processing of pollutants, and the consumption and fate of water transported to urban and agricultural areas. We will improve watershed-scale measurement capacities and evaluate possible future scenarios under projections of climate change and urbanization.

Focus Area 1 Q1– What is the water balance of forested, urban, exurban, and agricultural land cover?
Snow accumulation, sublimation, and melt in Utah's montane regions are important hydrologic processes that impact the quantity and timing of runoff as well as recharge of mountain block aquifers, both of which are critical to our water supply. While regional climatic patterns largely determine the size of the delivered snowpack, vegetation mediates hydrologic processes through evapotranspiration (ET) and partitioning of precipitation as infiltration or sublimation. As such, forest composition affects water yield [13], with conifer forests accumulating less water in the snowpack than deciduous forests such as aspen [14]. In human-dominated land cover, such as agricultural and urbanized landscapes, specific components of the local water budget are less certain. While the allocation of water resources to human use is known, the fate of that water outdoors, such as irrigation runoff, groundwater recharge, and ET, is unknown for most urban and agricultural areas in the western U.S. [15]. Heterogeneity associated with land management, landscaping, microclimate, and agricultural practice is high, particularly at the parcel scale. In addition, there are significant feedbacks of irrigation on micro-, regional, and global climates [16-18].

Focus Area 1 Q2 – What determines the quality of surface and groundwater resources?
Land use and human activities in the urbanizing valleys of the WRMA strongly influence water quality in the adjacent montane water source regions and the Great Salt Lake watershed. Particulate transport and deposition, nitrogenous compounds, and other pollutants from urban and agricultural activities impact both aquatic and terrestrial biogeochemistry with implications for surface water quality [19, 20]. In addition, dust deposition in snowpack from both adjacent arid lands and urban settlements impacts the timing and amount of snowmelt [21, 22]. Observational and modeling studies of atmospheric transport and chemistry will be used to quantify these linkages. Recent new faculty investments at UU provide a foundation for linking atmospheric to ecohydrologic and urban processes. In addition to our own network observations we will also derive data on particulate and pollutant loading from existing statewide networks (see commitment letters). BIOME-BGC models and supporting data collections will link water and nutrient dynamics in the biosphere-atmosphere system.

To assess water quality along the montane-to-urban transects we will need to estimate instream flows, longitudinal water balances [23, 24], incoming and reflected shortwave radiation at the water surface [25], and conduct real time water quality monitoring. In surface waters, we will measure total and dissolved solids, volatile suspended solids, dissolved organic carbon, dissolved inorganic nitrogen and phosphorus, total nitrogen and total phosphorus, and dissolved anions and cations. We anticipate that we will be able to establish chemical proxies for some of these parameters by relating water chemistry data to sensor output [26]. These data will enable estimations of daily flux rate, annual loads and yields of major ionic solutes and nutrients at each sample location. The combined data collection and modeling efforts will provide further understanding of the influences of land use on water quality via transport and biogeochemical processing of pollutants, and role of particulate deposition in snowmelt.

Focus Area 1 Q3 – How will availability of and demand for montane water resources change as a result of climate and land use change?

We will use observatories and models to improve projections of water quantity and quality in climate change and urbanization scenarios. We will capitalize on the existing climate analysis and modeling strengths (e.g., Utah Climate Center, UU Mesowest, UU Atmospheric Sciences, Utah DAQ) to build a new team of collaborative modelers among recent faculty hires at USU and UU. Climate scenarios will be developed by downscaling GCM simulations to produce regional models (e.g., WRF) [27, 28]. Particulate and atmospheric chemistry models (e.g., STILT-WRF) [29-31] will allow us to focus on interactions/feedbacks among arid, urban, and montane regions of the WRMA. The integrated hydrologic and water resources modeling cyberinfrastructure that is part of the CI-WATER track II EPSCoR project will provide a framework for testing hypotheses about effects of snowmelt dynamics, runoff generation, infiltration, ET, and deep percolation as a function of elevation, microclimate, and land cover. This will draw upon capability of existing integrated models e.g. RHESSys [32], PIHM [33], PARFLOW [34], that have been used to examine similar interactions in other locations [35], and SWAT [36] that brings in agricultural and water management processes. Our observations will supplement those of available national networks (e.g. the USDA SNOTEL system) Hydrologic, beetle infestation, and climate-driven shifts in the composition and structure of forest communities are likely to have feedbacks on hydrologic processes and water yield [14], and therefore understanding these processes can improve predictions of feedbacks and interactions among these different drivers. Non-linear processes that influence forest dynamics, such as drought-mediated insect outbreaks and fire, are likely to be particularly important.

Modeling human demand for water requires scientifically valid urbanization scenarios and better recognition of the feedbacks between ecological outcomes, human activities, and climate change, each of which are described in more depth in Focus Area 3 below. Urbanization scenarios will be linked to water quality and quantity outcomes using results of our ecohydrologic monitoring and modeling activities to assess the impacts of alternative urban futures on:

- Water consumption by urban and agricultural sectors
- Surface partitioning of precipitation into runoff, infiltration, evapotranspiration, and recharge
- Nitrogen pollutants, and the impacts on montane surface water quality
- Dust generation, and the impacts on the timing and quantity of snowmelt
- Local and mesoscale climate, through modifications of the urban heat island effect

Focus Area 1 Facility– Ecohydrologic Observatory

We propose a distributed observatory network in three rural to urban watersheds, spanning from montane forests to exurban land, agriculture, and urbanized basins. These are (a) The Bear which originates in the Uinta Mountains and passes through the agricultural but urbanizing Cache Valley; (b) Red Butte, which spans from the Wasatch Mountains to the Salt Lake Valley [37]; and (c) the Provo-Jordan, which links the Uinta and Wasatch Mountains to both the Salt Lake and Utah County valleys. Measurement systems will be distributed at key locations along each gradient. The observatory network will be designed to 1) leverage existing measurement networks in the study watersheds, 2) complement new NEON observatories in Red Butte Canyon and the Salt Lake Valley, and 3) fill critical data gaps for hydrologic, climate, and land surface modeling. Major components of air and water quality and water fluxes will be measured in each land cover type. The gradients originate at elevations above 3,000 m where the primary water input is precipitation in the form of snow and is approximately partitioned as 30-40% runoff, 40-60% evapotranspiration and sublimation, and 5-20% regional groundwater recharge [11, 38]. Before runoff reaches the valleys, significant quantities are stored and diverted for irrigated agriculture and expanding urban uses both within and outside the watersheds. Both the Bear and Provo-Jordan Rivers terminate at the Great Salt Lake. The proposed study sites represent a continuum of land uses ranging from nearly pristine (Red Butte) to extensively developed (Provo-Jordan).

Within each watershed, automated data collection will include climate observation, trace gas composition, water quality, stream flows, and land-atmosphere fluxes. Water and CO_2 fluxes will be measured using both sapflux measurements [39] of key species and eddy covariance at the stand level [40, 41] to provide assessments of how fluxes change with climate, water stress, phenology, management practice, and species composition. An existing, long-term, 6-station CO_2/H_2O-monitoring network provides the foundation for tracing local and regional land-atmosphere exchange [42, 43]. We will deploy new instruments for real time, high-resolution measurements of CO_2, CH_4, and CO to trace the transport of urban pollutants throughout the study region. These data will be used for parameterization and validation of models of local atmospheric transport and chemistry. We will also measure stream flows, water quality, and biogeochemistry in both natural and urban reaches.

These measurements will build on initial studies [8, 41, 44], complement a new NEON site, and build on the rich instrumentation and legacy data available in the Bear – one of the original NSF-funded WATERS Network of observatory test beds. iUTAH will enhance the existing, continuous stream flow, water quality, and weather monitoring sites in the Bear with studies of how discharge and water quality are impacted by behavior at both the individual farm and the irrigation system scales. Focus Area 1 observational data generated by the three observatories and simulation output from the detailed, process-level models will supply necessary boundary condition flows and water quality information that will feed analysis and modeling work in Focus Areas 2 and 3.

4.3.2.2 iUTAH Focus Area 2 - The social and engineered ecohydrologic system

Team (project leaders in bold): **Diane Pataki, Doug Jackson-Smith**, Li Yin, Bo Yang, Steve Burian, **Christine Pomeroy**, Carla Trentelman, Charles Sims, Daniel Bedford, Joanna Endter-Wada; 2 technicians; 1 post-doc; 8 graduate students; 10-15 undergraduate students.

Focus Area 2 will develop new infrastructure to instrument and collect data on the social and engineered systems in each of the three watersheds. By co-locating biophysical (Focus Area 1) and human observatory facilities, we will be well equipped to study the interactions of alternative urban forms and local hydrologic and ecological systems, and can explore the role of innovative green infrastructure to reduce water consumption and improve water quality. Focus Area 2 brings together diverse faculty studying different but overlapping aspects of the human dimensions of water and land use. The proposed observatory infrastructure will facilitate a new, joint emphasis on the social and engineering components of water sustainability along the WRMA that has relevance in our region and beyond.

Focus Area 2 Q1 – What are the current drivers of water and land use management in the region, and how are they changing?

We will extend observational infrastructure to include the human dimensions of the WRMA, including land use, water infrastructure and use, law/policy contexts, and adaptive behavioral responses to changes in environmental conditions and water availability. We will integrate primary data gathered through surveys and interviews, interpret and classify urban form in remote sensing imagery, and analyze existing secondary data and local government records. We will meld existing land use and water infrastructure data, water use records, population census data, and other spatially explicit datasets with these new observations. We will use these datasets to find out how and where undeveloped land has been converted for human uses, how built water infrastructure evolved across time, and the impact of changes in land use and urban form on water consumption patterns. Human land and water use patterns reflect the cumulative influence of decisions made by diverse individual and organizational actors [45, 46]. These decisions reflect the proximate objectives, knowledge, and resources that characterize each actor, but are also constrained by social norms; features of the built environment; and legal, policy, and market contexts [47-49]. Humans also make decisions in response to a changing natural environment, which will change the context for future decisions [50, 51]. To understand the micro-level foundations of land and water use change, systematic and coordinated random sample surveys are needed to describe the attitudes, beliefs, knowledge and behaviors of the major water user groups in our study communities. Surveys are best complemented by in-depth personal interviews and focus groups with key informants randomly selected from subpopulations of users stratified by patterns of water use that provide more in-depth information and explanation of causal processes. These data will enable us to better understand how key human actors behave, adapt, or make water management decisions in response to observed environmental changes.

We will develop a comprehensive spatial and temporal database of land conversion and urban settlement patterns, with their cascading effects on water distribution and use. This involves strategic investments in remote sensing data and analytical capacity to fill in data gaps. Coordination across the entire iUTAH team and with Utah's Automated Geographic Resource Center [52] will be particularly useful in this regard, as different research groups have access to different but highly complementary remote sensing and spatial datasets. Once integrated, these data can be used to develop spatial landscape metrics capable of classifying urban settlement patterns based on density, socio-demographic characteristics, spatial configuration, vegetative cover, and water use patterns. The resulting neighborhood typologies will help identify specific sites for the more intensive coupled human-natural system data collection described below.

Focus Area 2 Q2 – How do urban form and water availability interact?

Many aspects of urban form, including population density, parcel size, urban vegetation, impervious surfaces, people, and water and built infrastructure influence the water balance of cities and urbanizing areas, their water consumption, and the amount and quality of imported water in runoff and groundwater recharge [15, 53, 54]. In transitioning irrigated, agricultural landscapes, dense networks of water conveyance structures and field drainage systems provide a complex human-constructed ecohydrologic template on which new urban areas are typically built. There are also many interactions between urban settlement patterns, water use, and micrometeorology that result in modified local energy balance, such as the urban heat island effect [55-57]. These changes, in turn, further influence ET and other water cycle processes. In order to design effective engineering and urban planning solutions to mitigate water scarcity and pollution, we need to better understand the current and often unintended consequences of land and water management on local and regional interconnected water and climate systems, and tradeoffs inherent in different types of urban form.

The diverse types of settlement patterns identified in our study sites will serve as locations to compare and contrast the impacts of alternative urban forms. Neighborhoods with different water infrastructure, sociodemographics, housing densities, impervious surface cover, landscaping practices, and water use patterns will produce distinctive impacts on local hydrologic cycles and water quality dynamics. To capture these effects, we will combine data from the Focus Area 1 monitoring network and the spatial database of urban infrastructure and form within a multi-scale modeling system interacting in a dynamic two-way coupling mode. The framework will embed a state-of-the-art model that simulates small-scale atmospheric transport around built structures [58] and a high-resolution urban hydrology and green infrastructure model [59] into the well-established and supported Advanced Research Core of the Weather Research and Forecasting modeling system [28]. Using the coupled models, we can simulate the effects of both built structures and green infrastructure on water use, storm-water runoff, and microclimate to evaluate the effectiveness of different green infrastructure and urban planning scenarios.

Focus Area 2 Q3 - How can we design built systems in semi-arid regions to enhance sustainability?

Efforts to reduce water consumption and improve water quality in the urban environment have led to innovative approaches to planning, landscaping, and alternative 'green infrastructure'. Green infrastructure is comprised of the decentralized, interconnected networks of natural and constructed plant-soil systems within, around, and between urban areas [60]. In former agricultural landscapes, green infrastructure includes efforts to replace leaky irrigation infrastructure originally built for agricultural use with new pipelines and pressurized secondary water systems designed to serve growing urban populations. In more suburban and urban zones, it encompasses the integrated consideration of open space, parks, green roofs, storm water and wastewater systems (e.g., bioretention, constructed wetland), decentralized water management (e.g., rainwater harvesting), distributed energy generation, and restoration and protection of riparian areas. Potential benefits of green infrastructure include reducing built infrastructure and flood control costs, water and energy demand, emissions, and pollution [61, 62].

