

Project Description:

WSC-Category 1. Sustainability Dynamics for Water Resources in a Rapidly Urbanizing and Climatically Sensitive Region

INTRODUCTION

This incubation proposal develops an organizing framework for the disciplined understanding of and planning for a water-dependent process of sustainable urbanization in the Spokane, Washington-Coeur d'Alene, Idaho Corridor (SCC). The framework is grounded in an organized process of collaboration between scientists and the SCC communities. The principle guiding this collaboration is inherent in place-based, long-term social-ecological research. We strive to understand interactions across scales—such as fast and slow drivers of social and ecological change, thresholds, traps and time lags—to allow the identification of appropriate operations scales (PECS 2010). Water resources in this area are fundamental to developing theoretical frameworks and models that incorporate linkages and feedbacks among the complex of processes in environmental, social, governmental, and human-built environments. The incubation proposal will use faculty and student teams to build teams, hold workshops, verify sites and develop plans for study site work. Collaborating partners include an interdisciplinary team of social, behavioral, ecological scientists, engineers and extension agents from the University of Idaho (UI) and Washington State University (WSU), two land-grant institutions located eight miles apart, the US Forest Service, the Idaho National Laboratory (INL) and the Coeur d'Alene Indian Tribe. Community stakeholders include representatives from state agencies and city and county governments (letters of support; Supplementary Documents). We have been developing this collaborative with our stakeholders in past years, and recently in preparation for an Urban Long Term Research Area program (ULTRA). The support letters indicate the commitments that continue to be valid for this WSC effort because these stakeholders have identified water resources as the priority for their environmental concerns and the need for teams of scientists to develop the complex array of scientific knowledge pivotal to decision support, policy development, and implementation.

The report (Planning for Climate Change in the West) by the Lincoln Institute of Land Studies and the National Academy of Sciences (NRC 1996) publication on Understanding Risk acknowledge the critical role of local planners in confronting challenges posed by climate change. They also address the region's many political, cultural, demographic, and geographic factors that can be barriers to innovation and effectiveness. Mitigation and adaptation can best be accomplished if implemented on the ground, locally. As stated in the Lincoln Institute report, an array of smart growth strategies, with an emphasis on land use and transportation policies, may double as climate solutions leading to more resilient communities: building codes and standards, compact mixed-use development, transportation alternatives, distributed and renewable energy, water resource consumption and planning, preservation of open space and agriculture, and mitigation of wildfire impacts.

We are identifying an ambitious project that we believe is essential to the development of the program we envision. This incubation proposal initiates those efforts with the work plans developed in each area. The Universities and communities are committed to this as a long-term, interdisciplinary effort and will continue those work plan efforts until completed. At WSU continued development will occur through the Center for Environmental Research, Education and Outreach (CEREO) and particularly the integrated focus on Water, Atmospheric and Human Dimension dynamics, and at UI through Waters of the West, Building Sustainable Communities Initiative and a new office for Urbanization Dynamics.

The incubation proposal is contextualized by long term ecological research and subsequent research programs to understand the rapidly changing dynamic couplings between human and natural systems as influenced by cultural variations, multijurisdictional governance, biophysical factors and to develop a process of integrating science with decision making and policy implementation. The research and stakeholder outreach completed within this incubation proposal will extend existing community-university joint efforts and facilitate the integration of existing and ongoing biophysical research with new data on the human dimensions through collaborative modeling to integrate research with education. In the process, this will create mechanisms for outreach and engagement.

Water touches every aspect of community sustainability from law to culture to environmental drivers. There have been extensive studies in the SCC area, in some cases over many decades, along with

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numerous modeling activities that qualify it as a place-based research area. Currently, these actions are independent, by organization and disciplinary area. The challenge remains to identify, integrate and analyze myriad data types, and develop methods for integrating the independent modeling efforts on surface and aquifer hydrology, engineering solutions, remediation/restoration, atmosphere dynamics including climate scenarios, demographics, transportation, landscape transitions, and local land use planning under the laws of the state and nation. *A primary innovation will be the integration and optimization of modeling efforts across the multiple dimensions represented by disciplinary approaches to shape urbanization patterns for sustainable solutions.*

Overarching Goal of the WSC Incubation Project is to improve the understanding of linkages between human dimensions and water resources as a coupled human-natural system (CHANS) in order to better enact a sustainable and resilient water system. We are continuing to use our S-TURNS framework (Shaping the Trajectory of Urban and Regional use of Nature toward Sustainable communities) and CHANS approaches in this incubation effort. Within the WSC overarching goal, we will achieve four interrelated objectives during the two-year incubation project:

Objective One: Systematically integrate data/products from existing biophysical and engineering model outputs including water quantity, quality, climate simulations, land use, and pollution sources.

Objective Two: Collect new data on how human dimensions within the SCC impact sustainable management of water resources. Consistent with the CHANS approach, the following conceptual foci emerged from stakeholder engagement and scientific expertise.

Part A: Assess political jurisdiction impact on decision making for sustainable water management.

Part B: Analyze cultural and local ecological knowledge of water management and different groups' concepts and values of sustainability.

Part C: Assay the types of uncertainty manifest among political jurisdictions and social networks and assess its impact on decision making regarding sustainable water management.

Objective Three: Integrate biophysical and human dimensions data through two parallel yet distinct modeling efforts.

Part A. Utilize Modelcenter software to develop statistical, graphical, and decision-related algorithms to assess the economic and ecological costs and benefits of alternative eco-urban policies.

Part B. Engage the biophysical and social scientists in a collaborative systems dynamic modeling (CSDM) process to include poorly understood cultural and institutional variables in these models. The modeling process will drive interdisciplinary collaboration and thinking, capture the feedbacks between traditionally segregated disciplines and data, and include the development of hypotheses and data needs for a future WSC-2 project.

Objective Four. Build future interdisciplinary intellectual capacity through an education and engagement program that involves current and future partners and stakeholders.

Through these objectives, the WSC team will utilize the incubation grant to perform a targeted analysis of the S-TURNS framework (see below), focusing primarily on phase a of the framework with limited treatment of parts b and c. Emphasis on phase a will yield a baseline for future integration, understanding and prediction of the coupled human and natural systems in the SCC.

S-TURNS framework. Our incubation proposal utilizes a recursive process of feedforward from stakeholders and feedback from the scientific knowledge gained about the dynamics of water resource issues in an urbanizing ecosystem (see Figure 1). The model begins at a point on the urbanizing trajectory (a) during which stakeholders and partners provide local knowledge about the water resource issues, social and ecosystem drivers and nature of urbanization, and the consequences of past actions and consideration of current patterns. The assessment provides a structured framework for development of

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hypotheses and research questions based on stakeholder-partner input. Research teams then utilize systematic procedures (b), including modeling, for integrating the social, behavioral, ecological, engineering and technical sciences in interdisciplinary research on human-natural systems. This phase is represented by CHANS (Liu, et al. 2007a,b; Rosa et al., 2010), a framework that permits flexibility in the application of a wide range of analytic tools including conceptual and qualitative stakeholder modeling, mathematical and statistical models, computer simulation systems, and geographic information systems. The next phase (c) is re-engagement of partners and stakeholders in the deliberative process to develop refined and/or new research hypotheses and questions that feed forward into the CHANS framework (d) as the process moves forward in time. The outcome of the recursive process is a continued generation of new knowledge that will be applied towards shaping a sustainable urbanization trajectory.

