Nevada Infrastructure for Climate Change Science, Education and Outreach.

NSF EPSCoR RII grant; start date 9/1/08

Project Summary

Nevada seeks to *create a statewide interdisciplinary program that stimulates transformative research, education, and outreach on effects of regional climate change on ecosystem resources and supports use of this knowledge by policy makers.* Six capacity-building components will fill infrastructure gaps in climate modeling; ecological change; water; policy, decision-making, and outreach; cyberinfrastructure; and education. These components will build capacity to model regional climate change, evaluate methods to downscale model output, understand and quantify key ecological and hydrological processes, translate climate change science into formats usable by decision-makers, integrate models and data, and transform how students learn about climate change. In Nevada, a core group of faculty and existing infrastructure are well poised to address regional climate change and its impact on resources, specifically water. Critical existing infrastructure, programs, and faculty include physical and computational resources from past NSF EPSCoR projects; a regional climate center; a community climate and weather monitoring program; graduate programs in hydrology; faculty conducting research in climate; and a history of research into effects of climate change. Diversity strategies are woven throughout the components, and a comprehensive evaluation plan will involve external reviewers. An overarching management structure includes a leadership council, external research and technical advisory board, stakeholder advisory committee, and working groups.

Intellectual merit: Accelerated changes in climate are occurring now in Nevada and will continue into the future, leading to complex changes and feedbacks among climate, biophysical, and human systems. Most efforts to address these issues are directed at the global scale, and understanding of regional impacts and processes is limited. Developing improved understanding of global climate change on a regional scale is imperative since a major scientific challenge is how best to downscale global climate predictions. An integrated approach in which biophysical and human responses to climate change are studied will provide quantitative understanding of feedbacks among water resources, ecosystems, as well as atmospheric and human systems. To achieve an integrated approach, different mechanisms will be pursued to address two broad fundamental scientific questions: *How will climate change affect water resources and linked ecosystem services and human systems?* and *How will climate change affect disturbance regimes and linked systems?* Related questions to be pursued by interdisciplinary teams include identification of forcing factors underlying recent climate changes; feedback mechanisms between climate and vegetation; impact of locally generated aerosols on climate; and effects of change in precipitation type on hydrology. This integrated approach in the unique natural laboratory of the Great Basin has potential to transform climate change studies at regional and sub-regional scales.

Broader impacts: Outreach to diverse stakeholders will be accomplished by identifying important needs in climate change research as well as informing and involving the public in climate change science. Policy makers who need to make prompt and prudent decisions on how to act in the face of these impacts will be supported by scientific findings. A key strategy is to make results available from this enhanced capacity via an accessible, on-line data portal. Nevada has a strong history of involvement in K–12 outreach as well as undergraduate and graduate research. This will continue with summer research programs, academic year scholarships, mentorship programs for graduate students, and a "whole school" approach to broaden participation in K–12 education in which teachers will be trained on climate change science. Recruitment of new faculty and graduate students will target underrepresented groups. Communication of climate change science will be enhanced by use of cyberinfrastructure and involvement of a broad range of students and faculty. A statewide virtual information center for climate change will be created to focus on outreach, and visualization strategies will be employed to communicate findings to the public and policy makers. Partnership with the Nevada Small Business Development Center will assist businesses to address state and federal science and technology needs related to climate change and increase their competitiveness for federal SBIR and STTR grants.

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1.0 STATUS OF NEVADA'S ACADEMIC RESEARCH AND DEVELOPMENT ENTERPRISE

The Nevada System of Higher Education (NSHE) includes three research institutions. The University of Nevada, Las Vegas (UNLV) is an urban land-grant university with more than 28,000 students and \$107M/year in sponsored projects. The University of Nevada, Reno (UNR) is a land-grant institution with close to 16,000 students and \$188M/year in sponsored projects. The Desert Research Institute (DRI) is a soft-money institution with 101 Ph.D. faculty and \$36M/year in sponsored projects.

Nevada has had the fastest growing state population for 19 years in a row – with the exception of 2007 in which it was the second fastest growing state – mostly concentrated in Clark County (Las Vegas) and Washoe County (Reno). Even faster growth has occurred in groups underrepresented in the R&D enterprise. For example, from 2000 to 2005, growth of the Hispanic population, which represents 25% of the total population, was two times the state average; four of ten people now moving to Nevada are Hispanic. Main economic drivers during this period have been the service sector, construction, and an influx of retirees. While the scientific R&D enterprise played a minimal role as an economic driver, the professional and technical services sector has increased since 2001. In the last few years, economic forces have initiated a change with many high-technology companies moving or expanding from California to take advantage of Nevada's favorable business climate and reduced congestion.

Nevada's political, business, and academic leadership views this intellectual emigration from California as an opportunity to diversify the state's economy, while recognizing the need for a better-educated workforce and a stronger R&D enterprise to take advantage of it. A notable response from the state was a 30% increase in appropriations for higher education in 2003. Most of this increase provides full university "Millenium" scholarships for Nevada high school students graduating with GPAs greater than 3.25, encouraging some of the best students to stay in Nevada to attend college. Another key response has been a strong and continuing commitment to foster academic-industry partnerships via regular annual funding of \$2M to match private sources supporting academic research that promotes economic development and diversification in Nevada (statewide Applied Research Initiative).

While these are important indicators of Nevada's commitment to education and academic-industry partnerships, significant challenges remain for Nevada to expand the high-technology component of its economy. For example, data from the NSF Division of Science Resources Statistics show Nevada ranks near the bottom in 25 of the 40 Science and Engineering (S&E) indicators, including research intensity (total R&D funds/gross state product), employment in high technology as a share of total employment, science and engineering degree holders per share of workforce, science and engineering degrees as a share of higher-education degrees, and bachelor degrees conferred per thousand 18-to-20 year olds (National Science Board, 2006). While it is encouraging that large percentages of first-year students in NSHE community colleges and four-year colleges return for their second year, a very small percentage among first-time college students (36% compared to 64% in the top states) complete a bachelor's degree within six years of entering college (National Center for Public Policy and Higher Education, 2006). Also, NSF's Budget Internet Information System shows that Nevada averaged just 0.3 % of total NSF research funding during the last three years, and its NSF proposal success rate (21%) remains below the average of all states (25%), although the gap has narrowed during the last ten years (Fig.1).

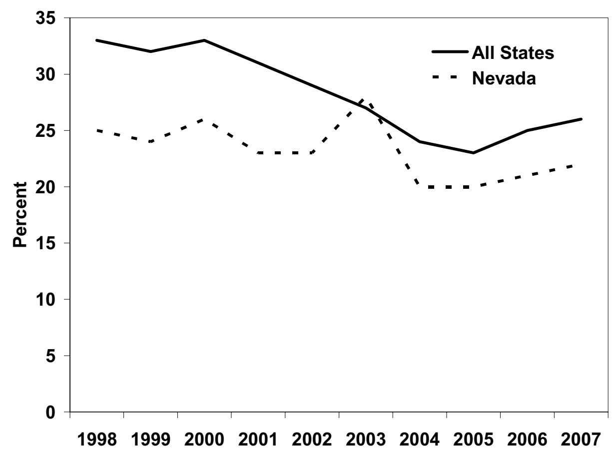

Figure 1. Trends in NSF proposal success rates comparing Nevada to all states, demonstrating the need for additional NSF EPSCoR infrastructure improvement funding in Nevada.

As part of a broader state effort to improve these rankings and provide a solid base for a healthier and more diversified economy, a group of state and community leaders convened in 2007 to form Nevada's first State EPSCoR Advisory Board. The Board was tasked with identifying priority research areas for the state's Science and Technology Plan. These include alternative and renewable energy, climate change, education, human health, technology (including informatics), urban and rural sustainability, and water resources and policy. The Science and Technology Plan examines each of these priority areas with special consideration to the specific challenges facing Nevada, assets available to meet these challenges, goals for how Nevada can increase research capacity of each focal area, and action items to meet these goals. NSF EPSCoR resources are crucial to help Nevada meet the goals set forth in its Science and Technology Plan by expanding the academic R&D enterprise and improving student education in science and technology.

2.0 RESULTS FROM PRIOR NSF EPSCoR SUPPORT

Nevada has been successful in using NSF EPSCoR funding to create major, nationally competitive programs. General measures of this success include Nevada's increase in total NSF awards from $3M in FY91 to $18.2M in FY07, a 600% increase. These improvements are directly related to successes of Nevada's NSF EPSCoR research focal areas in building statewide centers of excellence. Selected highlights from previous awards (EPS 9353227; RING-TRUE I, EPS 9977809; RING-TRUE II, EPS 0132556; and the on-going RING-TRUE III, EPS 0447416) provide prime examples:

- The Nevada Desert Free-Air CO_2 Enrichment (FACE) facility, built by leveraging NSF (including non-renewable grant EPS 9871942) and DOE EPSCoR funding, has been a premier facility for studying biological and ecological responses of plants to global change and the centerpiece for one of the best global-change biology and ecology programs in the U.S. Work under this program has garnered more than $13M in non-EPSCoR grants, including $2M from the Terrestrial Ecology and Global Change program and $3M from NSF's Integrated Research Challenges in Environmental Biology program (led by NSF EPSCoR target faculty).
- Research in chemical physics also leveraged NSF and DOE EPSCoR funds to build a critical mass of faculty and resources in specific areas, including development of the High Pressure Science and Engineering Center at UNLV, the Nevada Terawatt Facility at UNR, and a strong Nevada presence at two of the premier U.S. x-ray synchrotron-radiation sources (run by DOE). Altogether, chemical-physics programs in Nevada have received more than $27M in competitive grants since graduating from EPSCoR.
- The genomics strategy was to build a world-class facility and use it to attract faculty to create a nationally competitive program. By the end of the grant period, the UNR genomics facility was self-supporting with more than $300K in annual income from users. It also attracted several new faculty who together garnered competitive grants of $21M during a three-year period, compared to essentially no funding prior to NSF EPSCoR support. These grants included major awards from NSF's Plant Genome program and 2010 Project.
- The interface materials science program focused primarily on developing state-of-the-art instrumentation. This investment led directly to more than $6.5M in new grants in the first three years and was a linchpin in a larger statewide effort to bring Nevada to a level of national competitiveness in materials research. New faculty with expertise in this area were critical to the overall effort, which has now achieved annual competitive funding of more than $10M.
- Integrated approaches to abiotic stress (IAAS), which relies on the RING-TRUE I genomics facility, garnered more than $44M in competitive research funding since 2002, roughly three times baseline funding measured in 2001. IAAS-affiliated faculty published more than 170 peer-reviewed papers since 2002.
- Advanced computing in environmental sciences (ACES) established a new computational and communications grid based on a dispersed Access Grid which has facilitated environmental computing applications and communication within Nevada. The impact of this new technology

led to proliferation of Access Grid nodes around the state. ACES is now being used by faculty for teaching courses, meetings, and extensively in RII proposal development.

- The arid soils program has built a unique facility featuring large-scale weighing lysimeters to investigate hydrological and biological processes in arid soils (and will be leveraged by the work proposed here). This resource is bridging the gap in spatial scale between two existing Nevada facilities developed with NSF EPSCoR funding (Nevada Desert FACE and DRI's EcoCELL project). With the bulk of the facility completed at the end of the second year, faculty and students have begun research funded by competitive NSF EPSCoR seed grants.