Green infrastructure systems have been observed to reduce storm water runoff [62, 63], be carbon sinks [64, 65], mitigate the urban heat island, and in turn, improve air quality [66].

There have been a relatively small number of studies that fully measure and monitor the effectiveness of green infrastructure [67-69]. Most current knowledge is based on small-scale studies, few of which were conducted in semi-arid climates [70, 71]. Further, there is a critical gap in our understanding of the climate change resilience of green infrastructure design, which is not currently considered in most Utah community development [72]. iUTAH is distinct from previous studies in that it focuses on the Utah semi-arid region and it integrates experimental facilities and modeling to test green infrastructure options locally at watershed scales with the potential for real implementation. The WRMA system will be further augmented by the ongoing water quality monitoring study in the Daybreak community development, a "new urbanist" development that uses infiltration-based drainage design for storm water quality improvement. It is intended to withstand 100-year storms and is expected to save $40 million in storm water infrastructure costs, compared with a conventional artificial drainage system [73-75].

Focus Area 2 Facility – U-GREEN Experimental Facility

This facility will consist of (a) two 20-m^2 modular buildings with embedded temperature sensors adaptable for roof and wall modifications to accommodate green roof, green wall, and gray-water bioretention and bioswale research; (b) three 9-m^2 bioretention and three 9-m^2 bioswale test units for the study of nutrient cycling of gray water and storm water, and carbon and particulate retention; (c) equipment to measure CO_2, CH_4, N_2O, and H_2O fluxes and (d) portable instruments and CI linkages to study green infrastructure sites remotely. These units will provide an ideal location for research, outreach, and training in interdisciplinary interactions of ecology and design. They will also provide a starting point for choosing green engineering options to develop and test in real world settings, and to study human-technological interface issues that may be crucial for effective design and function. This facility will serve research, training, and workforce development associated with Focus Areas 2 and 3.

4.3.2.3 Focus Area 3 – The coupled human-natural system

Team (project leaders in bold): **Doug Jackson-Smith, Arthur C. Nelson**, **Carlos Licon**, Li Yin, David Rosenberg, **Jeff Horsburgh**, Bo Yang, Sarah Null, Ryan Jensen, Reid Ewing; 2 technicians; 1 post-doc; 6 graduate students; 10-15 undergraduate students.

Human activities both influence and are influenced by the natural environment in the WRMA. Understanding these interactions requires strengthening the disciplinary sciences described in Focus Areas 1 and 2, as well as developing new methods to bring together faculty across the social and natural sciences to study common problems in local water sustainability. We must enable communication, provide research facilities, and streamline data platforms to remove existing barriers to multi- and interdisciplinary research and training. These barriers now present some of the greatest challenges to developing innovative new solutions to Utah's environmental problems. In Focus Area 3, we propose two new facilities to overcome these barriers. First, we will build a CI facility (see **4.6**) that links data resources, modeling activities and participatory engagement activities. Our proposed modeling and data collection activities will be diverse and take place across different locations and institutions. We need CI systems that support and simultaneously integrate diverse, decentralized project activities. Second, we propose two linked "Environmental Situation Room" (ESR) facilities to explore, visualize, and analyze data and model simulations from the three Focus Areas. We will locate these facilities at the Natural History Museum of Utah (NHMU) and the Logan USTAR campus to increase communication among faculty, stakeholders, and water managers; enhance training and outreach activities; share data with stakeholders interested in exploring alternative water management futures; and display complex data and modeling results in visual platforms that facilitate understanding. Specifically, the proposed CI and ESR facilities will help us address questions such as:

Focus Area 3 Q1 - How can specific models representing hydrology, ecology, and human systems be coupled to ensure efficient exchange of inputs and outputs at appropriate spatial and temporal scales?

We recognize the great need to integrate specific, disciplinary models into a broader, integrative framework as a more holistic approach for predicting the full range of effects of management actions and/or climate change on water resources. Systems models are useful and powerful integrative tools to support water resources management, and can incorporate elements of specific, intensive computational models. Yet, systems models require extensive input datasets and data processing (in effect, aggregating results from Focus Areas 1 and 2) to provide a common quantitative framework to model to represent the system flows, stores, and evolution of water, energy, pollutants, and other phenomena of interest both spatially and temporally. In effect, systems models standardize data formatting so that sub-models can exchange information, provide a platform to examine management alternatives to maintain water and land use sustainability in Utah, and visualize results and data to effectively communicate with other researchers, stakeholders, and water managers.

By providing a coordinated data storage and processing platform, our CI facility will facilitate the work of proposed coupled systems modeling teams that will draw on expertise from across our participating universities. We will bring together faculty from disparate disciplines to develop common modeling tools by 1) chaining models so that output of one model serves as the input to another, and 2) creating dynamic linkages among models so that they can exchange inputs and outputs at each time step. This framework will form a comprehensive systems model that can simulate and predict overall system behavior and responses, including basic hydrologic, ecological, and decision-making processes.

This effort will build on current and emerging strengths within our Utah science team. First, the biophysical ecohydrologic and social/engineering subsystem models described in Focus Areas 1 and 2 provide crucial components that can be linked in a larger coupled systems model. Second, with recent social science faculty hires, we have an emerging capacity to characterize human decision-making in multi-agent models (MAMs) that include heterogeneous agents/individuals and simulate decisions, interactions, and adaptations to the environment [76-81]. A critical next step is to link MAMs with the models and data collection proposed in Focus Areas 1 and 2 within a common conceptual and analytic framework to reduce fragmentation between disciplines and scales. This work will highlight promising management strategies. Third, we will build on current efforts to adapt existing 'urban metabolism' models for the WRMA (W2M) to create a spatially explicit, parcel-based geospatial analytic tool using protocols developed by Ewing [82]. Urban metabolism models describe material and energy fluxes in cities and are used to understand large scale processes of growth, production and elimination of wastes [83]. This effort will also use data from Focus Areas 1 and 2 to develop a detailed accounting of water, energy, nutrient, and trace-gas stocks and flows at multiple scales.

Focus Area 3 Q2 - How can the coupled human-natural system cope with water resource changes?

Models can help integrate data for components of complex systems and identify linkages and feedbacks between human and natural subsystems. Representing and visualizing these connections can increase understanding of current problems and identify promising solutions. Building comprehensive models that represent alternative futures can point the way to more sustainable management. Our systems modeling will be designed from the beginning to answer applied water management questions such as: how can water utilities and conservation districts move water through the system most efficiently; how may climate change and changing water demands impact runoff to the GSL; how might changing water levels in the GSL alter lake-effect precipitation and impact local climate, dust generation, and air quality; which proposed infrastructure projects will best sustain water supply reliability and ecosystem health and function; where are restoration projects (and thus restoration dollars) most effective? Our interactions with stakeholders (described below) will ensure our models represent decisions by individuals, water utilities, conservancy districts, and other resource managers that most affect water system sustainability.

Focus Area 3 Q3 - How can we present and visualize our model and data products to enhance communication, learning, and experimentation among faculty, students and stakeholders?

We propose to create two linked ESRs to display spatial data, model outputs, and visualize alternative urban futures as projected by our systems models [84-86]. The ESRs will provide expanded opportunities for engagement among project scientists, between scientists and students, and between the science team and water management stakeholders. We will use the ESRs to engage city planners, engineers, land owners, and policy makers in the development and formulation of our models, in the selection and specification of model inputs, and to explore and analyze the effects of climate change, population growth, land use change, urban design, and infrastructure choices on water and energy use, carbon and nutrient fluxes, urban climate, and ecology. Initially, we will use ESRs to provide a focused and dynamic environment for discussing and visualizing our initial data collection and modeling plans with stakeholders. This will provide opportunities for water decision-makers to review and improve elements of our science plan to ensure that we capture key system components and appropriate decision-making scenarios. Later, the ESRs will use our extensive spatial datasets and integrated model outputs to visualize historical and projected changes in land use, water resources, and urban form and for creating displays of real-time data streams from our field data collection activities. The ESRs will be an ideal venue for facilitating participatory modeling where stakeholders, resource managers, and policy makers can explore outcomes and uncertainties associated with different future scenarios. Scenarios may include climate change projections, alternative urban form configurations, and policy alternatives, and can focus on diverse outcomes including water quantity and quality, air quality, and human and ecosystem health.

We will use the ESRs to display a variety of data and research products to audiences ranging from the general public to students, faculty, and stakeholders from government, private, and NGO sectors. The technical modeling groups will work with the External Engagement Team to develop innovative displays that convey data and model results in intuitive ways that are consistent with the technical expertise of different audiences. By enabling explicit comparisons between areas or municipalities in the WRMA that may be implementing different policies, plans, or programs, the ESRs will enable researchers and decision makers to learn from ongoing experiments. Scenario generation and evaluation can be extended to understand the implications of alternative management through a variety of indices, ranging from projected land values, to quality of life and sustainability assessments. This will allow an improved understanding of the benefits and risks of different planning decisions.

Focus Area 3 Facility – Environmental Situation Rooms

To maximize participation, we propose two linked ESR facilities with high performance Internet connections to the UEN network and state CI: 1) located at the Natural History Museum of Utah (NHMU), and 2) housed at the USTAR facility in Logan. This distribution will maximize the use of ESRs by faculty, students, and stakeholders, and provide common facilities for interaction and collaboration across the full gradient of land use contexts in the study area. Both ESR facilities will take advantage of technological advances in high-definition flat screen displays and visualization software to provide a venue designed to facilitate teaching, research, and participatory engagement activities. They will accommodate groups of up to 50 participants and be configured with large, multi-monitor, high-definition video wall displays. These video walls will be flexible, enabling presenters to display combinations of maps, images, plots, video and other media at sizes and resolutions not possible with traditional displays. Display controllers will be driven by a dedicated server with native visualization display software and links to the full CI network, yet will use standard desktop computer operating systems to enable presenters to use the video wall as easily as they would a projector.

Focus Areas 1-3 Synthesis Facility – iUTAH Modeling and Data Federation

The proposed research and modeling activities require a rigorous and structured approach to data storage and organization (see **4.6;** Project Summary). We will focus on determining how to contextualize each type of data with the ultimate purpose of creating a common data platform to support integrated modeling efforts. Data integration will focus on developing hardware and software to enter, store, backup, retrieve, and deliver data at the variety of spatial and temporal scales needed to support the work of our participants. These capabilities will include software tools that can run independently or in batch sequence to prepare modeling runs. Given the variety of data and model types and formats, and the extensive time currently needed to process data for use by models, a key area of research will be to develop automated data preparation processes that can transform raw/available data into the input forms needed for modeling, data retrieval, and publishing. The iUTAH Modeling and Data Federation will complement and leverage the existing data and modeling activities supported by the EPSCoR CI-WATER award (see **3.2**). We will build a data repository accessible to researchers statewide that provides access to data describing biophysical systems, land cover, water infrastructure, socio-demographics, and urban form classification. This facility will serve research, training, and outreach associated with Focus areas 1, 2 and 3 (see **4.6)**.

4.4 Diversity Plan

4.4.1 Goal **–** Increasing the institutional, individual, disciplinary, and geographic diversity of the STEM enterprise in Utah in order to address the water sustainability issues facing Utah and the Mountain West.

4.4.2 Current state of diversity **–** iUTAH will use all available human and institutional resources in the state to achieve the goals of Utah's S&T plan. Utah's population is ~80% non-Hispanic White, but the population of Hispanic or Latino origin is currently 12% and growing rapidly (US Census Bureau). Yet, only 67% of Hispanics in Utah complete a high school degree, compared with 94% of whites, and only 16% of Hispanic young adults enroll in college compared with 45% of whites. Native Americans account for 1.4% of the population in Utah, compared with 1.0% nationally, but only 19% of Utah's Native American population attend college. Of Utah's population, 0.8% is Native Hawaiian or other Pacific Islander, compared with 0.2% nationally. Most of the Pacific Islanders in Utah are located in the greater Salt Lake City area, with ~30% attending college. Women of all ages are another group underrepresented in Utah STEM. Utah women have not achieved the level of gender equity in career paths evident nationally. The Utah Women and Education Project (UWEP) recently conducted a study on the status of women in the Utah educational system. Their 2008 data indicates that only 47.7% of all bachelor's degrees are awarded to women in Utah, compared to 57.3% nationally [87]. The situation is especially striking in STEM disciplines, where only ~ 20% of STEM degrees are awarded to women compared to over 35% of women nationally. iUTAH will work with Utah colleges and universities to improve the levels of female enrollment and completion in STEM disciplines. S. Madsen on our Diversity Enhancement Team is a member of the Governor's new Commission on Women in Education and will help iUTAH incorporate their recommendations into our diversity plans.

4.4.3 Integration of diversity into all iUTAH activities – iUTAH has integrated diversity plans throughout the project to enhance institutional, individual, disciplinary, and geographic diversity of STEM. ***Institutional and geographic diversity*** are captured by expanding inclusion beyond the major research universities and involving students and faculty from community colleges, primarily undergraduate institutions, and branch campuses with a high proportion of underrepresented groups. iUTAH also goes beyond academic institutions and involves private industry, government agencies, NGOs, museums, and other informal science institutions. ***Disciplinary diversity*** is achieved with the involvement of biologists, hydrologists, engineers, social scientists, etc. in the research and education activities. iUTAH's efforts at ***individual diversity*** are specifically targeted at groups underrepresented in STEM. Specifically, iUTAH's strategy for diversity enhancement is focused on creating opportunities for women, Native Americans, Pacific Islanders, Hispanic Americans, and rural communities. We will use the proposed place-based watershed science and urban scenario modeling activities to engage students and teachers from diverse populations in discussions of water sustainability issues with cultural relevance to their communities. The iUTAH strategy and specific planned activities are described below.