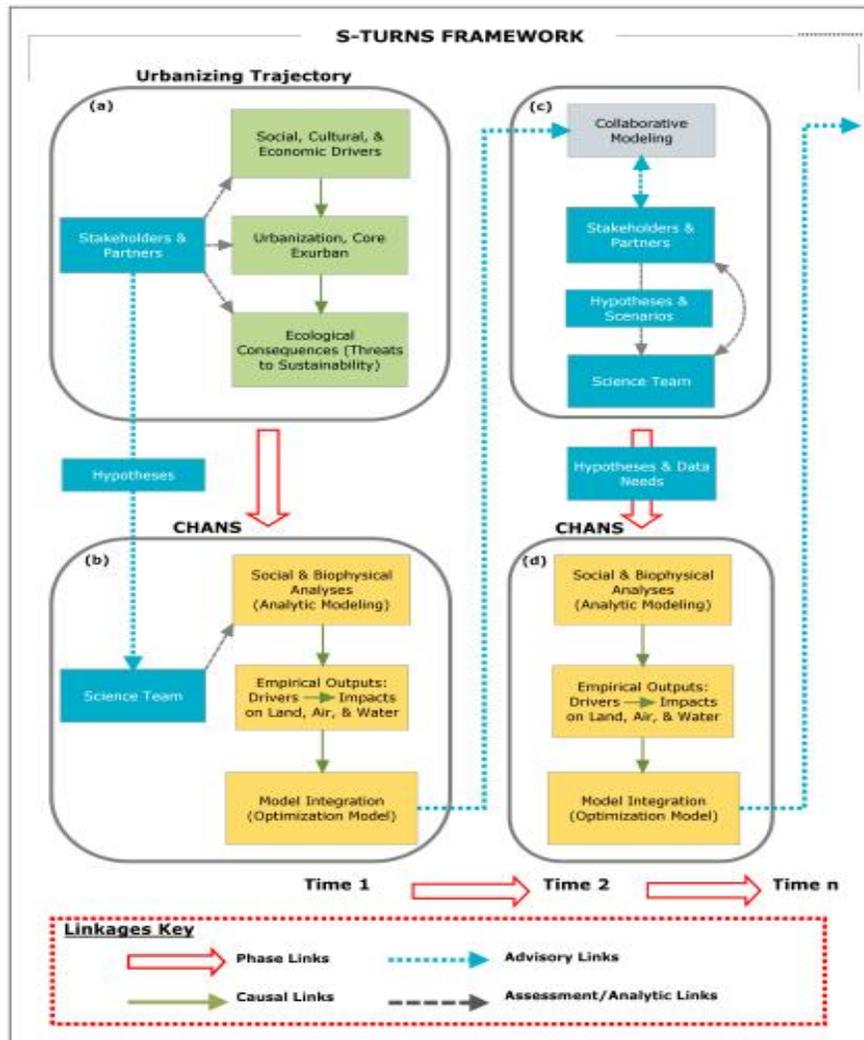


Figure 1. S-TURNS schematic.

The SCC as exemplar of water resource and diverse urbanization processes in coupled human-nature interactions. The western U.S. is experiencing new urbanization patterns associated with amenity-driven growth that often connects amenity sites (e.g., lakes, rivers, mountains, natural habitats) to urban centers and surrounding development, and places accelerated pressure on natural resources (e.g., water). Exurban development patterns have been found to consume 11 times the land areas as suburban

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development and to result in density of land fragmentation that affects water quality (Clark et al. 2009, Theobald 2005). Because areas within the SCC differ with regard to the interplay of environment, culture, history, growth patterns, development objectives, and regulations, the area typifies the complexities that appear within much larger areas. The SCC is an important natural laboratory because it is still in the early stages of large-scale urbanization with the potential to shape urbanization patterns in the future. This state of development amplifies the complexity of the social and biophysical factors that must be integrated into sustainability issues. The SCC exhibits complex social and biophysical interactions. Development along the corridor has been guided by jurisdictional issues of contrasting state (WA: mandatory Growing Smart v. ID: voluntary and private) and tribal management strategies (Althouse 2001). The diversity of interests and values are linked by the Spokane River and its surrounding watershed and airshed, which are managed by a complex and overlapping set of entities from sovereign tribal governments to small cities, county governments, watershed districts, special purpose non-governmental organizations, and the US Forest Service. *A measure of the success of the proposed plan will be the ability of the incubation process to design a program that advances scientific understanding of the coupled natural and environmental changes inherent in urbanization processes, leading to improved capacity of stakeholders to interpret and apply that knowledge in their decision-making.*

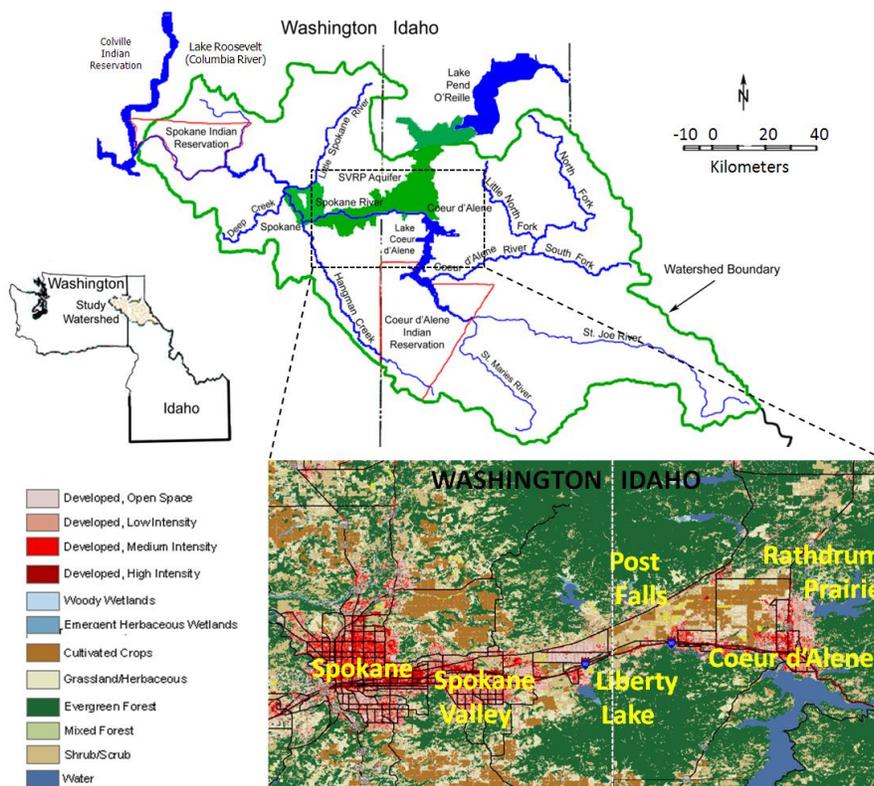


Figure 2. S-TURNS and SCC Research Area.