Hires specifically targeted in RING-TRUE II more than doubled the proportion of science and engineering faculty from underrepresented groups at state research institutions. Underrepresented faculty hires were specifically targeted by the NSF EPSCoR-supported Increasing Diversity in Science in Nevada (IDIN) initiative, which doubled the proportion of science and engineering faculty from underrepresented groups in NSHE research institutions. IDIN also enhanced math and science college preparatory work by underrepresented and underprivileged middle school and high school students in Nevada. Nevada's RING-TRUE III project is increasing outreach and diversity through its undergraduate research program, which has awarded 295 undergraduate research grants; its middle-school programs providing personalized instruction to students from underrepresented groups or underprivileged backgrounds; its high school programs helping 16 students from underrepresented groups navigate the transition from high school to college; and five new faculty hires from underrepresented groups with supplemental startup.

Overall spending on higher education in Nevada has increased by more than 90%, close to $400M, since 2000 with an annual average increase of about 10%. In addition, NSF EPSCoR has enhanced NSHE partnerships between Nevada and private entities. For instance, Nevada has consistently supported the Applied Research Initiative during the past decade. By partnering with the Nevada Small Business Development Center, a small annual NSF EPSCoR investment in Nevada's SBIR program has helped 18 companies obtain SBIR Phase I or II awards since 2004.

3.0 OVERALL STRATEGY TO IMPROVE NEVADA'S R&D COMPETITIVENESS

Although Nevada's success with NSF EPSCoR funds has been significant, more needs to be done to develop research infrastructure necessary to advance the R&D enterprise, science education, and economic diversification in critical new areas. Nevada's Science and Technology Plan provides guidance in identifying which research areas are critical to Nevada. In addition, we took guidance from a review of Nevada's EPSCoR programs by the American Association for the Advancement of Science (AAAS). In particular, four criteria identified by AAAS for selecting focal areas to be included in NSF EPSCoR proposals have been adopted and used by Nevada ever since: (1) areas of relevance to NSF in which Nevada already has significant *strength*; (2) areas of *uniqueness* that take advantage of Nevada's specific circumstances or constitute a well-defined niche; (3) areas related to new government or private *funding opportunities*; and (4) areas *consistent with strategic plans* of DRI, UNLV, and UNR.

In addition to responding to the Science and Technology Plan and general guidance by AAAS, NSHE's planning process for selecting new research areas is multi-faceted. It starts with bottom-up planning to ensure faculty commitment to new initiatives. Following AAAS guidance, the NSF EPSCoR Project Director issued a statewide call for infrastructure-improvement ideas in fall 2006. All of the 60 submitted ideas were made available to Nevada faculty on the NSF EPSCoR Web site; interested faculty were encouraged to form statewide collaborative groups with common goals based on these ideas. This process resulted in 40 infrastructure-improvement pre-proposals, which were reviewed by an external panel using AAAS-defined criteria. The panel included five researchers from outside Nevada – three of whom have led successful NSF EPSCoR state programs. The other two researchers were from targeted disciplines represented in the pool of pre-proposals. The Nevada EPSCoR Committee reviewed the proposals and recommendations from the external panel. After considering state and institutional objectives, including priorities set forth in the State Science and Technology Plan, the Nevada EPSCoR

Committee selected one research theme, climate change, which encompassed five of the pre-proposals. In making this selection, emphasis was placed on (1) combining existing research capacity to add value to the R&D enterprise; (2) establishing unique positions in focused research fields; (3) selecting a focal area with a high probability of operating independently of NSF EPSCoR after three – five years; (4) alignment with state and institutional research and economic development goals; and (5) potential for inter-institutional and interdisciplinary collaborations. This approach has served Nevada well in previous NSF-EPSCoR-funded programs.

The proposed climate change research focus is in perfect alignment with Nevada's State Science and Technology Plan which lists climate change as a priority area of research for the state. Other targeted areas in the Plan – water resources and policy, informatics, education – also are prominent components of the climate change theme presented in this proposal. Focusing on improving its competitiveness in climate change science comes at an opportune time for Nevada, which is just "waking up" to the potential ramifications of climate change for the state. In April 2007, Nevada's Governor Gibbons created a Climate Change Advisory Committee with the primary goal of making recommendations on reducing Nevada's greenhouse gas emissions. In February 2007, Nevada joined as an official observer of the Western Climate Initiative, which formed to enable Western states to collaborate in identifying, evaluating, and implementing ways to reduce greenhouse gas emissions and achieve co-benefits.

The climate change focus also builds on success and knowledge gained from previous NSF-EPSCoR funded research infrastructure improvements including specific areas of climate change research: global change biology (Nevada's first NSF EPSCoR award), advanced computing in environmental sciences (RING-TRUE II), bioinformatics (RING-TRUE I and III), scaling environmental processes in heterogeneous arid soils (RING-TRUE III), and undergraduate research (RING-TRUE III).

Three common barriers to research competitiveness intrinsic to Nevada's research capacity have been identified. The first results from researchers being spread among three relatively small and geographically separated institutions. The statewide process to develop this proposal led many researchers to identify potential synergistic relationships. The second barrier is gaps in faculty expertise that prevent Nevada from developing nationally competitive research teams. The third barrier is a lack of appropriate equipment and infrastructure. NSF EPSCoR resources will provide research instrumentation and infrastructure to help Nevada faculty reach their full potential in these areas.

NSF EPSCoR resources will provide immediate and obvious incentives for faculty to collaborate and assure that synergistic relationships move from discussion to real programs; help recruit new faculty to fill critical gaps so Nevada can form complete, well-bonded, nationally competitive research teams; and accelerate Nevada's efforts to increase student and faculty diversity and enhance involvement of undergraduate students in research.

4. PROPOSED INFRASTRUCTURE IMPROVEMENTS

Background and vision: An increasing body of evidence is accumulating to indicate that human activities have a profound influence on climate and already have resulted in unprecedented and very rapid climate change (e.g., regional and global temperature increases [IPCC, 2007]). These activities are predicted to continue into the future, and associated effects may become increasingly severe (IPCC, 2007). Arid regions, including Nevada, comprise 40% of the world's land surface and are home to one-third of the world's population (Ezcurra, 2006). These regions are especially vulnerable to climate change because of dependence on water resources, which are subject to increasing stress as a result of rapid urbanization (Field et al., 2007).

Developing improved understanding of impacts of global climate change on a local or regional scale is imperative for regions such as the Great Basin, which includes most of Nevada, and is considered one of the most endangered ecoregions in the U.S. (Chambers et al., 2006) as a result of numerous interacting factors including climate change, urbanization, changing land use, limited water resources, altered fire regimes, invasive species, insects, and plant disease. Close linkages that exist between stressors and their importance for land management and public policy highlight the need for an integrated approach in which biophysical and human responses to climate change are studied by interdisciplinary research groups.

Impacts from climate change are typically evaluated by downscaling Global Climate Models (GCMs) that have a resolution of several hundred kilometers. This is not sufficient to represent the complex terrain of the western U.S. and is too coarse for modeling basin-scale ecohydrology changes (Giorgi and Mearns, 1991; Leung et al., 2006). Statistical downscaling of GCMs has provided some valuable information for making basin-scale assessments (e.g., Maurer et al., 2007); however, there is a need to also develop dynamical regional-scale models that facilitate a better understanding of land-atmosphere processes that drive basin-scale climate change. This also requires good observational data (e.g., temperature, precipitation, humidity, wind speed, solar radiation) to calibrate and verify regional climate models and others that are used for basin-scale assessments (e.g., hydrologic, ecological, water demand). An integrated approach that includes observational and modeling activities is necessary to make robost assessments of climate change impacts.

Land and water managers, the public, and elected officials pleading for "actionable intelligence" have turned to the scientific community within the Nevada System of Higher Education (NSHE) for insights and advice on effects of climate change and variability. NSHE has a core group of faculty and existing infrastructure well positioned to address many aspects of climate change. Interdisciplinary scientific approaches and filling of key infrastructure gaps, however, are needed to fully address fundamental scientific questions (see integration section below) as well as meet the needs of decision-makers and the public. This has the added benefit of training future citizens of Nevada to be leaders in addressing challenges of climate change.

Our vision is to create a statewide interdisciplinary program and virtual climate change center that will stimulate transformative research, education, and outreach on the effects of regional climate change on ecosystem resources (especially water) and support use of this knowledge by policy makers and stakeholders.

Nevada and the Great Basin: The Great Basin is characterized by basin and range topography, arid to semiarid climate, and a history of sensitivity to climate change. The great range of relief in Nevada gives rise to vertical zonation of ecosystems ranging from semiarid to arid desert scrub and steppe in the valleys to montane forests at the highest mountain elevations. Mountain areas comprise about 10% of the landscape, yet are the areas of highest precipitation and generate 85% of groundwater recharge and most surface runoff. By contrast, internally drained valleys contain playas which are sources of mineral dust and deep alluvial aquifers, which may discharge via springs, wetlands, and phreatophytic vegetation. Evidence from a variety of sources indicates that the Great Basin is sensitive to climate change on millennial and centennial scales and has experienced climates both wetter and drier than today during the past 20,000 to 30,000 years and more (e.g., Sharpe, 2007). These characteristics make Nevada a "canary in the mine" and provide an ideal natural laboratory to study effects of climate change.

Nevada is both the driest (mean annual precipitation of 279 mm or 10.98 inches) and most urbanized state in the nation (88% of its population in urban centers [Kaiser, 2006]). Some of the most rapidly growing urban areas in the nation (i.e., Las Vegas, Reno) contrast with extensive, sparsely populated, rural areas of the state. Rapid growth is stressing the region's limited water resources, increasing fire and wildlife problems at the wildland-urban interface, and adding recreational pressure on the region's wildlands. Urban populations are dependent on water supplies from adjacent mountain catchments or, in the case of Las Vegas, from the Colorado River. Increasingly, cities are turning to groundwater resources located in rural areas to satisfy future water demands.

Current climate change strengths in NSHE: One key to success is utilizing and engaging expertise and resources that NSHE has developed for climate change research. A core group of NSHE faculty has expertise in climate change dynamics; ecosystem dynamics and characterization; policy analysis; climate monitoring; modeling; hydrologic analysis and modeling; engineering analysis of water systems; water resource modeling; and software development. We will utilize existing facilities (e.g., Frits Went Laboratory, Mojave Global Change Facility) including some developed with prior support from NSF EPSCoR (e.g., Advanced Computing in Environmental Sciences, Large Lysimeter Facility, Storm Peak Laboratory). We also will add faculty in select areas where expertise is lacking. Expertise also will be added via recruitment of post-doctoral fellows, some of whom may go on to become faculty members. Technical expertise will be added in key areas.

Scientific and societal priorities: Regionally, temperatures have increased significantly during the past 30 years (Fig. 2), leading to multiple effects (Cayan et al., 2001; McCabe and Wolock, 2007; Westerling et al., 2006). This drier and warmer climate pattern could be a precursor to what the region will experience in the future (Fig. 3), but improved measurements, modeling, and experiments are necessary to form a clearer picture of the direction and magnitude of climate change and its effects. Recently, the Intergovernmental Panel on Climate Change (IPCC) noted that in the U.S. there would be stresses on water systems, more heat waves, and increased forest fires in the coming decades with the Southwest experiencing the largest temperature increases in the lower 48 states (IPCC, 2007). Modeling of future change suggests that the region will be drier, with important implications for water resources (Dettinger and Earman, 2007; Seager et al., 2007): droughts similar to those in the 1930s and 1950s could become the norm and water supplies from the Colorado River, a major water source for southern Nevada, could be reduced by 10–20% (e.g., Christensen and Lettenmaier, 2004; NRC, 2007; McCabe and Wolock, 2007). Increases in winter and spring temperatures have resulted in earlier spring snow melt throughout the Sierra Nevada and reduced dry-season flows (e.g., Knowles et al., 2006). Future temperature changes are projected to lead to an increase in the proportion of winter precipitation falling as rain, resulting in greater winter runoff and a decrease in the snowpack (Dettinger, 2005), upon which much of the region depends for water supply and support of riparian ecosystems.