4.4.4 Diversity Enhancement Team (DET) – The DET is integral to the implementation of iUTAH's Diversity Plan. This Team is made up of representatives from institutions across Utah who are actively involved with recruitment and retention of underrepresented groups into STEM education. This Team has agreed (see letters of commitment) to assist with recruitment for all planned iUTAH opportunities, including all Research, Workforce Development, and External Engagement activities. They were selected for their expertise and knowledge of successful strategies with the diverse populations targeted across the region. The Diversity Enhancement Team will ensure that iUTAH's activities are inclusive and welcoming of many ideas and cultures. They will meet monthly, virtually or in person, to discuss the strategy for implementing the diversity plan, review applications for all workforce development and external engagement activities, and advise the Management Team.

4.4.5 Strategic recruitment of diverse populations **–** For all proposed research (see **4.1, 4.5, 4.7**), iUTAH will vigorously recruit from Utah's Native American, Hispanic, and Pacific Island populations, as well as female Utahns. Members of the Workforce Development (WDT) and Diversity Enhancement Teams will recruit diverse populations of students from their institutions and communities for undergraduate fellowships, graduate research fellowships, Summer Institutes, etc. (see **4.5**). We will place special emphasis on recruiting from institutions with large enrollments of underrepresented students, such as

Title 1 schools, Salt Lake Community College (SLCC), SUU, Weber State, and the USU regional campuses at Blanding and Vernal. Over 50% of the students enrolled at the USU-Blanding campus are Native American and Blanding has been very successful in increasing the graduation rate of Native Americans from 14% four years ago to over 60% in 2010. SLCC has an excellent track record of graduating female students and has been improving the recruitment and retention of Hispanic students. We will also specifically recruit from urban communities for iUTAH research opportunities directly related to urban ecology and modeling of future urban environments. The DET will ensure that iUTAH participants are selected from the applicant pools to maximize geographic, ethnic, cultural, and gender diversity. iUTAH will also provide students of diverse backgrounds with relevant role models and mentors to improve their recruitment and retention in STEM degrees. Working with the DET members, the academic diversity councils, and our industry and government partners, we plan to hold career seminars with diverse representatives from across the State to discuss career choices for high school and undergraduate students and thus inspire them to pursue STEM career paths.

4.4.6 Native American communities*.** In addition to the recruitment efforts mentioned above (**4.4.5**), iUTAH has strategically partnered with the ***Four Corners School (FCS) of Outdoor Education [88] in Southern Utah, which has a long history of working with teachers and students from Native American communities. Since 1984, FCS has provided a wide range of place-based outdoor education programs for some 82,460 participants, ranging in age from 6 to 90. For iUTAH, Four Corners staff will develop curriculum for diverse K-12 audiences based on iUTAH's watershed Focus Areas, test that curriculum across the region, and train K-12 teachers in the newly developed curriculum. Councilman Herm Olsen on our DET is fluent in Navajo, has extensive experience with Utah's Native American communities, and will connect iUTAH researchers with diverse populations statewide.

4.4.7 Women in STEM – Since the recruitment and retention of women into STEM is currently problematic in Utah, we will place special emphasis on this population. We will partner with successful local programs to expand their reach across the state and create ties with iUTAH projects. Specifically, iUTAH will expand the existing ***ACCESS for Women in Science and Mathematics***, which mentors women through their undergraduate STEM experiences. The program currently serves nearly 40 women per year. Female undergraduates will be recruited from institutions statewide for iUTAH research experiences (see **4.5.6**) and to take part in the ACCESS program. Selected iUTAH undergraduates will participate in the ACCESS summer science course along with the annual ACCESS cohort prior to entry into their research experiences. They will also take part in on-going mentored activities during the year with near-peer mentors and ACCESS faculty members. Through ACCESS and iUTAH's partnership with the Women's Technology Council (see letter), we will provide female students with role models, give them a better understanding of careers available for STEM majors, and increase the number of girls completing STEM college degrees. *We are targeting 12 to 15 ACCESS-REU students per year.*

***4.4.8 Rural Communities*.** While over 85% of Utah's population is located within the dense Wasatch Front Metropolitan Area, the remainder is broadly distributed geographically. Seventeen of Utah's 29 counties carry the federal Frontier designation, indicating areas with six persons or less per square mile and access to services is usually 60-90 minutes away. Students and learners of all ages from rural Utah have inconsistent exposure to STEM learning experiences. We will build on existing connections to Utah's rural populations through the regional campus system. In collaboration with our museum partners (see **4.7**), iUTAH will disseminate the results of the three Focus Areas (see **4.3.2**) to rural communities by bringing the 'Taking Learning Outdoors' program (NHMU) into five strategically located rural sites and creating content for the 'Leo on Wheels' programs. UEN will also enable us to distribute research products to rural schools statewide via the UEN backbone.

Of the currently identified iUTAH participants, 39% are women, 2% are Hispanic; 1 is Native American; no Pacific Islanders or African Americans currently are identified. *Our goal is to increase the participant diversity to 45% women, 5% Hispanic and 5% Native American/Pacific Islanders, combined.*

4.5 Workforce Development Plan – Formal Science Education

4.5.1 Goal **–** Enhancing the STEM workforce in Utah by developing educational programs for a diverse range of learners that will inspire students to choose STEM careers, promote the retention of students in STEM degrees, and enhance the success of faculty in STEM disciplines.
4.5.2 Strategy – Guiding principles for iUTAH's workforce development plan include 1) integration of research and education; 2) near-peer mentoring; 3) encouraging diversity; and 4) public-private partnerships. A strong STEM workforce is critical to building and sustaining research capacity and economic growth. The 2010 NAS report [89] highlights the state of the US scientific enterprise and emphasizes the need to rebuild US talent in STEM areas. That report specifically emphasizes the need to improve K-12 education and inspire students throughout the education pipeline to pursue STEM careers. iUTAH will improve the STEM workforce in Utah by conducting formal science education activities that span the entire range of the STEM education enterprise and directly integrate with the proposed research activities – ecohydrology, social and engineered systems, coupled natural-human systems, and urban scenarios modeling. Research and education activities are planned for K-6 students; middle school and high school students and teachers; undergraduates at community colleges, primarily undergraduate institutions (PUIs), and the main research universities; graduate students; postdoctoral fellows; early career faculty; and faculty. These experiences will be directly related to the research questions of iUTAH (see **4.1**), so will focus on the watershed observatories and modeling activities in the Focus Areas. We are also participating in the State's efforts to develop a statewide K-16 STEM Curriculum Plan, which will complement Utah's S&T plan and synergize with the education and outreach efforts of iUTAH.

Integration of Research and Education **–** iUTAH will **integrate research and education** by actively involving educators and students with research scientists in order to inspire students to pursue STEM degrees. At the same time, this will provide teachers with research experiences they can apply in their classrooms. Students and teachers from all educational levels, from K through graduate level, will be engaged in iUTAH research activities. The iUTAH Diversity Team (DET) will assist with recruiting for all planned activities to ensure diverse representation of students and teachers across geographic, disciplinary, institutional, and individual aspects (including gender, ethnicity, and disability). In addition, iUTAH will provide opportunities to include postdoctoral researchers and early career faculty in the research teams. All iUTAH researchers will be actively involved with mentoring undergraduates and high school students, as well as graduate students and postdoctoral fellows. This integrated approach will create unique teams of researchers, with an emphasis on crossing disciplines and education levels, to integrate the iUTAH research experience into the education of diverse groups across the state. The three, instrumented watersheds and the ESRs will serve as observatories or 'living labs' that will be used to involve statewide iUTAH partners in place-based research, as well as provide data for interdisciplinary modeling and urban scenario planning. In addition, iUTAH has created partnerships with private industry and government agencies to offer internship opportunities for students to give them real-world experience with careers available with STEM degrees.

In order to increase the STEM workforce and research infrastructure in Utah, it is essential to expand the involvement of students and teachers through all educational levels, beyond the main research universities in the state. Therefore, iUTAH has developed activities that will involve two-year schools and community colleges, primarily undergraduate institutions (PUIs), regional campuses of the research universities, and institutions that have a high proportion of groups underrepresented in STEM. Throughout all of the proposed activities, there will be a focus not only on recruiting students into STEM fields but also on retention of students. In collaboration with our education partners, more senior students will trained as mentors for beginning students to create a climate of near-peer mentoring, using techniques from such programs as the "Entering Mentoring" system [90]. Near-peer mentoring has the double benefit of increasing the comfort level of junior students in research, and thus their retention, as well as teaching mentoring skills to the more senior students. Faculty members and researchers will work with the mentors to help them gain the necessary mentoring and communication skills.

The Utah NSF EPSCoR Project Manager will coordinate the formal science education programs and the internship program in collaboration with the iUTAH Workforce Development Team (WDT). The WDT will assist with recruiting and integrating undergraduates, high school students, and K-12 teachers into iUTAH research teams. They will work closely with the DET to ensure that all activities include diversity at the individual, institutional, disciplinary, and geographic levels. The Project Manager will be tasked with maintaining current statewide partnerships and developing future partnerships.

4.5.3 Objectives **–** iUTAH activities have specific objectives for each educational level:

- **K-12 students: Engage at least 200 students annually**, along with faculty, graduate students and undergrads, in an active iUTAH research project that is relevant to their area; provide hands-on experience with the instruments/techniques used to collect data and with data analysis; provide them with near-peer mentor role models; and inspire them to pursue STEM degrees.
- **K-12 teachers: Engage at least 40 teachers annually**, along with faculty, graduate students and undergrads, in an active iUTAH research project that is relevant to their area provide hands-on experience with the instruments/techniques used to collect data and with data analysis; engage participants in drafting middle and high school curriculum materials related to the iUTAH project; motivate teachers to incorporate iUTAH research methods and outcomes into their classes.
- **Undergraduate students: Engage at least 30 undergraduate students annually** with iUTAH researchers; train students in research practices and critical thinking; recruit students to pursue STEM careers; provide them with near-peer mentor role models; retain students in STEM degrees; and provide them real-world job experiences with private or public entities.
- **Graduate students: Engage at least 20 graduate students annually** with iUTAH researchers to increase student research expertise; provide them with interdisciplinary research experiences; teach them how to mentor more junior students; provide them with near-peer role models; and retain students in STEM research.
- **Postdoctoral researchers: Engage at least 3 postdoctoral scientists** in iUTAH research projects to provide them with interdisciplinary research experience, connect them to faculty mentors; expand their collaborative network, and make them more competitive for their own funding from NSF and other sources in the future (See Postdoctoral Mentoring Plan in supplemental documents).
- **Faculty: Provide research funds for at least 10** early career faculty and faculty at primarily undergraduate institutions to engage in research with iUTAH, expand their collaborative research network, mentor undergraduate and/or graduate researchers, and make them competitive for their own funding from NSF and other sources in the future.

4.5.4 iUTAH-Water, the Environment, Science and Teaching (WEST) Fellows ***(Godsey, UU; Mesner, USU)*** **–** iUTAH will enhance the WEST program, a science inquiry program partnering graduate students with **K-12 students and teachers**. Since 2003, WEST has supported 54 Fellows who worked with an average of three public school classrooms throughout the year and engaged over 5,000 K-12 students and 70 teachers. For iUTAH, this program will specifically focus on water sustainability issues in Utah and the three research Focus Areas. iUTAH-WEST will provide funding for iUTAH graduate students (see **4.3.2**) to work with K-12 schools across Utah. The WEST Coordinator will train selected graduate students, who will work for at least 5 hours per week in K-12 classrooms throughout the semester. They will help develop lesson plans, lead field trips, conduct laboratory experiments, and provide tools that facilitate hands-on learning. iUTAH-WEST fellows will work with the existing cohort of WEST fellows, participate in bi-weekly WEST seminars, and develop interdisciplinary linkages across iUTAH projects.

4.5.5 iUTAH Summer Institutes ***(EPSCoR Project Office)*** – The place-based science being done on the three watershed observatories across the state will serve as a 'living lab' for engaging students and teachers at all levels in the STEM research enterprise. iUTAH will host an annual Summer Institute in which teams of students and teachers spend one week working with iUTAH faculty researchers at the watershed observatories or other iUTAH Facilities. ***Each team will include high school students, high school and/or middle school teachers, undergraduate and graduate students, a research investigator, and an informal science educator.*** Each team will study one watershed and will be involved in both designing their specific experiment and collecting data. After the field experience, the teams will come together to report their results and develop materials that translate the research results into outputs for community use. Working with the informal science educator, each team will develop either a digital or off-line product related to the research and targeted for subsequent museum exhibits or for formal education use. The Genetics Science Learning Center (GSLC) at the University of Utah has vast expertise in curriculum development of scientific concepts, so will work with teachers, students, and researchers to create highly engaging learning modules directly related to iUTAH research that can be used in classrooms. Teachers will produce a lesson plan or module that will be further refined by follow-up interactions with the science educators. Once these resources are refined for classroom use, UEN will broaden the distribution of these resources nationally through the PBS Learning Media. The district science specialists from Provo, Salt Lake City, Granite, and Cache school districts have already agreed to help recruit teachers and students for the summer institutes (see letters).