Spokane (pop. 600,000) is an older, industrial city while Coeur d'Alene City (pop. 140,000) is rapidly growing (40.5% growth from 1990-2000), due to the numerous recreational amenities of Coeur d'Alene Lake and adjacent National Forests. These endpoints are connected by rapidly growing smaller cities with a diversity of ecological settings and urban planning cultures and practices.

The SCC overlies the Spokane Valley-Rathdrum Prairie (SVRP) Aquifer, a transboundary sole-source aquifer. This sole source of drinking water (Fig. 2) is linked to Lake Pend Oreille, a large lake outside of the basin but with subsurface connectivity, and the Spokane River through

complex stream-aquifer relationships (Barber et al. 2009). It is susceptible to historic and future contamination from both urban and industrial sources. Multiple county and city governments within the SCC are currently in dispute over development in the SVRP prairie, and a number of cross-boundary NGOs are trying to reduce development over this fragile aquifer. The Coeur d'Alene Lake system has two major rivers and many tributaries flowing into and mixing with lake waters that then discharge to create the Spokane River. The surface water-groundwater system is directly influenced by land uses throughout the Coeur d'Alene Lake Basin. The 2009 Lake Management Plan is a collaboration between the Idaho

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Department of Environmental Quality and the Coeur d'Alene Indian Tribe (DEQ/Tribe Pub. 2009), an example of the same kind of collaborative processes proposed here. The SCC also represents a transition or gradient from an urban/agricultural interface on the south and west to a mountainous urban-forest interface on the north and east that will change in coming decades (Fig. 2).

The Bunker Hill Superfund site near Kellogg, Idaho, upstream (east) from Lake Coeur d'Alene, is a particularly vivid example of the conflicts of values and ethical problems that occur in a modern technological society. Located in an area known as the "Silver Valley" for its large number of mines, mine drainage flows into Lake Coeur d'Alene on the Coeur d'Alene Indian Reservation about 40 miles downstream, in the SCC area. A recent detailed 3D physical-biological-chemical model of Coeur d'Alene Lake explored how the lake may respond to altered loading of zinc (Zn) and nutrients from the dominant inflows from mining and urban development areas (Hipsey et al. 2006). The analysis used the Computational Aquatic Ecosystem Dynamics Model (CAEDYM), coupled with the 3D hydrodynamic model ELCOM. The report has used the validated model to examine the sensitivity of the lake to a range of long-term scenarios, which provided insights into the impact of remedial actions. Results show a combination of low phosphorus and Zn toxicity keeps the lake's algal biomass at an acceptable level. Efforts to alleviate loadings of Zn from the Coeur d'Alene River into the lake are unlikely to manifest in any significant reduction in Zn toxicity in the near term. (Kuwabara *et al.* 2006).

Climate dynamics in this area are predicted to affect water availability during the coming decades. The area is located at a boundary between maritime and continental air masses with annual and interannual dynamics causing significant patterns in precipitation patterns. Regional snowpack, and hence long-term water availability, are "at risk" with projected climate change (*sensu* Nolin and Daly 2006), and data at the Priest River Experimental Forest north of Coeur d'Alene show a decrease in snowpack from 18 cm to 12 cm in the March snow water equivalent from 1940 to 2005. Snow accumulations in the National Forests adjacent to SCC exist at temperatures close to the melting point, placing the system at risk of major changes because snowmelt represents the primary mechanism of soil recharge and the primary source of runoff for headwater streams and aquifer recharge. As we explore the likely future changes in basin hydrology, we will simultaneously investigate their implications for future urban water availability.

Urbanization is also significantly impacting air quality, due to in part to complex commuting patterns associated with amenity-driven development outside the urban core. Prevailing winds result in a net transport of nitrogen and other pollutants from Spokane and upwind areas into Coeur d'Alene and surrounding forested ecosystems that can influence water quality. Dynamism, uncertainty, and complexity dominate human-ecological systems (Leach 2008), and management requires cross-scale and dynamic science (Cash et al. 2006).

DEVELOPMENT OF OBJECTIVES INTO A RESEARCH AND EDUCATION PROGRAM

Objective one, Biophysical Models:

Water Quantity/Ground Water Dynamics (Leads: Adam, Boll, Keller, Goodwin, Vierling). Water quality in the Spokane River and Lake Coeur d'Alene is largely a function of water quantity, much of which is generated upstream in snowmelt-fed tributaries. Consequently, large-scale hydrologic simulation of the entire watershed is needed. The Variable Infiltration Capacity (VIC) hydrologic model will be used to simulate the large-scale impacts of climate and land use/land cover change on surface water hydrology over the entire watershed. Development of this widely applied research model (Liang et al. 1994, Cherkauer & Lettenmaier 1999) is a continuing process with our team members. Models will be informed by the social science components in this project to improve predictors of land use policy decisions by multiple jurisdictions (Langridge 2002). Understanding water resources in the SCC necessitates linking of the surface hydrology model to a groundwater hydrology model. Groundwater modeling of the SVRP Aquifer is currently being conducted to assess the availability of water resources in the region, and was developed collaboratively by the Idaho Department of Water Resources, the University of Idaho, the U.S.

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Geological Survey, and Washington State University. The model is based upon the groundwater flow model MODFLOW-2000, simulates flow in the aquifer and its interaction with the surface water, and includes all known components of inflows to and outflows from the aquifer (Hsieh et al. 2007).

Work Plan. VIC has been primarily employed at broad scales (e.g., Hamlet & Lettenmaier 1999, Matheussen et al. 2000, Maurer et al. 2002, and Elsner et al. 2009). Utilizing VIC watershed-scale simulation to study the Spokane River basin, we will use the calibrated and evaluated VIC model implemented for the Pacific Northwest with a pixel resolution of ~5 km by 7 km as described by Elsner et al. (2009). We will also integrate with the model customized for Lake Coeur d'Alene developed by the Coeur d'Alene Tribe and Department of Environmental Quality. This model simulates processes within the lake system such as: (1) inflow loading of metals and nutrients, and river plume flow through the lake, (2) sediment-water interactions, (3) primary production, and (4) organic matter cycling within the water column. Results from modeling will be integrated with other modeling efforts under Objective 3 to understand the dynamic interactions between urban growth, water quantity/quality, and air quality. The large scale modeling with VIC will be complemented by comparisons with smaller scale modeling to evaluate adaptation scenarios at the scale of smaller watersheds contributing to the basin. Examples are a GIS-based hydrology modeling, including climate change scenario testing in collaboration with climate modeling. These efforts can also integrate with water quality modeling, particularly the water and erosion modeling using the Water Erosion Prediction Project model (WEPP). It is already being used by several in the study area on effects of fire, roads, and hillslope management. Use of the groundwater flow model (MODFLOW-2000) will allow us to incorporate input from climate change scenarios (effect on supply) and land use and population growth (effect on demand), which will be incorporated into integrated modeling in Objective 3.