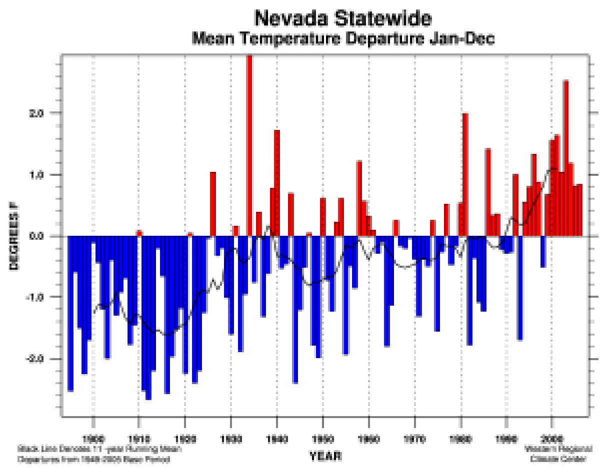

Figure 2: Nevada statewide average temperature from 1896 to 2006. (Source: Western Regional Climate Center).

As ongoing and future climate change and variability affect the Great Basin, complex and poorly understood changes and feedbacks between climate and biophysical systems (e.g., vegetation change leading to increased fire frequency) are likely to affect ecosystems and their ability to provide needed resources. These effects are compounded by Nevada's rapidly growing urban population. Research needs include (1) improved knowledge of past and present climate variability to provide a baseline against which to evaluate future changes; (2) modeling and visualization of interacting effects of climate change and ecosystem resources; (3) observations of regional climate, ecosystems, and hydrology to provide data to calibrate models, understand responses, and detect change; and (4) development of management tools (CIRMOUNT, 2006; Chambers et al., 2006; GAO, 2007; NAS, 2007.).

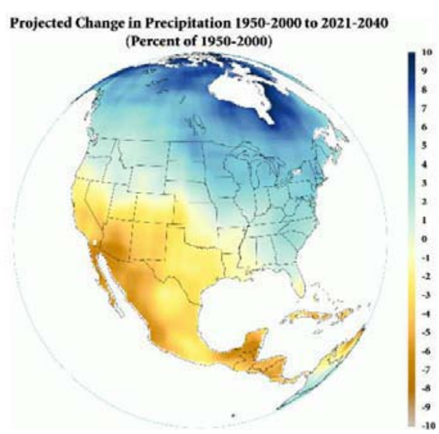

Figure 3: North American projected changes in precipitation for the period 2021–2040. (Source: Seager et al., 2007).

Developing infrastructure for providing a scientific basis for environmental management in the state will enable NSHE faculty to use the Great Basin to address fundamental scientific questions about effects of climate change, integrate across disciplines (Moore et al., 2001), bridge the gap between science and decision-making (National Research Council, 2007), and address key priorities in the state's Science and Technology Plan. Questions include identification of large-scale forcing factors that underlie recent changes in temperatures; understanding feedback mechanisms between regional climate and vegetation change; understanding effects of climate change on disturbance regimes, assessing effects of locally generated aerosols on regional climate; and understanding effects of change in precipitation type on hydrologic processes.

STRATEGIES FOR INFRASTRUCTURE BUILDING

Infrastructure building needs and strategies: Nevada's existing infrastructure (some from past NSF EPSCoR awards) and expertise position the state to be competitive in climate change science after several key infrastructure needs are filled. Needs include (1) enhanced ability to measure, analyze, and model regional climate change and its effects; (2) addition of faculty who will provide needed expertise, ability to form interdisciplinary teams, and contribute to educational programs; (3) addition of cyberinfrastructure that will faciliate interdisciplinary research; (4) enhanced ability to communicate scientific information for improved decision-making; (5) mechanisms for recruiting and retaining high quality graduate students; and (6) climate change curricula for students at all levels. Modeling and visualization address the need to assess effects of future changes and extrapolate results of observational networks to different scales, facilitate integration, and communicate results to decision-makers and stakeholders. Six major strategies are proposed to address infrastructure needs and attain our vision:

1) Develop a capability to model climate change at a regional and sub-regional scale and its effects to evaluate different future scenarios and strategies (**Climate Modeling Component**)
2) Develop data collection, modeling, and visualization infrastructure to determine and analyze effects on ecosystems and disturbance regimes (**Ecological Change Component**)
3) Develop data collection, modeling, and visualization infrastructure to better quantify and model changes in water balance and supply under climate change (**Water Resources Component**)
4) Develop data collection and modeling infrastructure to assess effects on human systems, responses to institutional and societal aspects, and enhance policy making and outreach to communities and stakeholders (**Policy, Decision-Making, and Outreach Component**)
5) Develop a data portal and software to support interdisciplinary research via integration of data from observational networks and modeling (**Cyberinfrastructure Component**)
6) Develop educational infrastructure to train students at all levels and provide public outreach in climate change issues (**Education Component**).

Specific strategies common to all components include (1) recruiting faculty and post-doctoral fellows in targeted disciplines; (2) attracting and retaining high quality graduate students through fellowships; (3) promoting a climate change undergraduate research program; (4) providing for faculty time and travel to foster interaction with colleagues, other experts, and stakeholders; and (5) organizing an annual State EPSCoR Conference focused on climate change.

1. Climate modeling: Climate varies across a wide range of temporal and spatial scales. Horizontal grid resolution of coupled Atmosphere-Ocean Global Climate Models (AOGCMs) is typically several hundred kilometers. This is too coarse for modeling basin-scale ecohydrology (Giorgi and Mearns, 1991; Leung et al., 2006) and capturing forcings and circulations most relevant for regional and local climate (Diffenbaugh et al., 2005). Statistical and dynamical downscaling of global climate models is used to provide information on regional and local climate. Statistical downscaling uses empirical relationships between large-scale climate parameters and regional climate (Wilby et al., 1997; Huth, 1999;, Vrac et al., 2007). Dynamical downscaling utilizes regional climate models (RCMs) with higher resolution, shorter time periods, and initial and time-dependent lateral boundary conditions from AOCGMs. These RCMs can successfully simulate effects of future climate change on extreme regional-scale events (Leung and

Ghan, 1999; Leung et al., 2003a,b), atmospheric aerosols (Solmon et al., 2006), and precipitation patterns (Rauscher et al., 2007). Our objective is to enhance Nevada's capability for modeling regional climate change and its effects on landscapes and ecosystems, including downscaling GCM output.

Existing strengths and resources: A core group of NSHE faculty has expertise in various aspects of meteorological, dispersion, and air quality modeling and forecasting (e.g., Dorman and Koracin, 2007; Isakov et al., 2007; Koracin et al., 2000a, 2000b, 2007; Podnar et al., 2002; Vellore et al., 2007). Another core group covers a wide range of techniques suitable for generating and analyzing paleodata (e.g., Biondi and Waikul, 2004; Biondi and Queadan, 2008; Hartsough et al., 2008; Mensing et al., 2007; Nicholas et al., 2007; Rhode et al., 2005; Sharpe, 2007). In addition, resources are available to serve as a foundation for collaborative research and outreach. These include the Advanced Computing in Environment Sciences (ACES) AGN, DRI's newly developed visualization facility (CAVCAM), the well-established Western Regional Climate Center (WRCC), Atmospheric and Dispersion Modeling Laboratory at DRI, and computational facilities available at UNLV's National Supercomputing Center for Energy and the Environment (NSCEE), where a western U.S. weather forecast model produced by NOAA is run daily.

Strategies and outcomes: A regional climate change modeling group will be established by augmenting existing faculty through two strategic faculty hires, one in regional climate modeling and the other in paleoclimate modeling. A support structure will be developed by adding computing resources (modular computer cluster configuration with archiving capabilities), funding technical support personnel, and providing post-doctoral and graduate fellowships. The computer system will be used jointly with the cyberinfrastructure group and others. Global (CCSM3 or later) and regional climate models (WRF Climate and RegCM3) developed by the National Center for Atmospheric Research (NCAR) and collaborators worldwide will be installed as primary tools for testing, predictions, and analyses.

Climatic processes relevant to the complex mountainous terrain of Nevada will be better understood and modeled to become input for hydrologic, ecosystem, and wildfire models. While serving mostly as a tool to predict future climate, RCMs also will be tested for ability to reproduce or explain past climatic conditions. Hindcast simulations of past climate will be evaluated using WRCC climate data. Results will provide guidance on expected uncertainties and errors in climate predictions. We will develop methods of statistical and dynamical downscaling of global climate forecasts to regional and local scales including use of principles of artificial intelligence. This component will be integrated with cyberinfrastructure for exchanging information between modeling/observational activities and interactive visualization.

2. **Ecological change:** Ecological changes at the landscape scale forced by climate change or disturbance processes occur at timescales spanning several orders of magnitude—from severe storms to wildfires and prolonged droughts. Instrumental observations provide enough replication for short timescales (Bales et al., 2006), but proxy data are needed for longer ones (Swetnam et al., 1999; Anderson et al., 2006). Combining these types of data allows for capturing a greater range of eco-hydro-climatic variability and extremes, so that current and projected trends can be placed into the context of naturally forced fluctuations (National Research Council, 2006; Biondi et al. 2007). This is particularly true for mountain environments, which receive most of Nevada's precipitation (Houghton et al., 1975) and are therefore critical for recharging groundwater resources. Furthermore, conservation and restoration of natural landscapes are guided by determination of ecological reference conditions (Egan and Howell, 2001). To understand how mountain ecosystems and landscapes respond to changes in frequency and magnitude of hydroclimatic events, major observational efforts are already underway in the Sierra Nevada (UC Merced instrumented watersheds; NSF-funded UC Davis Coast to Mountain Environmental Transect [COMET]); and in the eastern Great Basin [NEON core site near Vernon, Utah]). These complement existing observational networks (e.g., SNOTEL, RAWS, SCAN) maintained by federal agencies. Nevada currently lacks capability to detect and analyze climate change effects at a landscape scale. Therefore, the objective of this component is to enhance our capability to measure, analyze, and model key ecosystem and ecohydrologic processes at the landscape scale and understand interactions among climate change, landscape disturbance, and biophysical indicators of ecosystem response – with particular emphasis on how these changes may affect ecosystems (including water resources).

Existing strengths and resources: WRCC at DRI has extensive experience in planning and implementing climate monitoring networks, as well as archiving, analyzing, and disseminating data. Other relevant NSHE facilities include the Incline Creek Experimental Watershed and the Mojave Global Change Facility. Parallel NSHE projects that strengthen this component are ongoing reconstructions of wildfire/climate/vegetation relationships in Lincoln County (UNR DendroLab) and basin-scale modeling of evapotranspiration in southern Nevada (UNLV Center for Urban Water Conservation).

Strategies and outcomes: Existing faculty will be augmented by two new hires, – one with expertise in ecosystem modeling and the other in modeling surface-climate interactions – to form a cohesive interdisciplinary group to measure, evaluate, and model landscape and ecosystem changes linked to climate and disturbance processes. Existing observational networks will be enhanced to quantify landscape-level processes, especially in mountain environments. We will establish two new transects covering key parts of Nevada's basin and range topography. The first will be located in Southern Nevada and cover the Spring and Sheep Mountains, two of the most biologically diverse mountain ecosystems in the region. The second transect will be located in Great Basin National Park and reach the ancient bristlecone pine stands on Mt. Wheeler. These transects will be instrumented to measure key environmental variables and biological indicators of ecosystem responses to regional climate change (Table 1) and built to the standards of the National Ecological Observatory Network (NEON). These measurements will be coordinated with hydrometeorological measurements (see Water Resources) and integrated into new databases. Data will be available to researchers, decision-makers, and the public via a newly developed data portal. Sustainability will be addressed by working with community partners (e.g., land management and water agencies). National Resources Conservation Service (NRCS) has been contacted about partnering on the Southern Nevada transect; EPA and NOAA already maintain environmental sensors at Great Basin National Park. Data from the hydrometeorological and ecological change transects will enable Nevada scientists to develop collaborative NSF proposals in the future.