4.5.6 Collaborative Research Experiences for Undergraduates ***(Avery, Westminster College; Pataki, UU)*** – Undergraduate student-faculty collaborative research is a proven approach to engage young scientists and the benefits of research as a component of undergraduate curriculum are far-reaching [91]. We will provide summer research opportunities for undergraduates to work jointly with iUTAH scientists and graduate students. We will place special emphasis on recruiting from primarily undergraduate institutions and those with high enrollment of diverse groups, since these institutions often lack the facilities, time, financial support, and opportunity to provide research experiences for students. Students will work in close supervision with iUTAH scientists and engineers and will be encouraged to develop their own research projects as they gain research experience. Undergraduates will be paired with near-peer mentors, either more senior undergraduates or graduate students, to enhance their research experience. The DET will assist with recruitment to ensure there is a diverse pool of iUTAH REUs.

4.5.7 Internship Program ***(Ramsey, Canyon Concepts; C. Keleher, UDNR)*** – iUTAH will match **undergraduate students** with summer internships at private sector or government agencies that work in areas related to iUTAH Focus Areas. iUTAH's partners have agreed to provide students with stipends for summer months so that students can work with their mentors to learn about career opportunities related to water sustainability issues in Utah. Specific commitments have been received from a group of environmental consulting firms, the instrumentation company Campbell Scientific, Inc., and the Department of Natural Resources. The internship program will be expanded as more partners are added.

4.5.8 Water Sustainability Graduate Research Fellows ***(Crowl, USU; Pataki, UU; Aanderud, BYU)*** – **Graduate students** will apply for competitive research fellowships to work with iUTAH researchers. The Fellowships will be designed to provide students with interdisciplinary research experiences, so students from both the natural and social sciences will be encouraged to apply. One requirement of the Fellowships will be participation in the Summer Institutes, including pre-Institute training in near-peer mentoring and expected learning outcomes. The **EPSCoR Management Team** (EMT) will review the applications and make funding recommendations. Graduate students will also be recruited to join iUTAH research teams directly by individual researchers. In addition, we will provide summer research awards (see **4.9.1**). We will actively recruit mathematical modelers to seek Graduate Student Summer Research Awards to encourage collaboration with existing programs in mathematical biology.

4.5.9 Postdoctoral Fellowships ***(Ehleringer, UU; Jackson-Smith, USU)*** – To enhance cross-university and interdisciplinary research, iUTAH will employ a shared **post-doctoral** fellowship program designed to allow fellows to work with the iUTAH Research Focus teams (see **4.3.2**) while spending significant time with at least two different mentors from varying disciplines and from at least two of the major research institutions. This program is modeled after the newly created NSF-SEES post-doctoral fellows program. It will provide postdocs with a clear path toward existing NSF interdisciplinary programs and will complement and leverage the recently funded UU Interdisciplinary Continental Training in Ecology (ICTE) project that focuses on inter-university postdoctoral training. The EMT will review the applications and make the funding recommendations.

4.5.10 Faculty Research Fellowships ***(Crowl, USU; J. Keleher, SLCC)*** – To extend the research infrastructure in Utah beyond the main research universities, iUTAH will offer research awards for **faculty at primarily undergraduate institutions (PUIs) and for early career faculty** (see **4.9.1**) to work with iUTAH researchers on one of the three Focus Areas. Faculty will be encouraged to bring undergraduate students to participate in the research experience during the summer. Faculty Fellows will be mentored by established faculty, which will enhance faculty success with new research methodologies and facilitate technological transfer. Selection criteria will include the likelihood that the research experience will provide a platform for the faculty member to seek future NSF grants, including institutional RUI awards. Faculty fellows will also participate in grant-writing workshops, including the intensive one-day course "Write Winning Grants", and are expected to submit NSF proposals based on their research fellowship.

***4.5.11 Annual iUTAH Symposium** (EPSCoR Project Office)* – iUTAH will convene an annual symposium of all iUTAH participants for presentations by students, teachers, faculty, informal science educators, and other partners. The Symposium will focus on discussions among the participants about future plans for iUTAH, including lessons learned from the previous year's activities. The plan is to hold the annual Symposium in collaboration with the External Advisory Board meeting, so that the Board members can hear the results and suggestions from the previous year directly from participants.

4.6 Cyberinfrastructure Plan

iUTAH Cyberinfrastructure (CI) will increase the level of and capacity for collaboration through investment in shared computing infrastructure and integrated CI systems. We will build on existing CI expertise at USU, UU, and BYU through: 1) creation of a federation of data and modeling resources for integration of data and modeling; 2) adoption of standards for data sharing and curation to promote interoperability, open access, and long-term retention; 3) development of partnerships with existing data agencies, computational facilities, and CI programs; and 4) deployment of technologies that promote connectivity and collaboration. This initiative will catalyze collaboration between data collection, publication, and simulation efforts and will be the "glue" that enables the sharing and synthesis of data required for successful multi-disciplinary work.

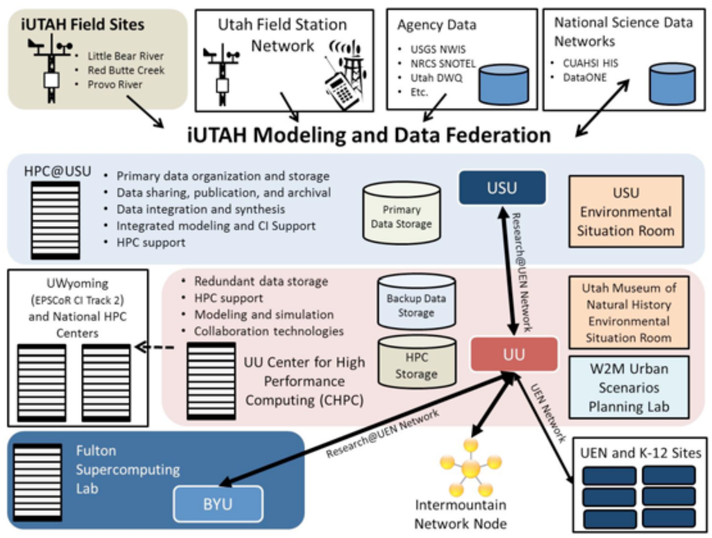

Fig. 4 – Proposed iUTAH Integrated Data Storage and Modeling

***4.6.1 iUTAH Modeling and Data Federation*.** Synthesis of diverse data collection and modeling requires creation of a facility with adequate storage, networking, computational, and human resources. Hardware, software, and data resources are already spread across the Utah universities. As such, we will build the iUTAH Modeling and Data Federation as a distributed facility (Fig. 4) that will support the full data life cycle, thus increasing capacity for data collection, organization, management, sharing, synthesis to higher level products, and integration with the proposed models. This facility will coordinate across Utah Universities. For example, primary data organization, archival, and publication will primarily be supported at USU, whereas we will coordinate data storage resources with UU for redundancy and for High Performance Computing support. We will leverage development of enhanced optical network connectivity through UEN and the recent EPSCoR RII C2 award as well as computational resources through the recent Utah/Wyoming EPSCoR CI-WATER award.

Assembly and organization of relevant existing and historical datasets, and implementation of software and middleware systems to support publication, synthesis, and interoperability of collected and generated data will be a major focus of the Federation. We will support streaming of continuous monitoring datasets from the proposed field sites into storage and archival databases. All field sites will have continuous connectivity to ensure near real-time retention of data. We will also work closely with the Education and Outreach Team to develop user-friendly data interfaces for novices and the general public to discover and access iUTAH data. Specifically, we will invest in virtual host servers at USU's enterprise data center for hosting web, application, and database servers, as well as an initial 100

Terabytes (TB) of shared disk storage at USU with 50 TB of redundant capability at UU. In subsequent years, available disk storage will be expanded to 150 TB at USU and 100 TB at UU. The Data and Modeling Federation will be a reliable, scalable, and cost-effective resource within which iUTAH researchers, regardless of their location or institution, can store, organize, and share their data.

We will support technical experts to assist in implementing the required hardware and software systems. Initially, these experts will build the necessary hardware systems, collect data from various sources, and develop network-based data delivery mechanisms. As our research data collection infrastructure comes online, their focus will shift to assisting researchers with data management issues and integrating new data resources. Horsburgh and Corbató will provide facility leadership and regular liaison with the research teams, coordinating with the statewide CI team from the RII C2 award.

This is a rapidly changing time, with emerging, location-enabled mobile devices that will allow for greater societal participation in iUTAH via data collection, input, and visualization. The hardware, database, and middleware services we develop will facilitate new projects that more extensively engage citizen science and deploy data collection and visualization products. These will be of tremendous use in workforce development, citizen science, and of general societal interest. Such developments will be transformational and can engage students at a younger age in the excitement of scientific discovery, especially in urban settings. Specific applications over the next 3-5 years are hard to predict, but our CI will be designed to be capable of accommodating and promoting new technology. The CI Team will work closely with the Education and Outreach Teams to take advantage of new data fusion approaches and technologies (e.g., web applications and apps for mobile devices) to develop user-friendly data interfaces for researchers, novices, and the general public to discover and access iUTAH data. This will require a CI development effort to make sure we can accept and display data in useful ways. The goal is to develop visualization tools and useful products for a wide variety of users and stakeholders.

4.6.2 Promoting Interoperability. A desired iUTAH CI outcome will be the sharing of both geospatial and temporal datasets describing land use, climate, water resources, and economic variables in formats that are highly available, easily interpreted and synthesized, and compatible with the evolving standards for published data products. Because our data will use many different file formats with heterogeneous metadata, common data and information models will be used to store data in formats that can be shared using standards-based web services. Examples include the CUAHSI Observations Data Model (ODM) and WaterOneFlow web services for point observations [92, 93]. The result will be data that are easily accessible from a variety of client software applications. We will use existing metadata standards and markup languages for describing and transmitting datasets, including Ecological Markup Language [94] and Water Markup Language [95] specifications.

We also will work with existing NSF-supported data publication and preservation efforts. Horsburgh is a member of the Core CI Team of the NSF-funded DataONE DataNet project, and both he and Tarboton have been instrumental in the development of the data publication software stack used by the CUAHSI Hydrologic Information System (HIS) [93, 96-99]. Tarboton is also a member of the external advisory committee for the Idaho-Nevada-New Mexico Tri-State Western Consortium's EPSCoR Track 2 CI project, which is an opportunity for collaboration with neighboring states facing similar water resources challenges. We are uniquely positioned to be early adopters of the CI data standards and technologies developed by these efforts, leveraging existing NSF investments to ensure the successful integration of the proposed observational and modeling activities and that iUTAH data are shared and discoverable as resources for the broader scientific community and the public.

4.6.3 Enhancing Partnerships. We will leverage data from local, state, and federal agencies by developing and enhancing strategic partnerships, hosting portions of agency data within the modeling and data facility, and assisting agencies in sharing their own data in interoperable formats. This will increase data availability for the synthesis efforts of this project. Our experience in developing community watershed information systems underscores the importance of the social as well as technical aspects of sharing data. We will build on our experience in developing partnerships with USGS for streamflow and water quality information, NRCS for snowpack and soil moisture information, and multiple Utah state agencies for environmental observations and geospatial datasets. Aided by participation in the CUAHSI

HIS and DataONE projects, iUTAH will improve access to large, distributed volumes of existing hydrologic, atmospheric, ecological, environmental, population, and land use data.

A critical element of the proposed activities is in quantitative simulations of future scenarios of availability and quality of water resources. The numerical modeling required is computationally expensive yet essential for interpreting and synthesizing iUTAH observational data. We will leverage the new 100+ TeraFLOP class computer system that is being constructed at the University of Wyoming as part of the recent Utah/Wyoming EPSCoR CI-WATER award. This supercomputer is specifically being built to support data intensive modeling of water resources. We will use this system and others available at USU, UU, and BYU for long, computationally intense runs and as a development platform for code testing before migration to larger systems like the TeraGrid and elsewhere. We will leverage the resources and staff at the UU Center for High Performance Computing and the new downtown data center in Salt Lake City. Resource faculty leads are Strong (UU) and Jin (USU).

4.6.4 Infrastructure for Connectivity and Collaboration. Utah is fortunate as UEN already provides sustained network connectivity and collaboration tools for Utah researchers at a level above many other states, particularly in the Intermountain region. In addition, the ongoing RII C2 project will deliver optical connectivity to BYU, and ongoing UEN upgrades will result in optical network upgrades to UU and USU. Leveraging existing network and videoconferencing capabilities of UEN, we will deploy a web-based collaboration system to enable on-demand meetings with desktop sharing, video, and audio.

4.7 External Engagement Plan – Informal Science Education

4.7.1 Goal **–** Developing informal science education programs that will enhance the development of a diverse, well-prepared STEM workforce and a more scientifically literate public in the state of Utah.

4.7.2 Strategy – iUTAH's external engagement plan focuses on outreach, communication, and dissemination activities to translate iUTAH efforts to diverse audiences, including the full range of ages of the general public, as well as decision makers and policy makers. By combining Informal Science education activities with the ESRs in Focus Area 3, iUTAH will use data and results from the three Focus Areas to engage the public in discussions about water sustainability issues in the Mountain West and potential solutions to water pollution and scarcity. iUTAH's plans for institutional partnerships, including engagement with private industry and government agencies, are described in the Workforce Development section (***4.5***). iUTAH's plans for facilitating the entry of women and members of other underrepresented groups into STEM careers are integral to the external engagement (see Diversity section ***4.4***).

4.7.3 Objectives **–** iUTAH activities will 1) provide new opportunities for public participation in iUTAH research, education, and outreach activities; 2) disseminate iUTAH project information, research outcomes, educational materials, and participation opportunities; and 3) engage local stakeholders in a dialog about water sustainability issues in Utah and the Mountain West.