Baseline and Future Climate Simulations (Leads: Lamb, Waldon, Ankeny). Climate modeling is critical to future water supply scenarios. To account for climate change effects, the Laboratory for Atmospheric Research (LAR) is conducting regional climate modeling to investigate the impacts of global change upon air quality for the 2050's (Chen et al. 2009; Avise et al. 2009). This involves using output from global climate and chemistry models to drive continental and regional scale weather and atmospheric chemistry models to simulate future conditions in the US. The regional models are the same as used in the AIRPACT daily forecast system and include the Weather Research Forecast (WRF) model. For the future climate simulations, the impact of global changes as well as the impact of changes in US emissions, including biogenic and fire emissions, US land use policy decisions (with poorly modeled impacts), and US weather patterns are explicitly taken into account. These future climate simulations include downscaling of global model simulations via the WRF weather model to yield the detailed meteorological inputs needed to drive the water resource modeling components for future case scenarios.

Work plan. To capture the range of uncertainty in predicted future climate, we will use an ensemble of climate model output covering a range of greenhouse gas emissions scenarios (i.e., A2, A1B, and B1, which are often used for high, mid, and low emissions, respectively). With the access we have to high resolution regional climate simulations, we are well positioned to examine the impact of climate change in concert with social and urban changes within the SCC. We also have addressed downscaling modeling through monthly outputs from many models (20+) and three scenarios at 4-km resolution for temperature and precipitation from 2000 to 2100, which gives us similar capabilities to the Climate Impacts Group at the University of Washington. Our work has made some improvements to their standard statistical downscaling method, especially in the areas of how data are interpolated and spatially-aggregated, and in how the extreme values of the cumulative distribution functions of temperature and precipitation are dealt with. These data provide good guidance on general trends of climate change in Idaho. We also have daily data at 8-km resolution, but for many more variables (Tmax, Tmin, Precip, RHmin, RHmax, 10-m meridional wind, 10-m zonal wind) and have run this technique on 13 models and one scenario. This new downscaling method has been developed by John Abatzoglou at U. Idaho and is called the "multi-variate, bias-corrected, constructed-analog method". This technique retains the co-variability between the various

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climatic variables. These data have already proved valuable because they are at a daily time resolution.

Non-point Source Pollution & Basin Erosion (Leads: Yager, Vierling, Galindo, Keller). Physical transport of sediment in the Coeur d'Alene River, floodplain, and Lake will significantly alter the spatial distribution and quantity of contaminated sediment deposits in the basin. Little is known about transport of contaminated sediment in the Coeur d'Alene River. The short-term measurements of bedload and suspended load are not of sufficient lengths to extrapolate long-term trends and do not specifically target contaminated sediment (Clark and Woods 2001). Furthermore, although 1-D and 2-D hydrodynamic (flow and sediment) modeling has been conducted, these studies have limited spatial extent and few tested hydrographs (Berenbrock & Tranmer 2008). Nor do they model the mobility of contaminated deposits or link to sediment transport models for the Coeur d'Alene Lake. None of the current hydrodynamic models account for boat-wave induced erosion of river levees, which can be a significant source of sediment input to Lake Coeur d'Alene (Earth Systems 2004). Altered hydrograph shapes, peak magnitudes, timing, and duration caused by climate change further increase the uncertainty in using current measurements and predictions of sediment flux.

2-D hydrodynamic models (e.g. MD-SWIMS, USGS; MIKE 21c, DHI), linked with hydrographs predicted using downscaled climate predictions and VIC modeling, could be used to calculate the transport and deposition of contaminated sediment for a range of future climate scenarios. These results will be used by other teams on this proposal to: (1) link with the ELCOM-CAEDYM models to better understand the input and transport of contaminated sediment in Lake Coeur d'Alene, (2) assist the public plan for future development of areas with potential deposition of contaminated sediment, (3) provide information for possible mitigation and restoration scenarios such as stabilization of contaminated sediment and addition of riparian vegetation to add bank strength, (4) provide non-point sources of metal pollution for water quality calculations, and (5) evaluate the impact of climate change on physical parameters (flow depth, velocity, shear stress, grain size distribution, sediment transport rates) in river channels that influence the available aquatic habitat.

Work Plan. We will assemble current measurements of water quality and bedload, suspended load, erosion, deposition, and grain sizes of sediment within the Coeur d'Alene river system. These data are needed to better understand the necessary future measurements in the basin. We will also construct a database of the current spatial extent of contaminated sediments within the Coeur d'Alene basin, hydrographs and recurrence intervals from active and inactive gages, and any hydraulic measurements (e.g. stage, velocity) necessary to calibrate a 2-D flow model. We will work with stakeholders and the USGS to identify existing hydrodynamic models for the Coeur d'Alene River and the model output parameters important to individual stakeholders. Finally, we will identify computational methods to link these models to the ELCOM-CAEDYM, QUAL2K, and VIC models.

Water Quality (Leads: Adam, Boll, Evans, Caudill, Keller). The VIC large-scale hydrology model and the aquifer groundwater flow model provide the spatial distribution of surface and ground water quantity in the Spokane system. These models will be linked to the water quality model, QUAL2K, which is a steady-state, 1-dimensional model to simulate water quality in well-mixed streams and rivers (Barnwell and Brown 1987). QUAL2K accounts for the effects of the diurnal cycle on water quality variables by simulating the heat budget as a function of diurnal meteorology. Point and non-point loads and abstractions are accounted for. Simulated water constituents include temperature, coliform bacteria, nitrogen, biochemical oxygen demand, algae, phosphorus, and dissolved oxygen. The model was developed by the U.S. Environmental Protection Agency (EPA) to use as a water quality planning tool in developing total maximum daily loads (TMDLs).