Table 1. Proposed environmental parameters and instrumentation of observational network.

Environmental Parameter	**Instrument/Sensor Platform**	**Locations**
Weather-related: humidity, air temperature, wind speed and direction, rainfall, solar radiation (total, net, PAR), NDVI, snowfall	Standard weather station, federal snow samplers	14
Multipoint relative humidity and temperature system	Hobo and Tidbit systems	14
Atmospheric; backscatter, absorption coefficients due to water droplets, optical density, PM_{10} concentration and sampling equipment for identifying and quantifying pollutants	Nephelometer, photoacoustics, sun tracking photometer, micropulse lidar, cell counter, tapered element oscillating microbalance, aerosol sampling	2
Tree radial growth	Automated point dendrometers	4
Shrub/tree specific transpiration rates	Multipoint sap flow gauge	4
Plant phenological activity/visual snow depth	Webcam	8
Whole system evapotranspiration and CO_2 flux	Geodesic dome system	2
Subsurface soil properties and conditions (water content, water potential, temperature, thermal conductivity, piezometric surface)	Thermistors, time domain reflectometry, heat dissipation, dual probe heat pulse, piezometers	14
Surface runoff	Flume/weir	2

Records of past environmental change will be spatially quantified from existing historical and proxy data to verify and calibrate models of ecosystem response. Simulation models of disturbance impacts (Chew et al., 2007) and GIS-based ecological niche modeling (Waltari et al., 2007) of present, past, and future species distributions will be developed. In addition, models and observations will quantify changes in aerosol levels due to wildland fires and assess their feedback effects on regional climate. Using regional climate change projections, these landscape-level models will allow probability-based assessments of landscape-level changes in ecosystem structure (e.g., species invasion, phylogeography) and functioning (e.g., primary productivity, plant water use).

Enhanced capabilities will facilitate studies to determine impacts of regional climate change for (1) tree growth and regeneration; (2) distribution and composition of native perennial vegetation and invasive species; (3) evapotranspiration in upper elevations; (4) large-scale shifts in types, abundances, and distribution of key species, accompanied by changes in biodiversity and interactions; and (e) generation and persistence of aerosols and assessment of their effects on optical properties and ecohydrology.

3. Water resources: Growing demand for water and land, increasing water scarcity, and impacts of climate change in the Southwest require quantitative and integrated understanding of the water cycle. A need clearly exists in Nevada and other arid regions to better quantify storage and fluxes associated with the water cycle, including linkages between surface and groundwater systems (National Academies Press, 2007). Especially important is definition of the amount of recharge (or perennial yield) that basins experience. Such recharge can be considered baseline water resources, against which future environmental changes are measured. In Nevada, infrastructure to quantify components of the water cycle is partially in place due to past NSF EPSCoR programs and ongoing in-state research activities. Nevada has a need, however, to augment existing infrastructure to provide a comprehensive understanding of how climate change will impact the water cycle and water resource systems. This need has been identified in a study performed by the USGS and DRI and is also identified as a priority in the state's Science and Technology Plan. Our objective is to develop infrastructure to measure, analyze, and model changes in water balance and assess changes in supply.

Existing strengths and resources: NSHE has a well-established group of faculty with expertise in surface and groundwater hydrology (e.g., Boyle et al., 2001; Tyler et al., 1996; Young et al., 1998; Smith et al., 1998; Yu, 2000), with nationally-ranked research and educational programs (e.g., UNR Hydrologic Sciences graduate program). This expertise is complemented by existing physical infrastructure including NSF-EPSCoR-funded facilities (e.g., Boulder City large lysimeter facility). NSHE faculty are working with the Southern Nevada Water Authority (SNWA) to measure evapotranspiration, groundwater depths, and rainfall on a basin scale. In addition, DRI has purchased equipment to measure recharge rates.

Strategies and outcomes: Existing expertise will be augmented by hiring one new faculty in ecohydrology who will work closely with climate modelers and ecosystem process investigators. The observational network described above will be shared with the Water Component. Data from the hydrometeorological network will be used to better understand processes controlling recharge and will be used with numerical models to evaluate interactions between surface and groundwater systems and assess how these interactions will differ under climate change. This includes development of probabilities of different recharge rates and application of these techniques to other high population areas in the Southwest. Model development will involve stakeholders from the region and be facilitated by new infrastructure from this project, including the data portal, visualization facilities, and socio-economic data.

4. Policy, decision-making, and outreach: A recent National Academy of Sciences (NAS) report reviewing the U.S. climate change program noted lack of understanding of societal impacts and adaptation strategies plus a need to translate climate change data and information more effectively to decision-makers (National Research Council, 2007); this applies equally to Nevada (Chambers et al., 2006). One priority is systematic translation of climate change science into forms understandable by stakeholders, decision-makers, and non-science audiences. Another priority is improving scientific outputs through feedback on perceptions and institutional barriers. Given vulnerability of arid lands to climate change and rapid urbanization, interaction between humans and climate change in these regions represents a relatively under-explored area of research. Nevada will serve as an excellent case because its rapidly urbanizing society faces significant climate change impacts. The objective of this component is to develop data collection, modeling, and visualization tools to better understand institutional and societal aspects of climate change and perform outreach to translate and communicate this science.

Existing strengths and resources: Existing resources for addressing policy and outreach include faculty with expertise in climate change assessment, demand-side management, environmental economics, environmental governance, hazards, mass media, Native Americans, political ecology, psychological evaluation, risk analysis and communication, spatial analysis, sustainable development, and water policy (e.g., Brookshire et al., 1992; Herzik, 1998; Priest and Gillespie, 2000; Fowler, 2005; Smith, 2003; Smith and Wang, 2007; Wang et al., 2006). WRCC at DRI has a long history of outreach and communication of climate data to the public and decision-makers. Physical resources include a visualization facility (CAVCAM) at DRI North and two facilities at UNLV: a visualization facility ("Solution Room") and GIS and Remote Sensing Core Laboratory (GRSCL) which will allow collection, storage, retrieval, and display of data.

Strategies and outcomes: Existing faculty expertise will be augmented by two new hires, one in demography and spatial analysis and the other in computer visualization. A *Social Science Climate Change Network (SSCCN)* will be created to focus on outreach to collect social, economic, environmental, organizational, and institutional data and help scientists envision how their work will best support policy making. A meaningful *two-way* flow of data and information between scientists and stakeholders will be created. Data shared with biophysical and computer scientists will help them target research outputs to specific audiences, spurring more interactions with targeted stakeholders, continuing the cycle as data and information are fed back to scientists (Smith, 2003). The network will operate in conjunction with biophysical studies related to our interdisciplinary questions (below). SSCCN builds on existing infrastructure at UNR (GRSCL) and CAVCAM. The data portal plus findings and analysis from the SSCCN, CAVCAM, and GRSCL will enable researchers to integrate interdisciplinary data and information, facilitating visualization of climate change impact scenarios across multiple temporal and spatial scales in the Solutions Room. This facility will allow for visualization, community-based modeling, scenario analysis, and collaboration.

5. Cyberinfrastructure: Modeling and observational activities will be data and computationally intensive, involving acquisition of large volumes of data from field instruments and surveys as well as model output. The first priority will be to develop and maintain computing, data storage, and visualization infrastructure to enable interdisciplinary climate change science. Although computing systems pervade modern science and engineering research infrastructure, many research software systems tend to be difficult to use, support, and maintain (Mattmann et al., 2006). Development and exchange of data and models among scientists from different disciplines and among various environments are often time-consuming and detract from synthesis and interpretation of data (Borne, 2006). These problems become more challenging in the decision-making environment, where non-specialists need to assimilate and understand complex data sets and interdependencies to evaluate alternative strategies (Jain et al., 2006). These issues must be addressed, and ways must be found to bridge gaps between scientists and decision-makers as well as among scientists from different disciplines. Our objective is to develop hardware, software environments, and a data portal to support interdisciplinary climate change research.

Existing strengths and resources: NSHE faculty have extensive expertise in large-scale software engineering, interactive systems, intelligent solutions, and advanced data visualization (e.g., Nicolescu et al., 2007; Quiroz et al., 2007; Sherman et al., 2007; Penick et al., 2007). This includes expertise in intelligent systems, computational cognitive models, and human-computer interaction built through previous NSF EPSCoR awards and other projects. Existing computing resources also will support this component. These include a new research grid at UNR; the Center for Information and Communication Technology (CICT) and NSCEE at UNLV; and the Spatial Analysis and Integrative Modeling Laboratory and Cave Automatic Virtual Environment (CAVE™) at DRI. WRCC has extensive experience in climate database development, maintenance, and archiving of data.

Strategies and outcomes: Proposed strategies will create a user-friendly, interactive, intelligent, and flexible cyberinfrastructure that will support research, applications, and education in climate change and link together all project groups. The centerpiece of the proposed project's cyberinfrastructure is the Nevada climate change portal. This portal will provide access to all project-related data, emphasize spatial databases, facilitate data-model comparison, and serve as the main gateway to climate change information and computing resources for all stakeholders. It will be linked to existing databases such as those maintained by WRCC. Robustness of the portal will be evaluated via usability testing. The data portal's architecture will consist of (1) a powerful Web server that will provide online interface to users for storing and retrieving data from high capacity storage units; (2) a high performance disk-oriented server ("database engine") which will optimize access to storage units, interface with the Web server, and connect for advanced data processing with the project's modeling cluster of computers; and (3) high capacity data storage units (disks) working in pairs for backup. Additional resources such as high performance servers and data storage devices, networked computing nodes, and visualization stations will be acquired for regional climate and hydrologic/ecological modeling efforts. New software environments and interaction solutions will be designed using expertise developed through on-going NSF EPSCoR funding to facilitate assimilation of data from models and observations and promote exchange of data.

6. Education (graduate, undergraduate, and K–12): Educating and engaging citizens and leaders of our state are essential if we are to respond successfully to environmental challenges and develop a sustainable economy. Nevada also needs a cadre of undergraduate and graduate students with understanding of climate change science to serve as future leaders in this field. The objective of this component is to develop educational infrastructure to train our best and brightest NSHE students and K–12 teachers to be leaders in climate change research and teaching.

Existing strengths and resources: NSHE has well established undergraduate and graduate educational and research programs in science and engineering along with a track record of collaborating with K–12 (e.g., Buck, 2003; Cantrell et al., 2007; Ewing-Taylor and Cantrell, 2006; Taylor et al., 2007; Teran et al., 2005). In the past two years, the undergraduate research program at UNLV and UNR has awarded 295 research awards during the academic year and summer months, 150 of which have been funded by the NSF EPSCoR RII grant. At the graduate level, individual faculty have experience mentoring M.S. and Ph.D. students and training them for careers in STEM disciplines. Currently, NSHE offers at least 10 undergraduate and graduate climate change courses. Finally, faculty have developed collaborations with K–12 programs, such as the UNR Raggio Research Center (RRC) that has worked with all 17 Nevada school districts and several NSF-EPSCoR-funded K–12 efforts focused on diversity.