4.7.4 Museum Partnerships ***(Runburg, NHMU; Giles, Leonardo; Yin, UU; Licon, USU)*** **–** iUTAH researchers will work with our informal science education partners, Natural History Museum of Utah (NHMU) and The Leonardo (a new interactive science museum), to disseminate iUTAH research outcomes to the public. They will translate results from the three Focus Areas (see **4.3.2**) into interactive museum programs for all ages of the general public. Specifically, K-8 students and teachers in the three watershed areas (see **4.3.2.1**) and in rural communities will participate in ***"Taking Learning Outdoors"*** (TLO), a multi-disciplinary science inquiry program developed by the Natural History Museum of Utah. TLO is designed to support participatory-based learning with both situated and constructivist learning principles. TLO involves scientists and graduate/undergraduate students who develop increased communication and engagement skills while serving as a bridge to the research community and STEM career pathways. iUTAH will also partner with The Leonardo to develop content for their **"Leo on Wheels"** program to bring resources developed from the three Focus Areas to rural audiences across Utah. These mobile exhibits target rural audiences (see **4.4.8**), thus broadening the dissemination of scientific knowledge beyond the high-density urban areas.

4.7.5 iUTAH Summer Institutes ***(Goetz, GOED; Stark, GSLC; Baker, USU; Pataki, UU; Crowl, PD)*** **–** As described in Section ***4.5.5***, the annual Summer Institutes will bring together teams of students and teachers to work with iUTAH researchers at each of the watersheds being monitored. The external

engagement portion of these Institutes involves working with informal science educators to translate the research results into outputs for community use. Each team will develop either a digital or off-line product related to iUTAH research and targeted for subsequent museum exhibits or for formal education use. Resources developed by these Summer Institute teams will be disseminated through a number of different avenues, including exhibits at NHMU and The Leonardo, the iUTAH web site, and UEN.
4.7.6 Visualization and scenario development* (Nelson, UU; Licon, USU; Runburg, NHMU; Menlove, NHMU) –** The modeling capabilities developed in iUTAH Focus Area 3 will be used to develop the capacity for participatory modeling activities using the ESRs (see **4.3.2.3**). Stakeholders will work with iUTAH researchers to explore scenarios that change parameters most relevant to their communities and discuss the impacts of potential interventions on water sustainability and/or other policy issues. Using the UEN backbone, we will make this participatory modeling available remotely to include numerous stakeholder groups across the State, including rural communities. The plan is to establish one Environmental Situation Room (ESR) at NHMU and the other at the USTAR Innovation Campus in Logan. iUTAH's museum partners will also use the modeling research results and the visualization technologies to create interactive exhibits, including enhancing the ***'Utah Futures' exhibits at NHMU.
4.7.7 Citizen Science* (Mesner, USU; Citizen Science Coordinator) –** We will leverage Utah's existing Water Quality Extension program which recruits citizen scientists for environmental measurements. The Citizen Monitoring Coordinator has the ongoing task of determining monitoring needs of agency partners, establishing standard operating procedures and training modules, and working with volunteers throughout the state to collect credible data. The two-tiered program provides data to agency and state partners for screening and decision making purposes. A 3rd tier of monitoring for education only is Stream Side Science, a Utah-specific water based curriculum for middle and high school students. We will engage citizen scientists to measure attributes of ecological structure and water quality at our watersheds, including macroinvertebrate taxa, benthic algae and plant distributions. These individuals will also increase their knowledge and develop a greater sense of stewardship of local water bodies and watersheds. Utah Extension's ***Citizen Science Program draws from all Utah counties, and so will be able to engage a broad geographic distribution of participants, from both rural and urban communities.
4.7.8 Communications Technology* (EPSCoR Project Office) –** iUTAH will employ a communications specialist at the EPSCoR Project office to assist with development of communications materials. They will work with the Project Manager to implement iUTAH's communication strategy, coordinate with UEN, produce monthly newsletters of iUTAH activities, and coordinate news releases with the iUTAH researchers. UEN will produce a comprehensive, public-facing website that builds upon the back-end data captured by the iUTAH CI, using models and concepts readily accessible to the general public. The site will also include STEM career video programs, all curriculum materials developed through this project, links to STEM community events, STEM news, and a directory of iUTAH researchers and field sites. Inter-jurisdictional communication and data sharing will be facilitated through the Utah Education Network (UEN) backbone and supported through Utah's EPSCoR CI activities (see section ***4.6 and NSF awards 1135351 and 1007027).

4.8 Evaluation and Assessment

4.8.1 Strategy – The proposed Evaluation and Assessment Plan will include review and evaluation of iUTAH activities by a diverse group of independent, external experts during the award period. Reports prepared by these reviewers will be conveyed to the NSF EPSCoR Office in a timely manner. The project's management team, in collaboration with the external evaluators and external advisory board, will continuously monitor progress toward the goals of the strategic plan. Recommendations from the evaluation teams will be used to inform plans for subsequent years of iUTAH activities. *The iUTAH evaluation and assessment plan will involve a four-pronged approach by independent evaluators: 1) Education and Outreach consultant, 2) Collaboration and Networking consultant, 3) AAAS Research Competitiveness Program, and 4) External Advisory Board.*
4.8.2 Education and Outreach – Jacque Ewing-Taylor (U. Nevada-Reno, NV EPSCoR) will conduct a comprehensive evaluation that measures the goals and objectives of the iUTAH education and outreach activities. Ewing-Taylor will be in frequent communication with the iUTAH team, and be responsible for

the evaluation design, survey data collection and analysis, and report writing. She is well grounded in quantitative and qualitative evaluation methodology and various formative and summative evaluation methods. She has conducted numerous program evaluations, including two Nevada Math and Science Partnership (MSP) grants, a Utah MSP grant, and an NSF Informal Science Education project. She has also been active in promoting effective classroom practices for STEM teachers as the Director of the Raggio Research Center for STEM Education in the College of Education at UNR. Ewing-Taylor has been working with iUTAH on the planning of activities during proposal preparation to ensure that each activity has measurable objectives and outcomes. Annual evaluations will provide recommendations that will be used to shape future iUTAH events. The evaluation component will employ a mixed-method approach, relying on surveys, questionnaires, observations, interviews and external reviews, to assess the quality, efficacy, and value of the proposed work and the ultimate return on the NSF's investment. Ewing-Taylor will ground evaluation activities in the intended outcomes of the project, focusing on several key questions, including to what extent and how does this project: help develop Utah's workforce; engage K-12 teachers and students; engage undergraduate and graduate students in partner universities and colleges; and result in increased public engagement in issues related to water in the arid west.

For assessment of workforce development activities, evaluation data will include numbers and demographics of participating teachers and students, enrollment trends for high school and undergraduate students, review of new curricula and lesson plans, evaluation of courses/seminars/workshops, number of STEM undergraduate majors at participating universities and PUIs, and use and success of near-peer mentoring programs. Other relevant data will include publications, grants, and presentations; products and publications use record; partnership results; types of communications; and testimonials. Data gathered from those participating in the internship program will also be used in the project's evaluation.

For the assessment of external engagement activities, evaluation data will include participant numbers and demographics, on-site assessment of museum events and activities, utilization analysis of resources developed in the Summer Institutes, analysis of interactive modeling events, Citizen Scientist numbers and demographics, and usage data for the communications technologies and the iUTAH Web site.

Objectives of the project's mixed-methods (NSF 97-153) formative and summative evaluations are to use qualitative and quantitative data to (1) provide information for refining and improving project implementation; (2) measure project progress in successfully meeting goals and objectives; (3) assess the impact of the project in developing strong intra- and inter-jurisdiction collaborations that address regionally relevant and nationally important science, policy, and education; and (4) assess the project's impact in discovery, learning, research infrastructure, and stewardship. Evaluation will utilize the following measures: added value evaluation, assessment benchmarks, and performance measures. Ewing-Taylor will report all findings and recommendations to the Management Team and the PI/PD who will be responsible for disseminating findings to NSF and appropriate stakeholders.

4.8.3 Collaboration and Networking – Alan Porter, from Georgia Institute of Technology, will assess iUTAH impacts on collaboration and statewide networking. Dr. Porter is a leader in the emerging field of 'scientometrics' and will conduct bibliometric analyses to determine the linkages among researchers in the State. He will analyze the publication and citation patterns of researchers at all Utah institutions to identify the level of interconnectedness before iUTAH is awarded and in year 4 of the award. This will indicate the connections between institutions, disciplines, and individuals that were stimulated by the iUTAH activities. The results of the year 4 analyses will be used to inform plans for year 5 and beyond.

4.8.4 AAAS Assessment – Dr. Mark Milutinovich, Associate Program Director of the AAAS Research Competitiveness Service, will lead a review by an AAAS external scientific advisory board. The AAAS Research Competitiveness Service will recruit and lead a panel of experts to evaluate the scientific, programmatic and administrative aspects of iUTAH. There will be one AAAS staff-only strategic planning visit (year 1) and two panels in years 2 and 4 to prepare iUTAH for NSF site visits and inform plans for the following years. The AAAS panel(s) will provide recommendations on scientific directions; management activities; supporting infrastructure and policies; and the evaluation process itself, if any or all need to be modified for the program to have the best chance of success.

4.8.5 External Advisory Board – iUTAH's External Advisory Board (see **4.10**) will meet annually in conjunction with our annual EPSCoR Symposium (see Section **4.5**) to advise the Project Director's Office and the Management Team on the effectiveness of our activities to enhance research, education, diversity, workforce development and external engagement capacities. Their recommendations will be discussed with the Management team and be made available on our website and to our external assessment team and NSF. The External Advisory Board will also provide forward-looking advice and vision for the future directions of the iUTAH research areas and best practices for education and outreach activities.

4.9 Sustainability Plan

The UT EPSCoR facilities and CI infrastructure were designed to maximize ongoing investments from existing state and federal agencies (Watershed Observatories), prior research support (Integrated Data Modeling and Storage), university priorities (Green Infrastructure, Futures modeling) and current EPSCoR funding initiatives (CI backbone, CI connectivity, CI high performance computing). The Vice Presidents of Research from the PhD-granting institutions have guaranteed support of the facilities, faculty lines and some technical support post iUTAH (see letters). Our watershed, green infrastructure and environmental situation room facilities will provide critical gathering places for continued collaboration and proposal development. These facilities will allow us to become immediately competitive in current NSF funding opportunities such as CZO, ULTRA, CNH as well as the newly developing SEES investments.

4.9.1 Seed Funding Opportunities **–** In addition to and in accordance with the draft Utah S&T plan, State USTAR activities, and missions of our institutions of higher education, we will ensure sustainability through: **PUI Awards -** We will provide 5 summer research opportunities ($10,000) annually for faculty from non-PhD granting institutions for research activities relevant to our focal areas of research. We will encourage close collaboration with existing faculty and/or the utilization of new EPSCoR facilities. We will make award selections based on the likelihood that the seed funding will result in collaborative proposal development or will result in targeted PUI efforts such as NSF's RUI program. Awardees will participate in the Summer Institute (SI) (***4.5.5***) and will present their results and future proposal development plan at the annual UT EPSCoR Symposium. **Graduate Student Summer Research Awards -** We will provide up to 10, $5,000 summer graduate research awards annually to encourage cross-fertilization of ideas and engagement throughout the state and across disciplines. Students will be selected based on the likelihood that their summer research activities will enhance their existing research (similar to Dissertation Improvement Grants) or provide them with experience with sensor, computing, or modeling facilities to broaden their existing efforts. Graduate awardees will also participate in the SI and present results at the annual UT Symposium. Finally, in years 3-5, we will provide up to 3-5 **Pilot Research Awards** ($10-25,000) to faculty that have identified new, emerging research opportunities.

4.9.2 Education and Human Resource Development **–** We have identified three critical areas of expertise that must be expanded to meet our EPSCoR goals. We will recruit at least two new faculty in the areas of interdisciplinary sociology, regional landscape ecology, or environmental engineering-hydroinformatics at USU or UU. The UU made four strategic hires as part of last year's EPSCoR effort. Both institutions have excellent records in faculty recruitment and retention. UT EPSCoR will provide support for 9 months of salary for two years, followed by two years of half time funding (3 academic plus 3 summer months), and three months of summer salary in the 5^{th} year. This represents a large EPSCoR investment; we think that providing continuous summer salary over a five-year period will maximize the quality of hires and success in establishing a strong research program with immediate and lasting impact.

4.9.3 Post RII Funding **–** Virtually all of our research, education and engagement activities have been designed with particular NSF (and other funding agency) programs in mind. Researchers and educators throughout UT have been very successful at obtaining disciplinary, core program support. Our greatest challenge lies in successfully competing for large, interdisciplinary funding opportunities where we can most effectively impact not only our own research and education capacity but also the UT and regional workforce. From our first five years of EPSCoR, we have identified the following: *Targets – two CNH, one RCN-SEES, two WSC, one SRN, one REU site and two RUI proposals. In addition, we will encourage and foster five SEES Fellows (Post-Doc), 10 Graduate Research Fellowship (PhD student) applications and at least five Career submissions.*

4.10 Management Plan

UT State EPSCoR Office Team (SEO): USU is the lead institution for this project and will act as the fiscal agent. The Project Director (PD; Todd Crowl) will dedicate six months time (0.5 FTE) to provide day-to-day management of the program. Crowl has extensive experience with large, interdisciplinary collaborative research efforts including being a Co-PI on LTER, BioComplexity and Neon (COREO) awards from NSF. He very recently was the Program Director for NSF's ($38 million) LTER program as well as active on the original implementation group for what is now the NSF SEES Program. All day-to-day activities will be conducted from this office as well as weekly and monthly face-to-face meetings. The PD will preside over the monthly EMT meetings and oversee all budgetary decisions. A 1.0 FTE Project Manager (PM) will be responsible for communications and cross-activity collaborations among iUTAH participants. The PM will work closely with team leaders from the research focus areas as well as the workforce development, external engagement, diversity, and assessment teams and will oversee the annual EPSCoR Summer Institute, iUTAH Symposium, and evaluation/assessment activities. The PM will provide monthly reports to the EMT (see below) and supervise a Communications Director and Administrative Assistant. The PM will hold a PhD in a STEM discipline and will have experience managing large, interdisciplinary projects. They will reside in the Vice-President for Research's Office at USU. A search is currently underway. An 0.5 FTE business manager will oversee all budgetary matters and will act as the direct liaison between the EPSCoR Office and the various university budget officers.