Work Plan. Through this incubation project, we will integrate surface, groundwater, and water quality components to yield a comprehensive system for simulation of water issues in the region. We will also utilize a model customized for Lake Coeur d'Alene (ELCOM-CAEDYM), funded through the Coeur d'Alene Basin Environmental Improvement Project Commission (BEIPC) with an EPA CWA grant. This

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model simulates important processes within the lake system including; (1) inflow loading of metals and nutrients, and river plume flow through the lake, (2) sediment-water interactions, (3) primary production, and (4) organic matter cycling within the water column. Results from this work will be valuable for comparison to the results from our integrated water resource and water quality modeling components

Land Use Transitions (Leads: Kang, Lowry, Vierling). The incubation project will explore how the dynamics of urban growth can use a probability matrix measuring transitions between present and future land use categories (Dezzani and Al-Dousari 2001, Pontius et al. 2004). We will evaluate a model based on a conditional probability, autologistic Markov random field (MRF) specification. Different from other regression methods, this approach utilizes inherent spatial and temporal dependence structures as a mechanism for determining the direction and rates-of-change over specific time periods.

Work Plan. We will develop spatially segmented models to account for the diverse land use patterns and regulations among different cities in the SCC. A unique advantage of this method is its ability to assess the rate of change for different spatial and temporal scales. These analyses—requiring very accurate, refined land use data—will use Landsat TM images (30 m) from different years, resulting in projections of changes in land use type and vegetation cover. Future change can be simulated with multiple “what if” scenarios that project different urban growth patterns and future development trajectories. Future land use patterns under different management strategies will be projected using the MRF model. The model will describe the overall changes in types of land use and will also provide estimates of where land use changes are likely to occur (Dezzani & Al-Dousari 2001), based on proposed transportation developments and other factors. One less-explored area addressed in following objectives relates to how to measure land use policy variables that affect predictions.

Objective two, Human Dimensions:

Part A: Planning and Jurisdiction (Leads: Pinel, Long, Norton). Landscapes that evoke the sustained attention of people are more likely to be ecologically maintained in a world dominated by humans (Nassauer 1997). Decision processes and policy implementation of water systems are necessarily impacted by political jurisdiction, cultural understanding, and uncertainty about both water systems and the politics involved in policy development and implementation. This study investigates: (1) the theoretically and stakeholder-generated hypothesis that fragmented governance impedes the implementation of climate-oriented land use and development policies that reduce exurban development to concentrate growth in existing urban areas, and (2) collaborative spatial planning theory (Healey 2006, Innes 2008, Porter 2005) by comparing how differing state institutional systems affect local government and water management. The State of Washington November 2008 report, *Leading the Way: Implementing Practical Solutions to Climate Change*, recommended strengthening the state’s 1990 Growth Management Act and the state’s Environmental Policy Act by including regional planning standards and incentives through all levels of government for comprehensive plans that encourage urban infill and reduce vehicle travel. The report concluded “Climate friendly development” approaches increase densities in already developed areas with good access to transportation options, jobs, and services.

The challenge is that local officials do not necessarily agree with climate science, especially in the Intermountain West (Carter and Culp 2010). This emphasis on bottom-up, voluntary, networked, collaborative, and coalition-building approaches to local and regional planning reflects political limitations without attention to the institutional challenges involved with overcoming fragmented decision-making, especially given amenities that extend along urban to rural wildland corridors. The SCC thus provides an excellent case study to better understand how western planners emphasize sustainable local and regional land use planning and to interrogate the limits of collaborative approaches to cross-jurisdictional governance (Soule 2007).

Work Plan. The incubation effort proposes a case study of the Spokane-Coeur d’Alene Corridor that combines analysis of geospatial and network dynamics, ethnographic interview, participant observation, and survey data to understand how regional growth measures are differentially adopted in distinct

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jurisdictions. The investigators will explore how local and tribal government officials on each side of the state line; (1) explain their decisions whether or not to adopt the “sustainable land use” policies to reduce impacts to water quantity and quality, and (2) regulate rural sprawl (unsewered development over the aquifer) and non-point-source pollution through stormwater management policies. Expert interviews, coding of minutes and text, and narrative discourse analysis will be used to analyze the structure and agency variables important in these policy decisions.

We expect a number of variables will go into those policy stalemates or decisions, including the incentives and penalties imposed by federal and state regulatory agencies; differing state land use and water quality standards and administrative systems, legal distribution of responsibility, authority, and power for land use decisions in the region; records of city and county decisions for a small representative sample of cities and counties; and legal pluralism (shopping for the best rules). We will compare findings with the agent-based framework (Zellner et al. 2009) that applied gaming theory to amenity-based and exurban areas and considered how four types of public and private actors would choose between forest cover and tax revenue values in making land use or zoning decisions. That research recommended empirical work on the model to add dependent variables, understand agency interactions, and apply to parcel-level data. This social research into jurisdictional complexity is critical to the value of the models described above because human responses are mediated by culture and institutions.

Part B: Cultural conceptualizations of water and water use in the SCC (Leads: Norton, Peterson, Salvador, Pinel). Social and ecological scientists recognize the importance of local-based ecological knowledge and cultural values. For example, the SCC stakeholders are strongly divided on ideas about climate variability and change, with some officials resistant to climate dynamics and others supporting the idea of global warming. We propose a community-based participatory research (CBPR) approach to better understand the way cultural values and norms impact individual and collective decision-making of water use. CBPR has gained esteem because it combines the ability to conduct locally-driven research with the potential to generate social action and change.

Specifically, we will engage a wide-range of stakeholders through a CBPR technique called Photovoice that engages stakeholders to solicit visual and narrative aspects of culture regarding their use of natural resources and promotes “civic engagement” among disparate stakeholders. This provides critical information on local-ecological knowledge on water sustainability issues and represents a critical feedforward process on how to incorporate sustainable water structures. Photovoice has been used as formative research to promote culturally appropriate practices, thus leading to greater likelihood of incorporation of sustainability efforts. “If we align the aesthetic experiences that people already value with the ecological health they do not know how to recognize, we can build landscape ecological structure while we are building new cultural expectations for ecological health” (Nassauer, 1997).

Work Plan: The planned Photovoice process will consist of four steps (recruitment, two rounds of implementation, and dissemination) to be followed by a potential fifth step (cultural adaptation of processes, practices, and products). First, the investigators and 5-6 graduate students from the WSU Murrow College of Communication will recruit community stakeholders to an informational session to discuss their thoughts on urbanization and the issues surrounding sustainable community building in the Spokane-Coeur d’Alene Corridor area. Following, they will be introduced to the Photovoice method. Interested participants will be given 2 weeks to photograph images in their community that illustrate their values and perspectives on water use, community, and sustainability. Subsequently, images will be collected and developed for the first of two consensus group meetings. In this first group meeting, breakout groups will select and share 3-5 of their most powerful images. Trained facilitators will guide the discussion toward group thematization. Individuals will then meet as a larger group to discuss similarities and differences followed by discussion of plans for a “second round” of images. Discussion after the second round of images will focus on potential avenues for dissemination of the results of the process to targeted audiences including decision makers and stakeholders or to a public audience.

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Although the process models action toward sharing vision and resolving conflicts, we believe that engagement alone is a positive outcome in itself.