Strategies and outcomes: Integration of climate change education and research will be enhanced through delivering training programs, developing K–12 curricular materials, and providing courses. K–12 teachers, community college students, university undergraduates, and graduate students will be involved in science research teams. Researchers on these teams will work with educators in developing new curriculum materials for middle schools, community colleges, and universities. At the K–12 level, collaboration will focus on the "whole school." Middle school has been identified as a critical time for science education (Koballa et al., 2007).

At the same time, Nevada has an inadequate number of qualified middle school science teachers: Nevada is home to only eight of the nation's 1899 Board-certified middle school science teachers. We will, therefore, identify six middle schools (three each in Las Vegas and Reno) for integrating climate change science into existing curriculum (following Nevada's science teaching framework and national guidelines). Professional development will be offered to five teachers in each school – drawing from science, math, and English teachers – to better integrate science education and communication, for a total of 60 teachers during the project. This will be a year-round collaboration, a key aspect of which will be summer fellowships where teachers will work with interdisciplinary research teams, shadow climate researchers, and receive formal training on climate change science and education. These teachers also will have the opportunity to attend one of two summer institutes each year. Teachers will return to focus each summer on a new aspect of climate change research. Each institute will focus on one of the two research questions (below), so each participating teacher at the end of the project will have taken two summer institutes and a three-credit climate change class. To ensure sustainability of these institutes, future climate change proposals from NSHE institutions will be linked with this program. New tools will be available for K–12 teachers to incorporate climate change; teachers will be given the pedagogical tools to effect incorporation. Assessment will be coordinated with schools to ensure that all state standards are met and student learning is enhanced through integration of climate change science.

Integration of research and education, and improvement of science curriculum at the Community and State Colleges will be accomplished by continuing the successful Community and State College Faculty Fellowship Program, which was initiated in RING-TRUE III, in which faculty fellows will participate in climate change research during the summer. Each fellow will work with a faculty sponsor at UNR, UNLV, or DRI and will be expected to bring knowledge gained as a result of their research experience back to Community and State College classrooms in Nevada.

Involvement in research is an effective tool to motivate academically talented undergraduates to pursue graduate degrees. Surveys indicate that research experience increased interest in graduate school in 84% of the students participating in the RING-TRUE III undergraduate research program. An undergraduate research program focused on climate change in the NSHE system will be developed, and an NSF ESPCoR-funded Climate Change Scholarship program offered annually to a total of thirty community college and university students. To ensure broad participation, a minimum of 50% of the scholarships in each award cycle will be awarded to students working on climate change topics, and any remaining scholarships may focus on other STEM research. These students will work with a cohort of faculty and graduate student mentors and will be required to participate in an interdisciplinary research team (see below). Two annual summer poster sessions will be held as well as an annual two-day undergraduate research symposium for all NSHE undergraduate researchers. A new minor in climate change studies will be created to provide an opportunity for students to augment their major field of work. This will be an interdisciplinary minor offering a system-wide suite of courses encompassing physical and human elements of climate change. The culminating experience will be a capstone course on climate change and society. New course development will be supported through an NSHE-wide competition in years two and three for curriculum development grants to fill key gaps and offer new courses. In addition, UNLV has committed to provide faculty reassignment for curriculum development. We anticipate adding between eight and twelve new courses at the undergraduate and graduate levels. Courses will be offered through both UNR and UNLV, and taught using distance technology to allow students at multiple NSHE campuses to enroll. Up to two DRI faculty per year will be supported to teach undergraduate and graduate level courses at UNR or UNLV. At the graduate level, a fellowship program will be created in which between 12 and 19 students annually will be accepted to work with NSHE faculty. Students admitted into participating programs will have an opportunity to obtain a certificate in climate change as part of their graduate degree. The graduate certificate program will include a set of core courses including seminars in science, policy, and communication. Graduate and undergraduates will have the opportunity to apply for conference and research travel support.

A symposium on climate change education will be held during the summer at the beginning of the second year and will include educators at all levels within Nevada plus professionals from outside the state. One outcome will be comprehensive evaluation of current climate change educational activities at NSHE institutions plus a blueprint for developing new curriculum and educational opportunities. This symposium will provide guidelines for developing and selecting new courses and integrating curriculum.

INTEGRATION OF INFRASTRUCTURE BUILDING COMPONENTS

To achieve full integration of program components, we will implement integrating mechanisms (based on topics, functions, education, and management) that will promote interaction of a diverse group of faculty, students, and decision-makers. A key element in this strategy is formation of two interdisciplinary and inter-institutional science teams that draw on faculty, students, educators, and stakeholders from various science, engineering, policy, and communication fields. These teams will address two overarching science questions following the examples of specific questions and activities summarized below. Formation of these teams will take place starting in Year 2 and continue until Year 5. Participation will be facilitated by competitive seed grants.

The two science questions were selected based on (1) scientific merit and societal impact, (2) interdisciplinary nature, and (3) intelligibility to the lay audience. In addition to the overarching science questions, each team will address uncertainty, adaptability, and vulnerability of natural and human systems in relation to climate change impacts. Questions will be addressed using an approach advocated by Anderson et al. (2006). This approach provides a conceptual and theoretical basis for integrating models and data across a range of timescales, by recognizing that the present state of landscapes and ecosystems is a legacy and that modeling of the present and future requires knowledge of the past.

Interdisciplinary Science Question #1: *How will climate change affect water resources and linked ecosystem resources and human systems?* Sustainable use of water resources in Nevada, as in other arid regions, requires that components (storages and fluxes) of the regional water cycle – including linkages between surface water and groundwater systems – are better quantified. Quantitative understanding of feedbacks among water resources, landscapes, and human systems will enhance ability to assess sustainable yields. Infrastructure developed in this proposal will be vital for better understanding these linkages. Science questions that may be addressed include:

- How can past and present linkages between ecological/biological/hydrologic responses to climate variability be used as a basis for projecting forward in time?
- What are expected signals of a changing climate in the state; how should they be monitored?
- What are drivers of climate change, physical and biological processes, and human systems?
- How will recharge rates in mountain and high desert regions be altered by climate change?
- How will climate change affect atmospheric aerosol concentrations and characteristics and their direct and indirect effects on radiative forcing, precipitation, and snow albedo/melt?
- How have climate and water resources varied during the past 1,000 years; how will they change in the next 100 years?
- How will changes in temperature and amount and type of precipitation impact water resources?
- How will shifts in water demand from rural to urban impact physical and biological processes?
- How will climate change impact different sectors of Nevada's society?
- How can we improve transfer of knowledge across science and policy communities?
- What information and which frameworks will increase knowledge about climate change most effectively in the public sphere and enhance likelihood of engaging in sustainable behavior?

Interdisciplinary Science Question # 2: *How will climate change affect disturbance regimes (e.g., wildland fires, invasive species, insect outbreaks, droughts) and linked systems?* Interaction between disturbances and climate will determine sustainability of land management strategies in the near future. For example, current fire-use policy relies heavily on watershed-scale assessments of wildfire regime, fuel conditions, and historical range of ecological variability, yet agency data on fire regimes seldom extend beyond the past 30 years (Westerling et al., 2006). In addition, published proxy paleoclimate records show that the Sierra Nevada, Great Basin, and Colorado River Basin regions have experienced much more intense droughts during the past several centuries than those observed in the instrumental record (Piechota et al., 2004; Woodhouse et al., 2006; Meko et al., 2007; Biondi et al., in press). Infrastructure developed in this proposal will enable Nevada scientists and the community to understand how disturbances will change in the future. Science questions that may be addressed by this team include:

- What is the relationship between climate change and disturbances and what timescales matter?
- What are the forcing factors (e.g., sea surface temperature, atmospheric aerosols) and atmospheric circulation patterns that lead to extended wet and dry periods and how can they be modeled?
- What is the range of Nevada's historic and prehistoric climate variability on different timescales?
- What is the fire-climate relationship before and after Euro-American settlements; how will this relationship change in the future?
- How will a change in fire frequency and intensity influence air, water, and ecosystem quality?

- What level of complexity and resolution is needed for predicting interaction among species invasion, wildfire regime, and climate?
- How will climate change and natural disturbances impact different sectors of Nevada's society?
- How will occurrence and magnitude of droughts change; what will be impacts to water resources, ecosystem resources, aerosol emissions, and human systems?

EXPECTED OUTCOMES

Infrastructure building components outlined above will provide NSHE, Nevada, and the region with new interdisciplinary capability to detect, analyze, and model effects of regional climate change on the atmosphere, landscapes, ecosystems, and water resources. Increased competitiveness will be built through development of**:**

1) Capability to model regional climate change and its effects on ecosystems and resources
2) Improved methods for assimilation of instrumental and proxy data into regional models
3) Instrumented observation networks and capability to perform experiments to understand processes and mechanisms of climate change impacts
4) Capability to analyze and communicate social and policy implications of climate change
5) Cyberinfrastructure, including a data portal and intelligent interactive software tools, and visualization infrastructure to enable communication and data sharing
6) Enhanced opportunities for education in climate change science at all levels
7) A virtual climate change information center for all of Nevada

Research resulting from this infrastructure will be transformative in the following ways: (1) interdisciplinary identification of linkages and feedbacks among climate forcing factors and natural/human systems; (2) establishment of clear and effective linkages among the scientific community, public, and policy makers; (3) extending worldwide research on global climate change to regional and local impacts; and (4) providing fundamental scientific understanding of impacts on regional resources.
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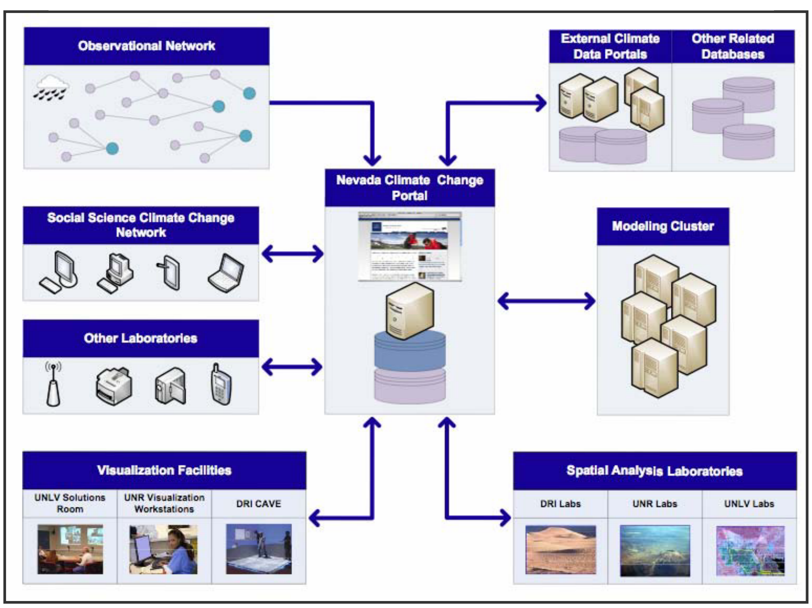
5. CYBERINFRASTRUCTURE PLAN

Not only is the time ripe for a coordinated investment in cyberinfrastructure, but progress at the science and engineering frontiers depends on it. Our communities are in place and are poised to respond to such an investment. This statement in NSF's Cyberinfrastructure Vision for 21st Century Discovery aptly describes the central importance of cyberinfrastructure (CI) in our proposed RII project (Fig. 4). Proposed CI infrastructure described above is (1) data intensive and (2) involves a diverse and geographically distributed community. A data portal is the centerpiece of the proposed CI and will provide data storage, documentation, and archiving from multiple sources. Software frameworks will aid data analysis and integration of

Figure 4. Cyberinfrastructure for Nevada's climate change RII.



information from different sources. Software will be platform-independent and flexible to meet future needs. Data structures and standards will permit exchange and integration of data with existing and planned observational networks (e.g., COMET, NEON). Existing computing resources will be enhanced by adding computing capacity at DRI and UNR to facilitate advanced modeling. These clusters plus other networks and resources will be linked via high bandwidth networks enabling real-time monitoring. Visualization is necessary for analysis of complex data sets as well as communication of research results to decision-makers. DRI's existing VisLab (NSF EPSCoR Ring True II), four-sided, and planned six-sided CAVE™ facilities, and the Solutions Room at UNLV will be central to providing interactive visualization of science data for researchers, the public, and decision-makers.