EPSCoR Management Team (EMT): will provide oversight and direction to the UT EPSCoR and is comprised of the Project Director, Co-PIs and key personnel from across the state including team leaders from the Workforce Development team (WDT), the External Engagement team (EET) and the Diversity Enhancement team (DET) and each of our three research focus areas (Fig. 5). We assembled an EMT with distributed leadership across institutions, disciplines, gender, and rank. The EMT have multi-disciplinary experience in aquatic ecology and biostatistics (Crowl; PI/PD), urban ecology (Pataki; Co-PI), climate science (Ehleringer; Co-PI), social science (Bedford, Jackson-Smith; Co-PI), biogeochemistry and hydrology (Baker; co-PI), engineering (Pomeroy), natural resources (C. Keleher), workforce development (Avery, Ostrowsky, Rushforth), STEM education (Goetz), external engagement (Runburg), and diversity enhancement (Ross, Morales). The EMT will hold biweekly tele- and videoconference and quarterly meetings at the UT EPSCoR office. The EMT will insure integration, coordination and implementation of the focal science areas, workforce development, external engagement and diversity enhancement. The EMT will oversee the implementation and utilization of our new facilities by scientists, educators and stakeholders. In addition, the EMT will meet annually to evaluate proposals for our REU, graduate student and PUI faculty research programs (see **4.5**, **4.9**).

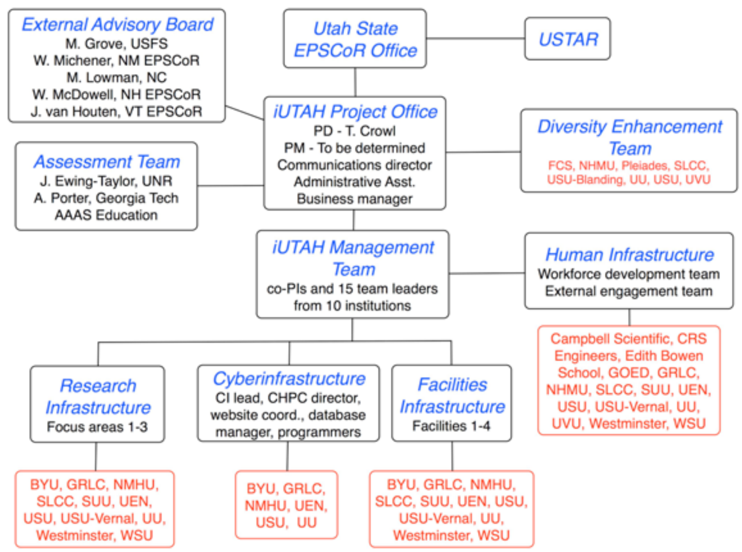

Fig. 5– Proposed iUTAH Management Structure showing integrated relationships among all research focus areas with diversity, workforce development and external engagement activities.

Half of the EMT membership are assistant or associate professors and were chosen to provide a natural **succession** of PIs and PDs. Because they meet with the PD and PM bi-weekly, there will be direct and complete transfer of knowledge for all EPSCoR activities as the project proceeds.

Diversity Enhancement Team (DET): is composed of faculty that are actively involved in recruitment and retention of STEM students, teachers and faculty. DET is represented by many STEM disciplines and a wide geographic and institutional distribution including SLCC (Hurd), UVU (Madsen), UU (Rossi) and USU (Denton) and industry (Dintelman). Denton is notable in that he operates a recruitment and retention program in the Four Corners area of Utah that includes Navajo, Ute and Hopi tribes and high schools. Morales oversees a highly successful Hispanic recruitment and mentoring program that we will implement statewide, especially where the Hispanic population is concentrated, such as UU and WSU. The DET will meet monthly to review recruitment into iUTAH activities and will meet biannually with the Project Management team to assess and revise our strategies for incorporating women and underrepresented groups into future iUTAH activities.

External Advisory Board (EAB): will meet annually in conjunction with our annual EPSCoR symposium (see **4.5**) to advise the Project Director's Office and the EMT on the effectiveness of our activities to enhance research, education, diversity, workforce development and external engagement capacities. Recommendations will be discussed with the EMT and made available on our website and to our external assessment teams and NSF. Our EAB is comprised of five diverse and nationally recognized experts in CI, data management and modeling (Michener), biogeochemistry and hydrology (McDowell), overall program, and specifically EPSCoR management (Van Houten), urban ecology and coupled natural-human systems (Grove) and formal and informal education and outreach (Lowman). Michener and Van Houten are current lead-PI's on EPSCoR awards (NM and VT, respectively) while McDowell is Co-PI on the newly awarded NH EPSCoR award.

Evaluation & Assessment Team (EAT): is comprised of three independent, external assessment experts including Ewing-Taylor (UNV), Porter (Ga. Tech) and the AAAS Research Competitiveness Team (see **4.8**). Together, they will provide a comprehensive assessment of our education and outreach (Ewing-Taylor), statewide collaboration and interdisciplinary productivity metrics, as well as an overview of our organization, implementation and effectiveness in attaining desired goals.

State EPSCoR Committee (SEC): governs and oversees all EPSCoR activities, with representatives from the Utah Legislature, Governor's Office of Economic Development, USTAR, private industry, State Board of Regents, State director, and Senior Administrators at UU, USU, and BYU as well as the PUI institutions. The committee provides oversight to all EPSCoR programs as well as the development and implementation of the UT S&T plan. The SEC meets biannually.

Utah Science Technology and Research Initiative (USTAR): is a state-funded investment to strengthen Utah's "knowledge economy." This initiative invests in world-class innovation teams and research facilities at the major State Universities (USU, UU) to create novel technologies that can be subsequently commercialized. USTAR will provide UT-EPSCoR with office space as well as a half-time communications specialist and staff assistant for the UT EPSCoR Office (see letter).

4.10.1 Jurisdictional and other support. We have office space, conference facilities, and communications and administrative staff at the USTAR office complex (see letter). This state support is unprecedented for this activity in Utah. USU and UU will contribute to the faculty hires (see letters and **4.9.2**).

4.10.2 Budget Table A *(See list of Institutions for abbreviations)*.

Awardee	Yr 1 ($K)	Yr 2 ($K)	Yr 3 ($K)	Yr 4 ($K)	Yr 5 ($K)	Total ($K)	%
USU-lead	$1,650.3	$1,503.7	$1,469.9	$1,432.5	$1,428.8	$7,485.20	37%
SEO	$1,017.4	$1,098.0	$1,071.6	$1,065.6	$1,067.2	$5,319.80	26%
UU	$868.1	$1,007.6	$985.4	$1,027.7	$1,019.7	$4,908.50	25%
BYU	$312.7	$237.4	$281.2	$288.1	$295.2	$1414.60	7%
NHMU	$53.3	$53.9	$92.2	$96.1	$97.9	$393.40	2%
UEN	$27.3	$27.3	$27.3	$15.7	$15.4	$113.00	1%
SUU	$23.1	$23.7	$24.3	$24.9	$25.6	$121.60	1%
WSU	$16.8	$17.3	$17.8	$18.3	$18.9	$89.10	0.5%
UVU	$16.2	$16.0	$14.8	$15.2	$15.0	$77.20	0.5%
Westmin.	$14.8	$15.1	$15.5	$15.9	$16.3	$77.60	0.5%
Total	$4,000.0	$4,000.0	$4,000.0	$4,000.0	$4,000.0	$20,000.0	100%

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RESPONSE TO EPSCoR REVIEW (EPS-1208732)

We welcome the opportunity to respond to the recent panel review and provide more details on our iUTAH EPSCoR activities in the Wasatch Range Metropolitan Area (WRMA). Here we expand on the conceptual model for coupled human-natural water systems that will guide our proposed research activities and respond to the five key issues raised by the review panel, as highlighted by Dr. Sian Mooney in correspondence dated December 20, 2011.

1a. Provide a detailed theoretical/conceptual framework *for the proposed research, including a discussion of how data collection will support modeling and decision-making. Clarify how this framework will contribute to the research team's efforts to address the three research focus areas*

iUTAH Theoretical Framework. An iUTAH theoretical framework exists and the data to be collected will specifically inform the conceptual model and allow testing and modeling of these conceptual relationships and patterns (Figure 1). We use a socio-ecohydrology model to organize and integrate research and educational activities outlined in the proposal (Focus Area 1 – The biophysical ecohydrologic system; Focus Area 2 – The social and engineered system; Focus Area 3 – The coupled human-natural system). This model significantly builds on prior research by iUTAH researchers (Pataki et al. 2011) and is designed to better understand the interconnections between important human and natural components of highly engineered water systems. It is relevant for all major US western cities and has guided the NSF-funded ULTRA Ex project in the Los Angeles area (D. Pataki, co-PI). In iUTAH, we have expanded upon this model to a) more explicitly incorporate critical aspects of water management at scales from individuals and households to institutions; b) integrate land use transitions and the role of urban form in influencing each component of the water system; and c) explicitly consider processes and mechanisms that determine water yields in the mountain source water regions of the study area.

The iUTAH conceptual model highlights the key features of the regional coupled human-natural water systems (Figure 1) and recognizes that most hydrologic and ecological processes in western US cities are highly altered by humans. Indeed, water budgets, vegetative patterns, and ecological communities in urban settings all reflect the direct and cumulative impacts of human water management, though they are also structured by local and regional biophysical conditions, such as climate, hydrology, and topography. Human water management includes a) a legacy of **built water infrastructure** that is used to transport water to, within, and out of urbanized landscapes, b) **institutional arrangements** that specify property rights, rules for water use, and affect market prices that guide water use decision-making, and c) **water use behaviors** by both organizations (e.g., cities, water conservancy districts, and irrigation companies) and individual actors that generate patterns of actual water use across space and time. Because these systems are highly engineered, there has been an implicit assumption that human aspect of the water system and the water budgets of urban areas are well quantified. However, this is not the case. Therefore, we propose to collect systematic data to be able to characterize human water management, water budgets, and other ecohydrologic conditions across our study watersheds (Table 1).

Our model recognizes that urban ecohydrologic processes directly influence and generate distinctive types and amounts of regulating, provisioning and cultural ecosystems services (Millennium Ecosystem Assessment, 2005), and these must be explicitly quantified including their linkages. We have structured our data collection and modeling activities (Focus Area 1) to translate biophysical processes into specific ecosystem services such as shading, cooling, stormwater mitigation, aesthetics, and other cultural services. We will gather primary data from diverse water users, managers, and stakeholders to better understand the ways that outputs from the WRMA coupled socio-ecohydrologic system are valued differently by various societal interest groups (Focus Area 2). These outcomes structure societal discussions and frame the specific configurations of recommended best management practices (BMPs) that will be used to advance sustainable water management (Focus Area 3). Our conceptual model also recognizes the critical role played by land-use transitions and patterns of urban development in mediating the four core components of this coupled human-natural water system. This is discussed further in response #4 below.

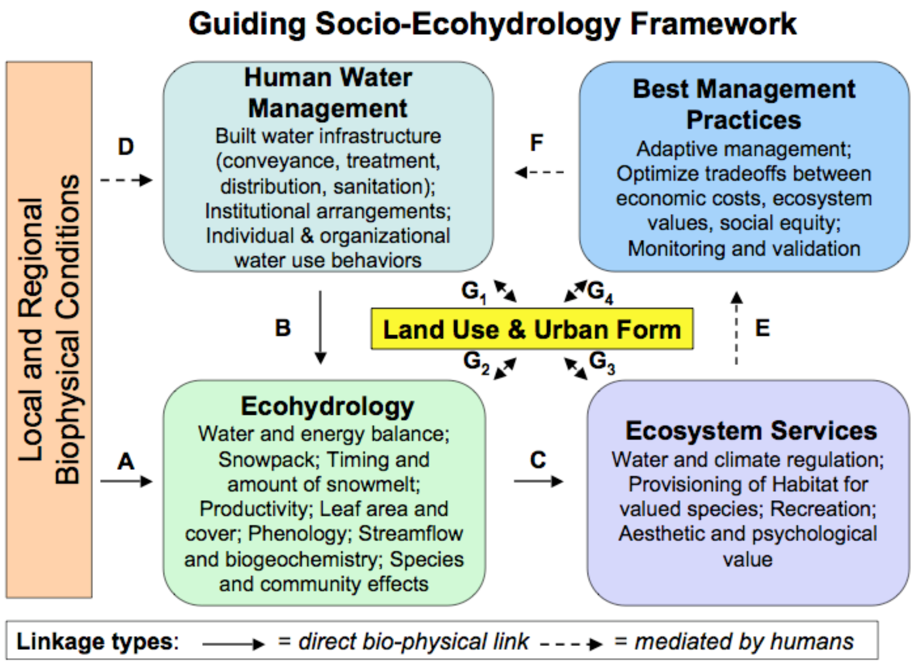

Figure 1. A theoretical framework for iUTAH. Variables, processes and exemplary data sets are listed within the core components. **Box 1** describes linkages among the iUTAH components. Relationships between core data sets and the linkages are provided in **Table 1** (page 4).