Part C: Human Uncertainty and Decision Making (Leads: Norton, Sias, Gaffney). Deliberating about the future of the SSC entails dealing with a great deal of uncertainty, including uncertainty about water issues (e.g., how will development and urbanization impact water quantity and quality; how jurisdiction issues impact urbanization and water use; and potentially, what efficacy conservation in one jurisdiction will have given multiple water users across multiple jurisdictions). As recent reports from the Congressional Budget Office (Holtz-Eakin 2005) and the Climate Change Science Program (Morgan et al. 2009) highlight, uncertainty regarding how to meaningfully use scientific information is a complex yet necessary process in social phenomenon. Uncertainty has important impacts on deliberation and decision making, leading both individuals and social collectives to avoid or delay making decisions (Germeijs & De Boeck 2003), to employ different and perhaps faulty cognitive shortcuts (a.k.a., heuristics) in decision making (Shafir & Tversky 1992), and to experience doubt regarding decisions made under conditions of uncertainty (Jordan 1960). Moreover, public deliberations about right to natural resource management use in the western United States is often characterized by a political divide between individual and collectivist rights to use (Norton 2008) and need to be tested longitudinally (Norton 2009, Sias & Wyers 2001). Understanding stakeholder uncertainty is critical to designing and carrying out effective collaboration among multi-jurisdictional stakeholders and the social and biophysical scientific expertise within the S-TURNS team. We will use existing uncertainty and uncertainty management models (e.g., Kramer 2004) to obtain data from relevant stakeholders, various jurisdictions via interviews, focus groups, and surveys to assess: (1) areas and issues about which the stakeholders are uncertain with respect to the SSC, (2) the amount of uncertainty stakeholders experience about SSC water and urbanizing issues, (3) the strategies stakeholders rely upon to manage their uncertainty, and (4) the perceived effectiveness of those uncertainty management strategies. We will then examine and develop methods for providing information and disseminating knowledge to reduce stakeholder uncertainty most effectively.

Work Plan: The above-listed investigators will train undergraduate students in Norton's senior research course (Communication Studies 475). For the past two years, students in this course have gained competency in both climate change issues and social research methods to perform large-scale qualitative and quantitative assessments. Specifically, students will proctor structured interviews, focus groups, and surveys with a range of stakeholders within the SCC including especially city and county public officials, different types of agricultural producers, mobile business contractors such as window washers and vent cleaners, and community development associations. Interview and survey data will inform focus group discussions, which, in turn, will inform Collaborative Systems Dynamics Modeling (Objective 3, below)

These objectives—jurisdiction, cultural values of and uncertainty about water and jurisdiction—are surely not the only salient couplings of the human and natural systems. We propose studying these three couplings as they respond to engagement between the science team and community stakeholders.

Objective three, Integrated Modeling of Biophysical and Human Dimensions:

Part A: Optimization Modeling: (Leads: Beall, Ankeny, Kang). The first part of this objective's task will consist of optimization modeling by the Energy Resource Recovery and Management Department at Idaho National Laboratory, located in Idaho Falls (INL; letter of commitment). This takes advantage of the computational models of ecosystem services, economics, and technologies being developed independently by multidisciplinary teams of scientists and engineers at many institutions. INL scientists integrate various numerical tools, including Geographical Information Systems (GIS), Multiple Criteria Multiple Alternatives Decision Support Systems (MCMA), and an integrated modeling environment (IME). IME describes an overall framework and associated software used to simulate large complex systems through comprehensive computational, statistical, graphical, and decision-related algorithms that integrate the contributions of many scientists. Through the internet, the IME can connect models running on computers located anywhere in the world, enabling our interaction despite the distance

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between the SCC study site and INL. INL has acquired Phoenix Integration's Modelcenter, which has been successfully used by specialty teams at different locations needing integrated optimization and tradeoff capabilities. It is implementable on supercomputers available to us as a requirement for the large data sets we will be manipulating. For the incubation project, outputs from the social and biophysical models can be input to Modelcenter, and its optimization objective functions can be used to assess the economic and ecological costs and benefits of alternative eco-urban policies.

Part B: Collaborative System Dynamics Modeling (CSDM) (Leads: Beall, Ford, Norton, Gaffney). This objective represents a comparison technique to the optimization modeling effort to fully develop new scenarios. Translation of complex scientific evidence to policy audiences has been successfully accomplished through collaborative modeling processes using system dynamics (Stave 2002, Tidwell 2004, USACE 2007). Such modeling processes are typically focused on a single resource (e.g., an endangered species) or quantity of available water, and are often initiated as the result of a social conflict. We will use this process in the incubation project to move our team from a group of people working in multiple disciplines to a fully interdisciplinary collaborative effort. This incubation effort will prepare us to fully integrate scientists with local stakeholders.

System dynamics modeling was developed by Jay Forrester (Forrester 1961) as a method to gain understanding about the dynamics of a system through the exploration of its structure. This methodology helps us shift our focus from single pieces (or disciplines) of a system to the connections between those pieces. This modeling paradigm is uniquely suited to capture feedback, time lags, and policy choices that are inherent to interdisciplinary modeling. We will use CSDM as a method to integrate multiple biophysical disciplines (objective 1) with multiple dimensions of the human system (objective 2). The first step of such a process is to facilitate the translation of biophysical and social parameters through the iterative process that creates an interdisciplinary system dynamics model capable of dynamic simulation. Through this translation process CSDM provides the opportunity to explore relationships and feedbacks between a variety of data types and variables that are typically not integrated. The result is a better understanding of system behavior and identification of unforeseen research questions, hypotheses, and data needs (Gardiner & Ford 1980, Beall & Zeoli 2008, Langsdale et al. 2009, Ford 2009). Using the sensitivity analysis capabilities of system dynamics software such as STELLA or VENSIM users, through simulation exploration, can identify areas of uncertainty or highly sensitivity for parameters that cannot be captured in discipline specific models.

The CSDM process is capable of advancing the team to a future WSC 2 project with a fully interdisciplinary frame of reference, rather than simply a multidisciplinary team integrating information when the opportunity arises. This will give the team a better understanding of stakeholder needs and challenges. Furthermore this perspective will move us away from single discipline driven data collection and help drive creative integrative scientific research that is focused on helping solve sustainability related problems. Scientists with this integrative perspective will be well suited for helping stakeholders manage the complexities of the SCC system for a sustainable future.

Work Plan: We will conduct 4-6 workshops with the science team over the course of two years with individual meetings as needed. Researcher will initially design a map of "the system". A simulation model will then be built through an iterative process that creates simulations early with generalized data from past research or hypothesized data from future work. Simulation analysis will drive iterative development of the model and will assist with hypothesis development and testing (Beall and Ford 2010).