CI structure will be designed to facilitate development of virtual organizations throughout Nevada and beyond via access to data from a variety of sources and development of software frameworks that encourage and facilitate collaboration. These virtual organizations will bring together geographically scattered communities and individuals to facilitate interdisciplinary research, education, and outreach. Other virtual organizations will enable K–12 students and educators, including those in rural locations, to access data sets, perform analyses in the classroom, and communicate results to their peers and public.

6. OUTREACH AND COMMUNICATION PLAN

Strategies in this plan are in the Education and Policy, Decision-Making, and Outreach Components and address the following three goals: (1) educate the next generation of climate change scientists for Nevada, (2) engage citizens of Nevada in understanding climate change and its impacts, and (3) partner with stakeholders to identify responses to potential climate change.

Educating the next generation of climate change scientists

K–12 program: As part of the "whole school approach," K–12 outreach targets middle schools to engage young students and facilitate interest among women and other underrepresented groups to pursue careers in STEM disciplines. We plan to recruit 12 schools with five teachers at each school (three science, one math, one English) for a total of 60 teachers. We will target schools of more than 800 students with large populations of underserved students (>50%) and large numbers of science teachers (~30%) who are not highly qualified. These teachers will reach as many as 1800 students per school during a two-year period for a total of 21,600 students in five years. The whole-school approach will broaden participation of all student sectors within Nevada, including underrepresented groups.

Summer institute: Institutes will build scientific literacy in each teacher cohort (30 teachers per cohort, 15 in Las Vegas and 15 in Reno, for two years). Two graduate student mentors will provide year-round support in teachers' classrooms. College courses and summer instruction will help middle school teachers become "highly qualified" in STEM disciplines and enhance opportunities for full certification.

Undergraduate program: We will award on a competitive basis 30 academic research scholarships per year (five for community colleges; 25 for four-year institutions). Awards will go to students in STEM disciplines, journalism, and political science to integrate science and policy and strengthen skills in communicating results. Scholarships will be marketed to women, Native Americans, and members of other underrepresented groups by working with established programs such as Women in Science and Engineering (WISE) at UNR and the Office of Undergraduate Research developed at UNR in part through previous NSF EPSCoR funding. Students will communicate research results through two summer poster sessions every year at UNR and UNLV, as well as one annual "Nevada Undergraduate Research Symposium (NURS)" held on an alternate basis at UNR and UNLV. NURS, initiated in 2004, will be held in conjunction with the annual Nevada NSF EPSCoR climate change meeting to enhance student career options by promoting interaction among students and the academic and business communities. At the end of the RII grant, 150 undergraduates will have gained this experience. Undergraduate science curriculum will be enhanced through the Summer Community and State College Faculty Fellowship Program.

Graduate program: We will award graduate research fellowships on a competitive basis that will fund approximately 18 students per year to work on the interdisciplinary climate research teams. Scholarships will be marketed to women, Native Americans, and members of other underrepresented groups. Emphasis will be placed on recruiting new students to NSHE through avenues such as working with each institution's human resources staff and online career resources (e.g., Association of Women in Science, American Indian Science and Engineering Society, and IMdiversity, which has targeted Web pages for specific cultures [e.g., Hispanic-American Village]).

Engaging Nevada citizens through technology that facilitates communication

Climate change data portal: Outreach will rely on the data portal described above, building on a history of outreach and communication of climate information through the WRCC and Nevada Climate Office.

Visualization cyberinfrastructure: Data generated will be made accessible through the portal and Core GIS and Remote Sensing Laboratory, supported by cyberinfrastructure. The Solutions Room at UNLV plus existing facilities at DRI (e.g., CAVE™, VisLab) will be available to decision-makers for scenario visualization. Biophysical and SSCCN data (see below) can be integrated using this new technology involving policy makers as participants.

Video production: We will produce a video for general audiences in both English and Spanish on climate change in Nevada, its possible impacts, and potential for citizen involvement.

Interactive Web sites: We will create interactive Web sites involving citizens, thereby providing a forum for two-way communication. The sites will be modeled after OurTahoe.Org. An internet-based, future-scenario analysis tool, "Nevada Life," will be created as a hybrid between the Google Earth and SIM CITY models to allow non-professionals access to visualization tools that simulate climate change.

Inter-jurisdictional workshop: Three western NSF EPSCoR states – Nevada, New Mexico, and Idaho – have chosen climate change as an overall theme in the present RII competition. To promote regional collaboration, we propose to put on two tri-state NSF EPSCoR workshops on climate change, "Addressing Climate Change Research and Education Challenges in the Western U.S." The first workshop would occur in year two (hosted by Nevada) with the second in year four (hosted by New Mexico).

Access Grid Nodes: Videoconferencing through AGN sites at DRI, UNLV, and UNR (developed with previous EPSCoR funding) has been intensively utilized in preparation of this proposal and will continue as a primary source of communication throughout the project.

Partnering with stakeholders to identify responses to potential climate change

Social Science Climate Change Network: Our outreach plan creates a "Stakeholder Advisory Committee" (SAC) with representation from 10 critical community groups, including the casino and construction industries; ranching and farming communities; Native American nations; education leaders; local, state, and national government agencies; seasonal resort communities; and rural and urban political representatives. The SAC will join our research teams to create the Social Science Climate Change Network (SSCCN) to connect stakeholders and researchers from the beginning to provide input into science questions that includes community priorities and feedback on how results can be best communicated. Another important goal of the SSCCN is to develop understanding of scientific approaches and policy options to help stakeholders digest outputs and determine how to integrate results.

National conference: We will sponsor a nationwide conference on climate change and policy in year five, with an emphasis on impacts to arid environments. This conference will build on jurisdictional workshops held in years two and four (see above) and include research from throughout the nation.

Economic outreach: The Nevada Small Business Development Center (NSBDC) is a statewide business assistance network with 33 professionals located at 11 full-time service centers with dozens of counseling locations throughout the state. In FY 2007, NSBDC counseled 1,257 businesses and trained 4,691 individuals. NSBDC will provide outreach to businesses and communities in Nevada to help them understand

and respond to climate change issues affecting the Great Basin and increase linkages between NSF EPSCoR researchers and their counterparts in research or technology-based small businesses. NSBDC will assist these businesses in addressing science and technology needs and increasing their competitiveness for federal SBIR and STTR grants. NSBDC outreach also will address water and resource conservation in business and government operations, incorporation of low impact development and drought tolerant landscaping practices for storm water recharge, and water conservation in residential and commercial development.

In addition to the activities described above, small travel grants will be available for NSHE faculty to visit NSF to discuss proposal development and increase communication with program directors.

7. DIVERSITY PLAN

Current state of diversity: All race and ethnic groups are growing substantially in Nevada, and Hispanics are expected to account for the majority of future growth in the next few decades. A gap remains between whites and Hispanics in the proportion of students enrolling in college, and completing certificates and degrees, although this gap has narrowed in Nevada during the past decade (National Center for Public Policy and Education, 2007). Increasing degree attainment of minorities will help Nevada's economy as high educational attainment correlates with economic strength and high income. NSHE is committed to increase enrollment and degree attainment among all ethnic groups. An NSHE Diversity Report provides updates of diversity performance indicators that map to diversity goals which are part of the NSHE Master Plan. A key diversity goal for NSHE is "Opportunity and Accessible Education for All." In 2006, the NSHE Chancellor formed the "Chancellor's Diversity Forum" and signed a pledge to increase recruitment efforts, scholarship and program funding, and seek out and hire additional qualified minorities in administrative positions. Nevada's Science and Technology Plan also recognizes the importance of diversity.

Proposed diversity impacts: Diversity is inherent in the proposed program design, providing opportunities to diversify at a broad number of levels which will aid NSHE in realizing its goal of "Opportunity and Accessible Education for All." Diversity will be increased through a number of mechanisms. For instance, we have allocated supplemental startup funds to encourage hiring faculty from underrepresented groups. This mechanism has been used successfully in the past two RII cycles. To increase the number of underrepresented groups represented in candidate pools, we will work with each institution's human resources staff to utilize online career resources and other advertising mechanisms targeting underrepresented groups. Our "whole school" approach at the K–12 level is a mechanism for broadening participation in all student sectors within Nevada. We also will market undergraduate and graduate student awards to women, Native Americans, and minorities. Outreach will take into account "cultural lenses" when presenting climate change information to the public. More detailed accounting of these mechanisms for increasing diversity can be found in the Outreach and Communications Plan above. The Project Director, G. Dana, works as a representative for Nevada's American Council on Education Office of Women in Higher Education – which convenes an annual conference to promote the advancement of women in higher education and increase the visibility of women's achievements and women's issues in the colleges and universities of Nevada. We promote institutional diversity by integrating all NSHE institutions into the leadership and management structure of the project (see Management Plan). Disciplinary diversity will be fostered by multiple mechanisms. First, we will provide competitive seed grants for NSHE science teams to conduct interdisciplinary research on climate change. The second mechanism is through the data portal and software framework. Finally, undergraduate student awards will be made in STEM areas, journalism, and political science to strengthen communication skills.

Enhanced geographic diversity will be achieved by broadening participation of scientists and citizens in Nevada and other western states. This will be accomplished through involvement of all NSHE institutions (including the community colleges) and the Stakeholder Advisory Committee described in the Outreach and Communication Plan above. The SSCCN and data portal will create information pathways with all populations in all areas including Nevada's Native American and Hispanic communities (targeted outreach products produced in both English and Spanish). Additionally, our proposed climate change workshop with New Mexico and Idaho will expand our efforts to the regional level. The proposed project also will promote economic development and diversification by translating climate change results to governments, businesses, and policy makers and through its partnership with NSBDC described above in the Outreach and Communication Plan.

8. EVALUATION AND ASSESSMENT PLAN

The ultimate goal of this RII – to strengthen Nevada research, education, and outreach in climate change science through sustainable improvements in R&D capacity – will be met by four project goals that integrate collaborative productivity. The rationale, existing strengths and resources, and strategies and outcomes for each of these goals can be found in the component sections above and are summarized in the logic model (Table 2). Evaluation data for each goal is summarized below.

Goal 1 *– Promote climate change scientific discovery by carrying out nationally competitive collaborative capacity building in climate modeling, ecological change, and water resources.* Evaluation data will include publications, grants, and patents; record of involved faculty, post-docs, graduate students, technicians, and K–16 students; amount of financial support; collaboration results; and event evaluation using the Kirkpatrick Model (Kirkpatrick and Kirkpatrick, 2006).

Goal 2 *– Institutional and societal impacts of the project's research findings will be documented, interpreted, and communicated to decision-makers, educators, and the public.* Evaluation data will include publications, grants, and presentations; products and publications use record; partnership results; types of communications; and testimonials.

Goal 3 *– Cyberinfrastructure will facilitate and support interdisciplinary climate change research, policy, decision-making, outreach, and education by developing and making available integrated data repositories and intelligent, user-friendly software solutions.* Evaluation data will include number and types of products and disseminations; documentation of how products and services supported and enhanced other components; and publications, grants, and presentations.