Box 1: Linkages within the iUTAH theoretical framework:

A: Topography, geology, soils, and climate directly impact form/function of ecohydrologic processes.
B: Human water infrastructure, institutional arrangements, and behaviors directly affect water and energy flows in both montane and settled areas. These effects are mediated by biophysical constraints.
C: Ecohydrologic processes generate distinct patterns of ecosystem services.
D: Water management decisions respond to short- and long-term changes in biophysical conditions.
E: Desired ecosystem services are determined by societal values; best management practices (BMPs) enhance and maximize ecosystem services.
F: Acceptance and implementation of BMPs is a long-term process involving politics, negotiation, and learning
G: Land use, land cover and urban development are dynamically linked to all core elements.

- **G1**: Legacies of built water infrastructure and established institutional arrangements impact patterns of urbanization; land use transitions alter water management.
- **G2**: Ecohydrologic processes facilitate and constrain land use; land use change impacts ecohydrology.
- **G3**: Ecosystem services provided by ecohydrological processes are influenced by forms of development; actual and perceived ecosystem services inform current and future patterns of land use change.
- **G4**: Sustainable water management BMPs are closely tied to specific patterns of land use and urban form.

Measurements (Table 1) and data analyses across our study watersheds will allow evaluations, support modeling, and provide a basis for decision making. By encompassing highly urban areas, rapidly growing suburban neighborhoods, transitioning agricultural landscapes, and wildland water source regions, we have an opportunity to understand the dynamics of an urbanizing water system and the transition of western private lands from public lands and traditional irrigated agricultural uses into exurban, suburban and urban residential settlements.

1b**. Provide a detailed theoretical/conceptual framework for the proposed research, including a discussion of how data collection will support modeling and decision-making.* ***Clarify how this framework will contribute to the research team's efforts to address the three research focus areas

Within the conceptual framework presented in Figure 1, we have listed exemplary data sets that will be collected to address each of the components and linkages of the framework. Table 1 demonstrates how the data sets we plan to collect will specifically address the research questions posed within each Focus Area. Focus Area 1 will instrument 3 watersheds of mixed land use and cover to measure hydrologic, ecological, and biogeochemical parameters (Figure 1 - Ecohydrology). Focus Area 2 will conduct surveys, focus groups, interviews and analysis of secondary data to identify drivers and processes of decision-making related to the local water system. This research will characterize farm and household water use, environmental perceptions, built water infrastructure and pricing, and the role of institutional contexts (e.g., water law and land use policy). Focus Area 3 integrates knowledge gained in Focus Areas 1 and 2 to translate our results into a quantitative understanding of water mediated services, benefits of ecohydrologic processes to society, and best management practices that will enhance and sustain these benefits. In this way, we will integrate the more disciplinary understanding of ecohydrology and decision-making gained in Focus Areas 1 and 2 into an interdisciplinary, quantitative framework for studying dynamics of the coupled human-natural system. Further information about the modeling platform and linkages among component analytical models is given in response #2 below.

***2. Identify and clarify the degree of coupling and feedbacks** between the different models. If coupling is anticipated, please identify potential difficulties and challenges.*

Focus Area 1 and 2 activities will quantitatively model individual water system components while Focus Area 3 activities will couple and model feedbacks among system components (Table 1). Coupling will be both difficult and challenging because the component models are currently standalone, separate products. They use different data inputs with different spatial and temporal resolutions. Outputs from one model do not correspond to inputs required for a subsequent model. Some model features may duplicate features in other models while other features are missing. Further, models are implemented in different software environments that do not allow exchanges of input data or outputs among models. And finally, we must organize model execution both in parallel and series to efficiently run the coupled models.

To overcome these difficulties, we will identify, extract, and couple key local biophysical, ecohydrology, ecosystem service, human water management, and best management practice elements from existing scientific models to build an integrated socio-ecohydrologic model. Coupling will occur in three stages. First, we will ensure all modeling components are built using compatible spatial and temporally explicit data from the integrated digital water system database. We will ensure compatibility by bringing together faculty from disparate disciplines to develop common data and metadata standards and building a Cyberinfrastructure facility to warehouse Task 1 and Task 2 raw and derived data using agreed-upon standards. Second, we will program an Open Modeling Interface (OpenMI) for each model component to allow the model components and their elements to exchange data and results. OpenMI is a model interface standard that allows models to exchange information with otherwise independent environmental models on a time-step by time-step basis as they run. OpenMI can interface both new and legacy models and is well suited for our purposes. Third, the integration team will use tools like the OpenMI Configuration Editor and other component-based modeling systems (Syvitski et al. 2004) to link model components, execute them, and evaluate system behavior and scenarios identified with our stakeholders.

This coupling will occur across many aspects of the water system and enables our team to assist Utah stakeholders with analyzing impacts on human and environmental water management from climate and population density changes. Modeled feedbacks to ecohydrology, biophysiology, land uses, and ecosystem services can be used to inform and update BMPs with changing conditions. As a specific example of the outcomes of modeling activities, coupled models will enable the integration team to overlay land use transitions and anticipated climate changes with water management decisions and urban ecohydrology models to better understand water variability (flooding and drought) in suburban, urban, and rural neighborhoods. Future development and land use transitions will change water use behavior and institutional water agreements. Coupling will allow us to simultaneously combine the data needed to run the models, link models to our data collection and observational systems, and launch scenario analyses to identify and predict the effects of climate, market, policy, and other system changes.

Table 1. Linking data collection activities to research questions and the conceptual framework.

Focus Area/ Research Question	**Required Data**	**Key Linkages**	**Potential modeling Packages**
1. Ecohydrology			
What are the water and energy balance of WRMA forested, urban, exurban, and agricultural land areas?	Precipitation, meteorology Soil moisture, snow depth CO2 and H2O fluxes Leaf area, productivity, and land cover Phenology, timing of snowmelt Streamflow, runoff, groundwater depth	A, B, C, G_2, G_3, F	CGMs; snow melt runoff; stream flow; SLTL; WRF; PIHM; RHEESYS; PARFLOW
What determines the quality of surface and groundwater resources?	Land use and land cover Soil and water biogeochemistry (solutes, turbidity, dissolved oxygen) Precipitation, meteorology Built water and green infrastructure	A, B, C, G_2, G_3, F	SWAT; PHABSIM
2. Social and Engineered System			
What are regional drivers of water and land use management?	Key informant interviews with local, state and regional water managers State and national laws and policies; regional economic data on land, housing, water markets Census data at neighborhood scale Household survey data of management objectives, knowledge, perceptions, resources and constraints Household and neighborhood water use records Parcel and neighborhood land use transactions	D, G_1-G_4, B, F	Regression Models; CA Models; ABMs
How do urban form and water availability interact?	Surface energy and water balance Turbulence, convective mixing Leaf area, evapotranspiration, and land cover Stream flow, storm water runoff, recharge Built water infrastructure Urban form measurements (road density, lot size, landscaping/vegetation, etc.)	B, G_1, G_2	SWAT; PARFLOW; Hydro-economic
How can we design built systems to enhance sustainability?	Experimental bioswales, green roofs, rain gardens Irrigation system efficiency improvements Household survey data of aesthetics, psychological value, recreational uses Focus groups, stakeholder workshops Economic data	E, F, G_1-G_4	Contingent Valuation; Hydro-economic; Optimization models; Urban Metabolism Model
3. Coupled Human-Natural System			
How can we couple models to exchange inputs and outputs?	Task 1 and 2 data inputs and model outputs Spatial-temporal referenced data repositories for Task 1 and 2 data inputs and outputs	A, B, C, D, E, F, G_1-G_4	Data model; Open MI
How can the coupled system cope with water resource changes?	Spatial-temporal referenced data repositories for Task 1 and 2 data inputs and outputs	A, B, C, D, G_1, G_3	GCM; Rainfall runoff; Hydro-economic; ABM; Open MI
How can we present and visualize model and data products to enhance learning, communication, and experimentation?	Spatial-temporal referenced data repositories for Task 1 and 2 data inputs and outputs	E, G_4, F	Urban Metabolism model

3. Provide more background on the likely future water scenario for Utah.

Likely future water scenarios for Utah. Future water resource availability in Utah, and the Intermountain West region more generally, is driven by human population growth and decisions to use water for specific purposes (e.g., agriculture), as well as by hydrologic responses to climate change/climate variability. Statewide, Utah receives an average of 13 inches of precipitation annually. The principal basins of the Wasatch Range metro area receive considerably more (22-26 inches/year) with the majority of this as snow (UT DWR 2001). Despite greater precipitation inputs to the WRMA, in-basin water resources are not sufficient to meet current municipal, industrial, and agricultural demand (Figure 2, US Bureau of Reclamation, 2005, so water is imported to the WRMA from the upper Colorado River basin via the Central Utah Project. At the same time, municipal and industrial use in these basins is projected to at least double by 2050 (UT DWR 2001).

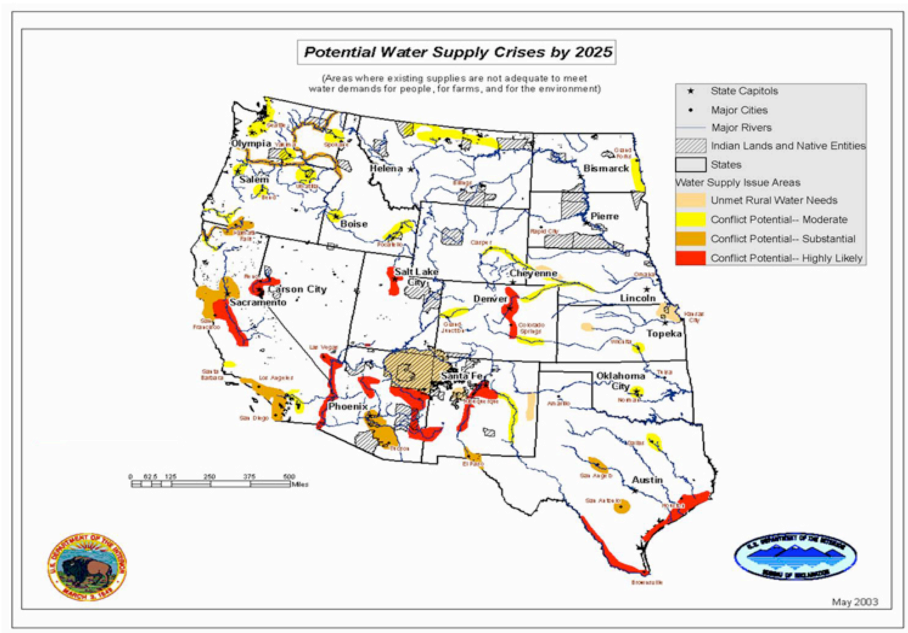

Figure 2. Areas where existing water supplies are not adequate to meet water demands for people, for farms, and for the environment. (United States Bureau of Reclamation, 2005). The WRMA is shown near the center of the figure in red, indicating **highly likely** water supply crises in the near future.

In response to requirements of the SECURE water act, the United States Bureau of Reclamation (2011) has issued a report examining climate change projections from downscaled climate models. Projections include: a) temperature increases of 5-7 degrees Fahrenheit with a "bulls eye" over Utah; b) a precipitation increase over the northwestern and north-central portions of the western United States and a decrease over the southwestern and south-central areas; c) a decrease for almost all of the April 1st snowpack, a standard benchmark measurement used to project river basin runoff; and d) an 8 to 20 percent decrease in average annual stream flow in several river basins, including the Colorado which drains much of Utah. Projected changes in temperature and precipitation are likely to impact the timing and quantity of stream flows in all western basins, which could impact water available to farms and cities, hydropower generation, fish and wildlife, and other uses such as recreation.

There is also extensive scientific literature on the changing climate and water cycle of the Western US. (e.g. Luce and Holden, 2009; Das et al., 2009; Barnett et al., 2008; Gangopadhyay and Pruitt, 2011). Precipitation and streamflow show high interannual variability in the western US, influenced by both the El Nino Southern Oscillation and Pacific Decadal Oscillation (WSTB 2007, Mohammad and Tarboton 2011). The Great Basin has warmed at least 1.5F since the 1950s – the most substantial warming of the lower 48 states (WTSB 2007). Global circulation models predict climate warming to continue for the region over the next 40 years. Model forecasts with temperature increases alone predict decreased stream flow regionally (e.g. McCabe and Wolock et al. 2007). A recent study showed a decreasing trend in precipitation accumulation over much of the Intermountain West (Miller and Pechota 2011). Hydrologic implications of warming include possible earlier snowmelt, greater evaporation/ablation, and less runoff (WSTB 2007). For example, a 26-year analysis of SNOTEL sites in the Great Salt Lake Basin showed the date of peak snow water equivalent has increased by about 15 days (Bedford and Douglass 2008). Many SNOTEL stations in the western US show a similar trend (Miller and Pechota 2011).

Flooding is also a potential hazard regionally. Extreme floods in the Unita Range of northeastern Utah have become more frequent since 1960, with the largest flood events associated with cool spring temperatures that preserve maximum snowpack (Carson 2007). Similarly the Blacksmith Fork River in Cache Valley shows variations in snowmelt floods associated with ENSO and PDO, which have cooler spring temperatures regionally (Jain and Lall 2000). Human modification in our study basins include dams and diversions to protect both human settlements and agriculture from flooding hazards – for example, over half the annual flow of the lower Provo-Jordan is diverted to a "Surplus" canal to avoid flooding in downtown Salt Lake City.