Strategic Planning for Research Data Management (Leads: Gollberg, Gosz, Lamb, Norton). The University of Idaho is implementing a Data Management Initiative (Northwest Knowledge Network) that will be staffed and provide services for the region. A strategic plan has been developed for its research data management system with the mission of making multidisciplinary research data more accessible, comprehensible, usable, and secure for data providers and data users. The plan will complement the University's current cyberinfrastructure capability and the statewide cyberinfrastructure strategic plan by promoting commonly accepted policies, standards, and protocols and supplying services (e.g., secure data

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storage, seamless discovery, exploration, transfer of data between and with user groups, etc.) that are adaptive to changing data management and storage needs. The objectives of the Northwest Knowledge Network are to provide: (1) backup for data created by currently funded projects, (2) archival storage of project data once a project is complete and closed, (3) support staff who will work with researchers to catalog their data, (4) secure mechanisms for researchers to share their data in a controlled environment, (5) when otherwise unavailable and appropriate, provide public access to data, and (6) support for tools (e.g., for discovery, visualization, analytics, etc.) that will enhance interoperability of the data and the overall utility of the system. The incubation award would begin the process of accessing and archiving existing and new data to be managed by the Northwest Knowledge Network.

***Objective Four.** Build future interdisciplinary intellectual capacity through an education and engagement program that involves current and future partners and stakeholders.*

Embedding broader impacts in the incubation program planning (Leads: Mulkey, Gaffney, Galindo, Norton, Oliver, Sias). The involvement of stakeholders and partners is key to the iterative use of the project's social and biophysical modeling efforts. The WSC project will require an education and engagement program that involves core stakeholders (cf., Hungerford and Volk 1990, Joerin et al. 2009, Tidwell et al. 2008). The public workshops of the CSDM will provide a platform for education and exchange of information with stakeholders during the two years of this award. Thus the incubation effort will function to meet NSF criteria for broader impacts consisting of the following: (1) public fora that **advance discovery and understanding**, (2) **broad dissemination** of products to stakeholders and publics throughout the SCC, and (3) the delivery of **direct benefits to society** through the exploration of policy options with decision-makers. The WSC program will partner with education programs to **provide STEM** (Science, Technology, Engineering, and Mathematics) and sustainability products **for K-12 programming and teacher training**. In partnerships with the tribes, we will **focus on integrating underrepresented groups into the research planning effort** and will engage indigenous and non-indigenous graduate students in development of stakeholder workshops and education programs. Integrating is cultures also a valuable broader impact.

Necessity of keystone partnerships with tribes (Leads: Galindo, Mulkey). The Coeur d'Alene, Spokane, and Colville Tribes own extensive property and resource rights throughout the region that will be affected by urbanization. With their rich culture and history, they are essential partners in the research and outreach of the WSC effort. The Coeur d'Alene Tribe plays a key role through ownership of the southern portion of Lake Coeur d'Alene, for which they maintain extensive GIS data layers and data on water quality. Representatives of the Coeur d'Alene Tribe have committed to this project (Supplementary documents). UI Extension will facilitate access to tribal data and information through its established relationship with the Coeur d'Alene Tribe, while WSU Extension will perform similar services through arrangements with the Spokane and Colville Tribes.

Active Extension programs of UI and WSU enhance the opportunity for local engagement in this project. WSU Extension's offices in Spokane and Spokane County, along with its Tribal Extension programs (especially its Federally Recognized Tribes Extension Program (FRTEP) with the Colville Tribe) complement UI Extension presence in Kootenai County and Coeur d'Alene and the UI Extension Educator, Laura Laumatia, located in the Coeur d'Alene Tribe's Natural Resource Department. Together these provide a wealth of existing connections to citizens, special populations, volunteers, and the land along the corridor. The Extension programs facilitate the engagement of the people of the corridor from positions of familiarity and trust (MOU from previous collaborations, Supplementary documents). Marcos Galindo, a Yaqui tribal member and Director of the Natural Resources Tribal Cooperative, will work closely with the Native American Students Centers at the UI and WSU and the modeling teams to coordinate these efforts.

Linking the SCC program to graduate courses and institutional programs (Leads: Mulkey, Evans, Lamb, Norton, Pinel). Graduate courses at UI and WSU can include student participation in the CSDM. Possibilities include: (1) Human Ecology (WSU) graduate seminar, where the contents of the

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course can be organized around CHANS, (2) Systems Modeling, (WSU) where students can acquire experience integrating social and biophysical models as they assist research teams, (3) Social Ecology of Natural Resources (UI), where teams of students can design a CHANS monitoring program that will include data displays for stakeholders, and (4) a new transportation course (UI) that will examine interdependency between the land use and transportation planning, including environmental and economic implications. Student coursework will help inform the research program through the workshops of objective 3. In addition, UI Building Sustainable Communities Initiative (BSCI) links six colleges and University Extension to deliver a graduate Bioregional Planning and Community Design degree, which includes a Learning Practice Collaborative (LPC) that engages students and faculty with local governments. During the incubation award period, the BSCI will use existing resources to work with the research teams to develop LPCs with SCC governments, help facilitate workshops, and assist in developing models.

New IGERT programs at WSU (Award #0903714) and UI (Award #0903479) and a new Professional Science Master's (PSM) program (NSF funding recommended for #1011374, April 2010) will integrate graduate training with the WSC program planning where appropriate. The WSU IGERT focuses on nitrogen cycle dynamics that will include training in communication with policy makers. The program features a capstone policy internship that will articulate with the WSC program. The UI IGERT evaluates resilience of ecological and social systems in changing landscapes with teams of students working in the Northern Rocky Mountains and Palouse wildland urban interface. The two IGERT programs will provide a project in which these teams can develop their multidisciplinary scholarship, and their results will inform the long-term research program. Beginning in fall 2010, the PSM program will use the S-TURNS framework and the CSDM process as a vehicle for graduate research where appropriate for a student's chosen specialty.

Management and use of resources for engagement (Leads: Gosz, Mulkey, Norton). Engagement must be centrally managed for our proposed program to function as a coordinated agent projecting a coherent message. Whenever possible, the WSC incubation project will execute engagement through existing personnel and resources in the SCC identified in letters of commitment (Supplementary Documents). UI and WSU research teams, plus Extension and university education professionals in the SCC, will organize their activities with an Education Engagement Coordinator (EEC) from each institution, who will jointly manage resources for education and engagement across the research planning program. In addition to working with the essential tribal partners, the EEC's will manage engagement with three core stakeholder groups: (1) official governing bodies of municipalities and counties, (2) local, state, and federal agencies, and (3) informal policy-influencing community groups such as neighborhood associations and NGOs. Graduate and undergraduate students, especially those with tribal affiliations, will assist with (1) holding the facilitated workshops associated with Objectives 3, (2) centrally coordinating communication with local and tribal governance, and (3) establishing and maintaining a comprehensive, interactive website used to educate and solicit input.