Goal 4 *– A scholarly environment will be created to promote research skills and intellectual development for all Nevada teachers and students (K–12,undergraduate, and graduate).* Evaluation data will include participating student demographics, high school student and undergraduate enrollment trends, panel review of new curricula and climate change lessons, evaluation of courses/seminars/workshops by participants and observers, and number of STEM undergraduate majors at UNLV and UNR.

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 impact of the project in developing strong intra- and inter-jurisdiction collaborations that address regionally relevant and nationally important climate change 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 (Table 2), milestones (Table 3) and logic model (strategies, inputs, outputs, outcomes/impacts) (Table 4). The project's management team in collaboration with the External Evaluator and External Research and Technical Advisory Board (ERTAB) will continuously monitor how well the project is moving toward the goals of the strategic plan, which will be developed immediately after the grant award. In addition, in years 2 and 4 of the project, AAAS – through the AAAS Research Competitiveness Service – will recruit and lead an unbiased panel of experts to provide assessment and guidance on the project to NV EPSCoR. The AAAS panel 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.

The External Evaluator, Rose Shaw, Ph.D., has extensive experience evaluating National Science Foundation projects (EPSCoR RII, UBM, GK12, LSC, CETP, IGERT, Phases I, II, III and BD of LSAMP, ADVANCE and ITEST) and other projects (e.g., USDE Reading First, Colorado MSP). She recently consulted with Xavier University (LA) on an NIH Research Centers in Minority Institutions proposal. She was an invited member of the NSF national site-visit team that evaluated the UNC-Chapel Hill MSP (2004), and was one of a two-member team that developed an evidenced-based framework for the national evaluation of NSF's EPSCoR program (2006).

Feedback from the six project component teams (Co-PIs, faculty, graduate students, and post-docs) will be collected periodically by the management team with meetings each semester and by NSHE's Center for Design Research and Analysis (CDRA) using a Web survey that will be collaboratively developed with the PI/PD and External Evaluator. CDRA will disseminate written reports of survey results to the PI/PD, Co-PIs, and the External Evaluator within two weeks of the end of each survey timeframe; the External Evaluator will review and make recommendations. CDRA also will collect the approximately 25 metrics reported annually to NSF (e.g., numbers of publications, patents, grant awards) and will report these to the PI/PD, Co-PIs, and External Evaluator as part of the implementation and progress monitoring phases of the formative evaluation of the magnitude of the additional value of this RII (NSF 02-057).

The Evaluation Coordinator (Alice Ward, NV EPSCoR Office) will maintain education component metrics including undergraduate, graduate, post-doc, and teacher participants' demographics (e.g., gender, race/ethnicity, disability, majors, teachers' highly qualified, and full certification status), alumni tracking (project's influence on skills, interests, continuing education, and careers), quality of education activities (surveys, focus groups), and records of how evaluation information was used to improve the Education Component. The Evaluation Coordinator will partner with the management teams of the Climate Change Data Portal, SAC, SSCCN, and NSBDC in collection, summarizing and reporting of qualitative and quantitative outreach and communication evaluation data. The Evaluation Coordinator also will arrange for ERTAB, AAAS, and External Evaluator site visits and will work closely with the PI/PD and CDRA in coordinating all internal evaluation data collection, analysis, and reporting. The PI/PD, Evaluation Coordinator, External Evaluator, and CDRA will collaboratively develop a standard evaluation questionnaire for collecting feedback from all participants of seminars, classes, and workshops administered by CDRA on the Web or by paper-and-pen so that inter- and intra-component longitudinal comparisons can inform the project.

The External Evaluator will report all findings and recommendations to the PI/PD who will be responsible for disseminating findings to NSF and appropriate stakeholders (e.g., Co-PIs, Evaluator Coordinator, ERTAB, and External Advisory Committee). In addition to survey development and annual updating of surveys, the External Evaluator will make 1–3 site visits each year (one will be the same time as the annual ERTAB visit), assess added value of all aspects of the project including inter-jurisdictional collaboration, cyberinfrastructure development, outreach and diversity; review all internal evaluation processes, protocols and findings; and make improvement and refinement recommendations. Using surveys, interviews, and/or observations, the External Evaluator will externally collect each of the five years concrete, meaningful data aligned with internal evaluation data. In an annual summative report, the External Evaluator will triangulate external and internal evaluation data to document the extent to which the project met anticipated outcomes and added value, progressed toward long-term sustainability, provided sustained development that addressed intra/inter-jurisdictional and national climate change issues, implemented internal evaluation components, and effectively used evaluation feedback. Processes the External Evaluator will use to satisfy the evaluation objectives may include interviewing the Co-PIs and PI/PD to gain insights into project planning/implementation and to ascertain the project's anticipated and actual outcomes, on-site observations of project activities, additional surveying, interviewing, critiquing the project's internal evaluation processes, and reviewing whether the processes are well suited for implementation and progress monitoring, identifying project strengths, and making recommendations for improvement. Some formative evaluation data will be used by the External Evaluator in the summative evaluation to assess the project's impact.

Table 2. Added-value evaluation, assessment benchmarks and performance measures		
Outcomes	**Activities/Outputs**	**Metrics and Measures Collected Annually**
Research production in focus areas	Publications, patents, products, submitted proposals, new curriculum	Increase in total number; increase in average research production per researcher;
Research portfolio quality	Federal funding by NSF and others; highly qualified faculty	Increases in number/dollars; faculty retention; increases in climate research by students
Human resource development and improved education	Broadening participation, quality of educational activities; new faculty development; outreach	Demographics (increased diversity), numbers served, increased STEM degrees/jobs, number of HQ and certified teachers
Research investments and materials	New facilities, equipment and technology, leveraging	Dollars raised for conducting research; increased space and equipment
Research collaboration and networking	Intra- and inter-jurisdictional collaborative workshops, proposals & awards, cross disciplinary projects	Increases in number and dollar amounts, involvement of climate scientists from across the nation and from EPSCoR jurisdictions
Research climate, culture and communications	Policies, research incentives, public policy, responsive system State EPSCoR Committee Activities, economic development activities	Funding allocations, stakeholders' satisfaction, policy changes, engagement of Nevada citizenry, increased inter-jurisdictional publications and grants

Table 3. Summary of Nevada RII Implementation Milestones					
RII Component	**End of Year 1**	**End of Year 2**	**End of Year 3**	**End of Year 4**	**End of Year 5**
Climate Modeling	Strategic plan final; hiring started; equip purchased	Hires done; climate modeling underway; collaborations active	RCM efficiency studies done; integration obvious	Jurisdiction partner-ship publishing global climate forecasts	Virtual Center for Climate Change funded
Ecological Change	Equipment purchased; south-north transect setup; start networking	Transect set up complete; modeling underway	Hires done; Faculty integrated into research productive interdisciplinary group	Interdisciplinary climate change research recognized	
Water Resources	Equipment purchased; Eco. group and RII set up on transect; Technician hired	New partnerships in place; transect complete; modeling underway	Hires done; Publications/grants increase significantly in water and climate change research	Jurisdictional partnership recognized as leader in climate change research	
Policy, Decision-Making, and Outreach	SSCN created; Stake-holder Advisory Comm. formed; all component pieces started	National partnerships strengthened; outreach programs piloted	Solutions Rm. equipment purchased; collaborative publications, regional partners interface	Hires done; National and regional decision-makers are using program info; network recognized in region and nation	
Cyber-infrastructure	Soft- and hardware purchased; technicians hire; data portal started	Software frameworks developed; data portal in place	Data portal extended - used in schools/businesses	Software frameworks being used by all project groups.	
Educational	Undergrad & middle school programs started; new teaching tools developed; curriculum dev. begins	Graduate fellowship program started; post-doc hired; hands-on science increased at universities and K–12	GK12, REU funded; climate change curriculum aligned to state standards and used in K-12 schools	Scholarship and fellowship pro-grams institutionalized symposium held; Prof. Dev. highly rated	

Table 4. Logic Model for Nevada RII

▼ Continue improving NV S&T infrastructure, R&D capacity and hence its national R&D competitiveness ▼

Strategies	Inputs	▶	Outputs Activities	 Participants	▶	Outcomes - Impact
Build Infrastructure ➢ Climate Modeling ➢ Ecological Change ➢ Water Resources ➢ Policy, Decision-Making and Outreach ➢ Cyber-infrastructure ➢ Educational Integrate Infrastructure Building Components ➢ Two interdisciplinary science questions ➢ Interaction of faculty, students, decision-makers ➢ Science, policy, engineering and communication interact Sustain Infrastructure ➢ Collaboration ➢ Research opportunities ➢ State support ➢ Institutional support ➢ Partnerships ➢ Cost recovery Improve Competitiveness ➢ Align with NV S&T Plan ➢ AAAS guidance Practice Good Stewardship ➢ Manage ➢ Plan Diversity Outreach Communication ➢ Advance R&D enterprise Science education Economic diversity	Expertise Education Research Modeling Climate Change Institutions DRI; UNLV; UNR; NSC Comm. Colleges Facilities ACES CAVCAM Computer Ctrs. DST NSCEE NV GC facility SEB SEPHAS GBERL Visual. Labs WRCC Infrastructure AGN CICT Cray XD1 GRSCL Modeling lab NOAA model NEON NV Cooperative Research grid Spatial Labs Partners Policy makers Experts Educators SNWA USBR VV Water Dist. Grants Previous RII Current grants NSF DOE	▶ ▶ ▶ ▶ ▶ ▶	Hire Researchers Technicians Postdocs Conduct Research Classes Colloquia Conferences Seminars Workshops Study Adaptability Climate Change Disturbances Ecological Chnge. Policy Water resources Purchase Hardware Software Technology Tools Develop Books Curriculum Data portal Data sets Databases GRSCL Guidelines Models Networks Paradigms Publications Research teams Reg. modeling Software SSCCN Videos Visualization Education Workshops Lab experiences Symposiums	Researchers Current faculty New faculty Postdocs Students K–12 Undergraduate Graduate STEM majors Journalism Policy Educators K–12 Community College University Partners ID EPSCoR Businesses Educators Experts School districts Managers Media NGOs NM EPSCoR NSBDC NSHE Policy makers SNWA USBR VV Water Dist. EPSCoR Office Administration Staff Coordinators: Evaluation Education Evaluation External Internal: ERTAB Evaluation Coordinator Management Team ERTAB	▶ ▶ ▶ ▶ ▶ ▶	Increased, nationally recognized research production in climate, culture and communications Improved research portfolio quality Human resource development with increased involvement of all groups strengthened by improved K-16 and graduate education in climate studies Increased research investments and materials Increased research collaboration and networking Strengthened infrastructure for sustaining climate change research and public policy decision-making informed by high quality research

Internal Evaluation, External Evaluation and AAAS ↔ Management Team

Focus – Collect NSF RII metrics and other data – Analyze/ interpret data – Report – Refine/Improve

9. SUSTAINABILITY PLAN

Project infrastructure building components will be sustained after five years through (1) increased number of interdisciplinary proposals to competitive programs that will build on new collaborations; (2) continued institutional and state support of faculty, technicians, and facilities; (3) partnerships with government agencies; and (4) mechanisms for cost recovery.

Development of new collaborations and research opportunities: New infrastructure and collaborations will facilitate development of interdisciplinary proposals to crosscutting programs at NSF and other funding agencies. As part of the Interdisciplinary Science Team seed grants, each team will be required to submit a proposal in Year 5 to one of the NSF crosscutting programs or another relevant agency such as NOAA. New faculty hired as part of this project will be required to submit at least one proposal to a competitive program after their 2nd year, utilizing new infrastructure in fostering development of research ideas. Educational strategies will be integrated into undergraduate and graduate curriculums of UNR and UNLV. Further development of the graduate program will be through an IGERT proposal that will be submitted in Year 4. Undergraduate fellowships will continue after Year 5 through REU proposals submitted in Year 4.