This project will address and contribute to a better understanding of all aspects of water resources, including shortages of supply during drought, flooding, environmental demands, ecological considerations and conservation. We note that we do not include direct data collection in the Great Salt Lake. While the lake effects are clearly incorporated into our regional climate models, the lake is too large to adequately instrument within the confines of this project. Further, because the lake is a terminal, hypersaline lake it has little direct influence on freshwater availability.

4. *Explain if the project will engage in* ***description/forecasting of land use transitions.***

Land use change analysis is an important component of our proposed work. As noted above, our overarching conceptual framework recognizes the central role of land use change in mediating the development and processes of urban socio-ecohydrologic systems. The WRMA is one of the most rapidly growing regions of the United States, and different patterns of residential settlement at the neighborhood level – or *urban forms* – are associated with distinctive ecohydrologic outcomes. As the population in this region expands, we expect the continuation and acceleration of recent processes of land conversion. The WRMA study area provides an ideal location to explore the distinctive dynamics of land use change at different points along the urbanization gradient. For instance, the Bear River watershed study area is well suited to inform modeling of exurban land use change as farmland is converted into low density/land-use intensity urban development. In contrast, the SLC/Red Butte watershed study area lends itself to modeling redevelopment because the buildable land supply is very nearly built-out at moderately high urban density/land-use intensity. The Provo watershed study area lends itself to modeling processes of infill and redevelopment of moderately low suburban density/land-use intensity. Our study sites were selected because they represent a continuum of stages of urbanization with a variety of urban form configurations.

Our proposed research activities will involve describing and forecasting land use transitions in the WRMA at two distinct scales. **First, we will describe current patterns and project future changes in land use across the full reach of the WRMA.** We will utilize existing data from government records and remote sensing imagery to better characterize the current mosaic of land use and urban forms, and to document recent land use trajectories and patterns of residential settlement across the WRMA. **Jackson-Smith, Sims, Yin, Nelson, Yang, and Endter-Wada** all have spatially-explicit land use datasets based on previous research in the region that will be compiled into a single regional land use change data archive. These data include digital land records from larger municipalities, unique parcel-scale records compiled every few years by the state for water-related land use on all private lands (UDWR 2011) and land cover data collected by the Southwest GAP Analysis project (USU-RSGIS 2011). This land use database will enable us to select representative neighborhood areas within each study site for more intensive research and monitoring.

Yin, Sims, Nelson, and Jackson-Smith will combine data on recent land use changes from this database with information about socio-demographic and landscape characteristics, land markets, and local policy context to develop multivariate models to explain variation in recent land use patterns and the likelihood of future urban development of private agricultural parcels across the study region (Irwin and Bockstael 2002; Muller et al. 2002; Nelson 2004; Radeloff et al. 2005; Theobald 2005; Veldkamp and Lambin 2001). Based on prior research by iUTAH researchers, we will use a hybrid land use change model that integrates logistic regression techniques (Landis and Zhang 1998; Muller and Yin 2001; Carrion-Flores and Irwin 2004) and the cellular automata (CA) approach (Batty and Xie 1997, Clark and Gaydos 1998; Muller and Yin 2010) to simulate land use change (Muller et al. 2008; Yin 2010; Yin and Muller 2007). Regression models capture the logic of land transaction and development decisions by statistically evaluating influences on land conversion between two historical points while accounting for spatial heterogeneity and autocorrelation (Schnier and Felthoven 2011). Spatial allocations will be established based on a land use conversion model built on 1 ha grid cells with varying suitability for land use change. Four primary groups of independent variables are considered corresponding to the drivers in Figure 3: institutional context; biophysical environment; neighborhood morphology; and accessibility. A logit regression is used to estimate the probability that housing development of different types will occur in a specific land unit (Muller and Yin 2001, 2010).

Second, **more fine-grained analyses of drivers and patterns of residential development and land use change will also be conducted at the neighborhood scale**. However, at this scale we will integrate modeling of the simultaneous human decisions that affect both the land use and water management decisions of individuals and organizations. **Yin, Sims, and Jackson-Smith** will develop dynamic agent-based models (ABMs) to simulate the interacting processes that shape land use and water management decisions of individual and organizational human actors in selected urban, suburban and exurban neighborhoods identified from the logistic-CA model. This approach will allow us to characterize the behaviors of different types of agents with different preferences/utilities across the full urbanization gradient present in the WRMA. It also can incorporate interactions between agents, and feedback loops reflecting the impacts of new land use and water policies imposed in response to changes in land use.

The ABM will be parameterized using information from the multivariate analyses of recent land use changes, landscape characteristics, and detailed information on homeowner and organizational objectives and management behaviors derived from our household surveys and interviews with key informants (described below). Behavioral rules for each agent will be defined by a combination of empirical data (Castella et al. 2005; Dia 2002) and optimization (Berger 2001; Ng et al. 2011). **Jackson-Smith** and **Endter-Wada** will collect information about land use change and water use behaviors through surveys, interviews, and observations which will be used by **Sims** and **Yin** in profit/utility optimization models. The ABM will be constructed using the open-source, GIS-compliant Recursive Porous Agent Simulation Toolkit (RePast) ABM software library (Yin and Muller 2007) to represent the temporal and spatial variability of agents. With this library, they will spatially situate agents in the WRMA and tie their decisions to relevant, geo-referenced, social, hydroclimate, and ecological data provided by and delivered to the other model components.

Our landscape-scale regression models and the neighborhood-scale ABM models will inform one another. The logistic-CA and ABM will also incorporate feedback from biophysical models developed to characterize future changes in climate and ecohydrologic conditions. As discussed in the section on couplings and feedbacks above, the land-use and ecohydrologic models can be coupled by the exchange of data using input and output files. For each time step of the simulation, the land-use model simulates land-use changes first and then new water use is estimated wherever residents are located. The land-use model then creates a file with this information that is an input to ecohydrologic models. These models then simulate new outputs (groundwater level, carbon, etc.) in response to the change in land use or other imposed external changes from the other models. Performing a series of land use change simulations in parallel with the hydroclimate and ecological models creates a full socio-ecohydrologic feedback loop which will allow us to show how actors currently make decisions (Finnoff et al. 2005), what their aggregate and unintended effects are (Armsworth et al. 2006), and how they might alter contextual factors such as local policies or information networks to affect outcomes (Dellink et al. 2011).

5. Discuss in more detail the roles for the ***specific social science members and any new social science hires*** *and the* ***perceived weaknesses in the social sciences.***

Social Science Activities. Social science activities will inform the core human components of the coupled human-natural water system model. We have assembled an inclusive and talented team of social scientists from throughout the state. There is also significant room to improve the integration of Utah's current social scientists into EPSCoR-funded water-systems research and EPSCoR will allow us to attract new social scientist expertise to Utah to complement our current areas of strength. We have targeted our first two faculty hires and post-doc cohorts to expand social science capacity and inject more depth and breadth very early in the project. One faculty hire will be an interdisciplinary sociologist with a focus on urban water systems (to complement Jackson-Smith's expertise on the sociology of water behaviors in agriculture, rural and exurban environments). We will also hire a regional landscape geographer with expertise in coupled socio-ecohydrology systems in human-impacted landscapes.

Our social science team members share an interest in quantitative modeling of patterns of land and water use across time and space. Given our diverse disciplinary backgrounds, we are excited to compare the relative importance of social, cultural, economic and policy drivers of both individual and organizational land use and water management behaviors. While writing the original EPSCoR proposal, social scientists on our team developed a conceptual model that characterizes the critical factors and interactions between human actors and between humans and their biophysical context (Figure 3). This model identifies proximate drivers and actors behind water and land use behaviors at the 'neighborhood scale' (described below), but also recognizes the importance of regional institutional arrangements (law, policy, markets). We plan to utilize mixed research methods (interviews, focus groups, surveys, analysis of secondary data, and various types of multivariate modeling) to evaluate a series of specific social science research questions:

- What social, cultural, economic, and law/policy drivers influence urban settlement patterns and patterns of water use? (Figure 3 below)
- How do values, experiences, and scientific information affect perceptions of water availability, quality, and ecosystem services among diverse water-users? (Figure 1, linkages D, E, and F)
- How rapidly do biophysical water systems have to change before water users see a need to adapt to or mitigate hydrologic change? (Figure 1, linkage D)

Elaborated Research Methods & Role of Particular Social Scientists. The proposed project will develop an integrated database regarding land use, water infrastructure, and ecohydrologic conditions at the landscape scale across the entire WRMA. However, more detailed social science data will be collected at the 'neighborhood' scale in strategically selected areas from within each of our three study watersheds. Sampling of neighborhoods will be designed to capture representative examples of distinctive urban forms, and to ensure we have detailed information about built infrastructure, institutional arrangements, and water use behaviors from across the spectrum of urban population densities in the region. We anticipate selecting 3-5 neighborhoods within each study watershed for more intensive research. At least one neighborhood will be selected to represent an example of more progressive or innovative approaches to urban water management in each study area (e.g., areas where 'green infrastructure' has been most widely employed).

Within each selected neighborhood, **Jackson-Smith, Sims, Nelson, Endter-Wada, Bedford and Trentelman** will design and implement random sample household surveys. Household surveys will allow us to better understand the drivers of diverse resource constraints, motivations, and actual water use behaviors for both farm and nonfarm actors across different neighborhood settings (Figure 3). Random sample surveys provide an efficient way to gather data from representative households to parameterize the human aspects of neighborhood and landscape-scale land use and ecohydrologic models. Because our sample frame is geographically concentrated, we can utilize drop-off/pickup survey methods which have yielded much higher response rates than mail or telephone methods (Steele et al. 2001; Allred and Ross-Davis 2011). Selected study neighborhoods will also serve as locations for the intensive collection and modeling of data on (a) the built water infrastructure, (b) parcel- or household-level water consumption, based on available municipal water billing records, and (c) ecohydrologic system conditions.

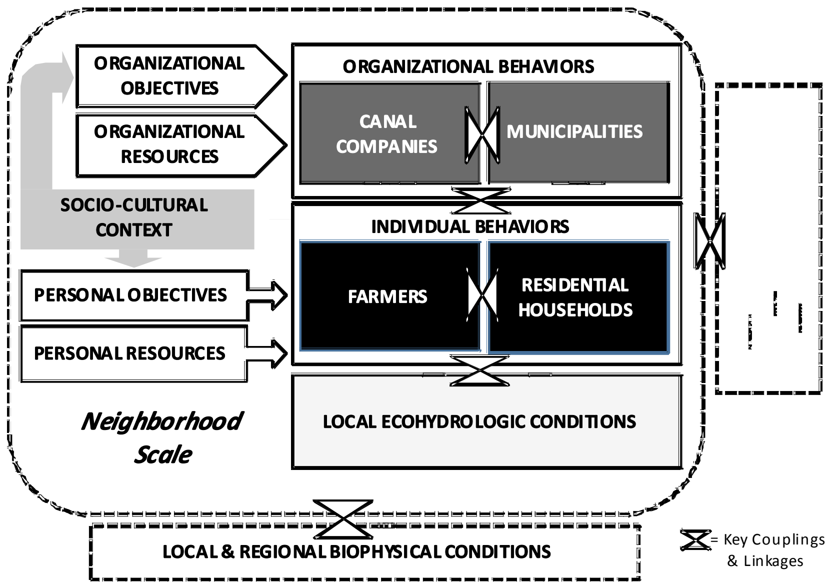

Figure 3: Conceptual Model for Human-Actors in the Socio-Ecohydrologic System

While surveys can be useful in collecting data on individual farmers and homeowners, information about organizational water decision-makers requires a different methodological approach. **Jackson-Smith, Endter-Wada** and others will organize and lead a series of key informant interviews with managers of irrigation companies, water conservancy districts, and municipal water systems within each of the selected neighborhood areas. These semi-structured interviews will explore the decision-making logic, information needs, and perceived drivers and constraints that shape organizational decisions about infrastructure investments, water allocation, and local water pricing policies. We will also probe for details on how key decision-makers respond to perceived changes in water availability and other ecohydrologic system conditions through time.

As noted above, individual and organizational water decisions are always embedded in a larger institutional context. Led by **Endter-Wada, Nelson, Reid, Yang, and Licon**, information about important state and regional laws, policies, and market conditions that shape water and land use decisions will be gathered through collection and analysis of secondary data, published reports, and strategic key informant interviews. This information will both characterize current governance structures and institutions, but also evaluate their ability to respond to future ecohydrologic conditions associated with climate change and changing societal expectations.

Finally, Focus Area 3 activities will employ our research findings to facilitate dialogues among stakeholders and water decision-makers to improve the capacity for adaptive water management in the WRMA (links E and F in Figure 1). This dialogue depends on understanding the tradeoffs between water management, land use, and the quality and quantity of regulating, provisioning, and cultural ecosystem services provided. In a managed ecosystem, it is important to elicit values for each of these services because it is difficult to provide all desired services simultaneously (Barbier et al. 2008; Koch et al. 2009; Raudsepp-Hearne et al. 2010). Diverse methods exist to elicit values for ecosystem services (Brander et al. 2006; Woodward and Wui 2001), and values can vary widely due to numerous natural and economic factors (Camerer 1995; Heimlich et al. 1998; Caplan et al. 2006). We plan to use contingent valuation methods (CVM; Arrow et al. 1993; Mitchell and Carson 1989) to measure willingness-to-pay (WTP) for a small hypothetical increase in an ecosystem service. CV results will be combined with data collected in interviews with water managers to ascertain values for key ecosystem services impacted by water and land use transitions in the WRMA.

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