State and institutional support: Letters of commitment and support (see Supplementary Documents) demonstrate that there is broad institutional and state support for this program. In addition, a significant amount of state resources have been committed to support various aspects of this project including Nevada EPSCoR staff salaries, graduate student fellowships, interdisciplinary science team seed grants, and minority supplemental startup funds. The institutions also are committed to retaining the seven new faculty hired as part of this proposal beyond duration of NSF EPSCoR funding. Courses and undergraduate and graduate programs will be sustained by the institutes. New cyberinfrastructure will be hosted at the existing Research Grid at UNR, the SEB and NSCEE at UNLV, and DRI. Six new technicians will be supported by a combination of funding sources from each institution and by including support in new proposal budgets. The goal after Year 5 will be for each of these positions to be supported 50% by the state and 50% by grant funds. Nevada's Science and Technology Plan also indicates that climate change is a priority. In Years 3–5, the PIs will work with state officials to identify resources that should be allocated to understand climate impacts.

Partnerships with government agencies: Long-term sustainability of the observational network will be addressed by ongoing and future partnerships with sponsors such as the Natural Resources Conservation Service, National Park Service, BLM, DOE, and non-federal sponsors (e.g., water purveyors, private developers of water resources). The network will be constructed to the standards of the National Ecological Observatory Network (NEON). A Year 5 goal will be for the NSHE system to be a member of NEON and for at least one of the transects to be a candidate NEON site. The Policy, Decision-Making, and Outreach Component also will result in new partnerships between NSHE and stakeholders. The PIs will work with the SAC in identifying key research priorities for Nevada.

Cost recovery: The last strategy for sustainability will be establishment of cost recovery mechanisms to maintain the new infrastructure. In Year 4, the Water and Ecological Change Components, Policy, Decision-Making, and Outreach Component, and Cyberinfrastructure Component will establish mechanisms for faculty to write into their grants use of the new infrastructure. These resources will be used for sustaining key personnel and other maintenance costs. Rates will be set based on experience.

10. MANAGEMENT PLAN

Nevada's climate change RII has a comprehensive structure to effectively manage all aspects of the project. Key features are a Management Team, Leadership Council, NSHE Steering Committees, an External Research and Technical Advisory Board (ERTAB), Stakeholder Advisory Committee, and Ad Hoc Working Groups (Fig. 5). The Management Team will be responsible for administrative and budgetary oversight of the project and will be led by PI/PD (G. Dana) and includes Co-PIs (Lancaster, Piechota, Mensing) who are institutional leads. The Management Team will interact with the project's external evaluator (Dr. Shaw), AAAS review panels, ERTAB, internal evaluator (CRDA), and internal evaluation coordinator (Alice Ward). The Leadership Council – institutional leads and leads for the six components – will be responsible for science oversight and will work to ensure specific components are meeting goals and milestones (Table 3).

Each infrastructure building component will have a three - four member Steering Committee. Steering Committees will be composed of one faculty member each from UNR, UNLV, and DRI with one of those members as component lead, and one of the PIs will act as a liason for each group. The Steering Committee faculty makeup for each component is (component leads are italized): Climate Modeling (*Koracin*, DRI; Bassett, UNR; Yu, UNLV); Ecological Change (Arnone, DRI; *Biondi*, UNR; Riddle, UNLV); Water Resources (*Young*, DRI; Saito, UNR; Devitt, UNLV); Policy, Decision-Making and Outreach (Stone, DRI; Kauneck, UNR; *Smith*, UNLV); Cyberinfrastructure (DRI – to be determined; *Dascalu,* UNR; Latifi, UNLV); Education (Buck, NSC/DRI, Collopy, UNR; Saiidi, UNR; *Hassenzahl*, UNLV). A Stakeholder Advisory Committee will be formed to provide input regarding climate change science, resilience, and opportunities for adaptation. Ad Hoc Technical Working Groups will be formed as needed.

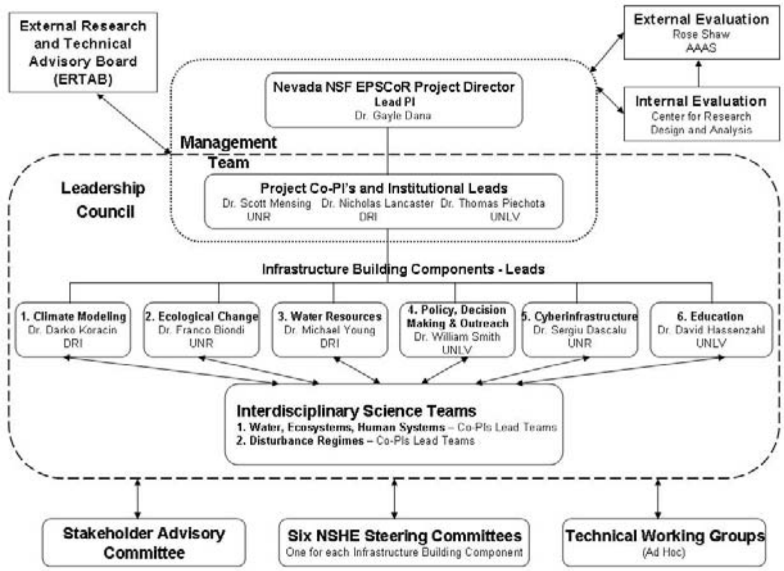


Figure 5. Overall management structure of Nevada's proposed RII

The External Research and Technical Advisory Board will interact with the Management Team and Leadership Council annually. ERTAB will be made up of six national experts in the project's component areas (climate modeling, ecological change, water resources, policy and outreach, cyberinfrastructure, and education), a former Nevada NSF EPSCoR Project Director, and an NSF EPSCoR State Director from Nebraska (Table 5). ERTAB will (1) make five on-campus external site visits (one for each year of the grant) to advise the Management Team; (2) evaluate program progress and suggest corrective actions; and (3) review progress toward achieving outcomes of the Strategic Plan.

Table 5. NV RII External Research and Technical Advisory Board (ERTAB)
• Dr. James Coleman, Vice Provost for Research, Professor, Ecology & Evolutionary Biology, Rice University, Houston, TX (Dr. Coleman is a former NV NSF EPSCoR Project Director)
• Dr. Fred Choobineh, Director, Nebraska EPSCoR, Milton E. Mohr Distinguished Professor of Engineering, University of Nebraska, Lincoln, NE
• Dr. Lai-Yung (Ruby) Leung, Climate Physics Laboratory Fellow, Pacific Northwest Laboratory, Richmond, WA
• Dr. Malcolm Hughes, Regent's Professor, Laboratory of Tree-Ring Research, University of Arizona, Tucson AZ
• Dr. Michael Campana, Director, Institute for Water and Watersheds, Oregon State University, Corvallis, OR
• Dr. Young-Doo Wang, Director and Professor, Environmental and Energy Policy Program, University of Delaware, Newark DE
• Dr. Jeffrey Gray, Associate Professor, Computer and Information Sciences, Univ. of Alabama, Birmingham AL
• Dr. Eban Goodstein Lewis and Clark College, Professor of Economics, Lewis and Clark College, Portland OR

Prior to each site visit, Dr. Dana will prepare a project update synthesizing evaluation findings, project activities, accomplishments, implementation plan variances, and progress barriers. ERTAB will prepare an evaluation after each visit which will be disseminated to the NV Management Team, NV EPSCoR

Leadership Council, and External Evaluator. Other components of the Management Plan include the EPSCoR Governing Committee, the Nevada Statewide EPSCoR Committee (Operations and Management), and EPSCoR Administrative Management Team. The PD coordinates with all these entities to ensure a seamless interface.

Nevada EPSCOR Governing Committee: Nevada recently developed an EPSCoR Advisory Board consisting of 12 industrial partners, legislative council, university faculty, former federal employees, and community members (Fig. 6) knowledgeable about developing research, science, and technology NSHE. This board is determined to enhance training in state colleges to prepare students for matriculation into the research institutions and develop employment skills.

Nevada EPSCoR Governing Committee
Nevada EPSCoR Advisory Board
Dr. Penny Amy, Chair
Dr. Mark Brenner, VPR-UNR
Dr. Hatice Gecol, Director State Office of Energy
Mr. Somer Hollingsworth, President NV Development Authority
Mr. David LaPlante, CEO, Twelve Horses North America
Dr. Christopher Maples, VPR-DRI
Dr. Susan Moore, Senior Policy Advisor, Office NV Lt. Governor
Dr. Katharina Phillips
Mr. Tim Rubald, NV Commission on Economic Development
Dr. Ron Smith, Interim VPR-UNLV
Dr. Troy Wade, Chair, NV Alliance for Defense, Energy & Business
Dr. David Ward, Deputy Director of Scientific Affairs, NV Cancer Institute

Figure 6. The EPSCoR Governing Committee oversees all EPSCoR programs in Nevada.

Nevada Statewide EPSCoR Committee (Operations and Management): All EPSCoR programs in Nevada are under control of the Statewide EPSCoR Committee directed by Dr. Penny Amy, Nevada's State EPSCoR Director. Members of the Committee include the Vice Presidents of Research from DRI, UNLV, and UNR. This body provides policy guidance and oversight of research programs in Nevada, including NSF EPSCoR and all other statewide programs. This arrangement allows central coordination.

EPSCoR Administrative Management Team: The NSF EPSCoR PD works in partnership with Dr. Amy and Dr. William Schulze, Director of the Nevada EPSCoR Office (NEO), in implementing the NSF EPSCoR program. Financial and administrative assistance is provided by the NEO, which administers all of the state EPSCoR programs. Key personnel within the Administrative Management Team include: Pamela Levins (Full-time; NSF EPSCoR Project Administrator) responsible for budget administration, coordination with the NSHE institutions' research offices, collecting baseline information, documenting accomplishments of project milestones, and general administration of sub-awards; Alice Ward (Full-time; NSF EPSCoR) coordinates RII evaluation activities (see Evaluation Plan), education outreach programs, and statewide student solicitations and works with faculty to increase diversity for project components; Communications Specialist (to be hired) responsible for the Nevada EPSCoR quarterly newsletter. This person will provide information and updates for the Web developer, design brochures for specific projects, work with the NSHE PR office for all press media relations, and work with the campus PR staff to incorporate NSF EPSCoR highlights for faculty, staff, and students. Other full-time NEO staff involved in project management include**:** Al Hardimon - financial administration; Lori Brazfield – sub-award preparation and monitoring; Angela Poole and Marilynn Lewis - financial and credit card transactions, travel coordination, and general administrative support. NEO Web site maintenance is provided by Laura Mercer, an independent contractor (consultant).

Sponsored research offices at DRI, UNLV, and UNR support the NEO in managing and reporting NSF EPSCoR expenditures. All offices work together in identifying funding opportunities and statewide collaborations which are then administered through the NSHE office. Campus leaders also collaborate in recognizing additional faculty to facilitate outreach programs. In the case of a succession plan, if key personnel step down from their roles, NSHE works to select a successor familiar with the particular component. In the case of a PD being replaced, a statewide search is conducted by a search committee while an interim director is named.

In addition to technical and administrative assistance provided by the state EPSCoR office, key assistance is included to support infrastructure building components. This includes administrative assistance to run educational programs; a computer system administrator and programmer to support climate modeling; a software developer to create the data portal; a database administrator to maintain the data portal, computing clusters, and resources; and a technician to set up and maintain the field observational network. We also will continue our technical services in high-level editing and pre-submission review to assist faculty in proposal preparation.

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