PROJECT MANAGEMENT

Project PIs Gosz (UI) and Norton (WSU) share responsibility for overall direction and are responsible for final decisions and interactions with NSF. The CoPIs from each institution represent the Executive Committee and each will have leadership responsibilities on one or more project areas as identified in the proposal. The Executive Committee will meet at least monthly, or more frequently if needed during the initial stages of the project, to exchange progress development and review collaborative activities among projects and interactions with stakeholders. A third group consists of Senior Personnel that represent the necessary range of disciplinary expertise and skills to perform the proposed research. They consist primarily of faculty from UI, WSU, and INL. The leads from Senior Personnel identified in above sections will facilitate broader group meetings with all Senior Faculty to broaden disciplinary input.

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Summary meetings will be held with the Executive Committee on at least a bimonthly basis. A fourth group consists of researchers and technicians from the Coeur d'Alene Indian Tribe and key contacts in the jurisdictions and other stakeholder groups. They represent various commissions, mayoral offices, NGOs, and citizen associations involved with natural resource issues and their own studies in the study area. Our outreach/engagement program will take the lead on public presentations and workshops with stakeholders as defined in the proposal. There will be ongoing interactions among various Executive Committee members and Senior Personnel with our stakeholders on a frequent and continuous basis, as we believe frequent communication is essential to project success. A National Advisory Group will be formed during year 1 to assist our program planning efforts.

Senior Personnel

Biophysical Sciences and Modeling

Adam, Jennifer, WSU, Civil and Environ. Eng.	Link, Timothy, UI, For. Res.
Antenucci, Jason, U. Western Australia, Water Res.	Lowry, Michael, UI, Civil Eng.
Barber, Michael, WSU, State Water Res. Center	Mack, Richard, WSU, Sch. of Biol. Sci.
Boll, Jan, UI, Biol. and Ag. Eng.	Moffitt, Christine, UI, Fish and Wildlife Coop.
Breckenridge, Roy, Idaho Geol. Survey.	Mount, George, WSU, Lab. for Atmos. Res.
Coats, Erik, UI, Civil Eng.	Phillips, William, Idaho Geol. Surv
Evans, David, WSU, Sch. of Biol. Sci.	Vierling, Lee, UI, Nat. Res. Ecol.
Fremier, Alexander, Fish and Wildlife	Walden, Von, UI, Geography
Goodwin, Peter, UI, Coll. of Eng.	Wilhelm, Frank, UI, Fish and Wildlife
Gollberg, Greg, UI, For. Res., Inform. Mgmt.	Yager, Elowyn, UI, Civil Engin.
Gosz, James, UI, For. Res.	
Haselbach, Liv, WSU, Civil & Environ. Eng.	
Huyck Orr, Cailin, WSU, Earth and Env. Sci.	
Keller, Kent, WSU, Sch. of Earth and Environ. Sci.	
Kennedy, Brian, UI, Fish and Wildlife	
Lamb, Brian, WSU, Dir., Lab. for Atmos. Res.	
Lewis, Reed, Idaho Geol. Survey.	

Optimization and Systems Dynamics Modeling

Ankeny, Mark, INL, Energy Res. Recov. & Mgmt.	Beall, Allyson, WSU, Earth & Environ. Sci.
Alessi, Sam, INL, Energy Res. Recov. & Mgmt.	Ford, Andy, WSU, Sch. of Earth and Environ. Sci.

Social Sciences and Modeling

Brady, Mike, WSU, Sch. of Econ. Sci.	Pinel, Sandra, UI, Conservation Social Sci.
Joireman, Jeff, WSU, Dept. of Marketing	Rosa, Gene, WSU, Inst. Of Pub. Policy & Pub. Serv.
Kang, Hejun, UI, Geography	Shrestha, Manoj, UI, Political Science
Long, Jerrold, UI, Law School	

Education and Engagement – Coordination and Extension

Galindo, Marcos, UI, Tribal Liaison	Peterson, Jeff, WSU, Coll. of Comm.
Gaffney, Michael, WSU, Gov. Studies and Serv.	Salvador, Michael, WSU, Coll. of Comm.
Mulkey, Steven, UI, Environ. Sci.	Sias, Patricia, WSU, Coll. Of Comm.
Oliver, Sylvia, WSU, Health Sci. Lab Op.	

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Results from Prior NSF Support

Coats: Co-PI of an NSF-sponsored project (2006-09; \$320,000) entitled “Advancement of a Sustainable Microbial Wastewater Treatment Process for the Removal of Phosphorus” (BES 0607329). At UI, a total of 3 graduate and 6 undergraduate students have participated in research related activities to date. Dr. Coats is also PI of an NSF-sponsored project (2009-11; \$123,923) entitled “EAGER: Toward Commercial PHA Production on Dairy Manure: Analysis of Mixed Microbial Consortia to Identify Critical Proteins and Metabolisms associated with Feast-Famine PHA Synthesis” (CBET 0950498). The research will advance the integration of proteomics and engineering to identify proteins statistically relevant to the feast-famine PHA synthesis process.

Gosz : New Mexico EPSCoR RII project focusing on water resources and nanomaterials. Served as PI and Project Director, 03/05-02/08, (\$6,750,000).

Polishing a Gem for Wilderness Research and Education: A Planning Proposal for Taylor Wilderness Research Station, Award 0829494, 10/2008-9/2009 (\$25,000), B. Kennedy, J. Gosz, M. Scott.

Collaborative Research: FSML-Enhanced Cooperative Research and Education at Flathead Lake Biological Station and Taylor Wilderness Research Station. NSF Field Station Marine Lab Award 0934085. 09/15/2009 – 09-14-2012. (\$254,497), J. Gosz, H. Hess, M. Galindo, B. Kennedy. This project developed power infrastructure at the Taylor Station and installed sensor arrays for aquatic research.

Pinel: University of Idaho NSF Grant, co-PI, awarded Spring 2010 (PI Waits). “An Interdisciplinary Team-Based International Research Experience in Biodiversity Conservation and Sustainable Community Development in the Ecuadorian Andes”, \$144,000 for undergraduate research experience.

Lamb: IGERT grant: Nitrogen Systems: Policy-oriented Integrated Research and Education (NSPIRE) with Lamb as lead-PI and Evans as one of four co-PIs (\$3,034,301). The IGERT will be directly applicable to linking water and air quality issues in the Spokane-Coeur d’Alene corridor and environs. Lamb and Evans are also co-PIs (Jobson lead PI) on a current award through the Major Research Instrumentation program to develop a Mobile Atmospheric Chemistry Laboratory (\$806K). Disjunct Eddy Flux Instrumentation for Ecosystem Biocomplexity, ATM-0119995, 10/2001 -5/2007, (\$1,927,000), B. Lamb, H. Westberg, G. Mount, P. Shepson, A. Guenther, and P. Curtis and Urban VOC Flux Measurements during the MIRAGE Field Campaign, ATM-0531273, 10/1/2005 – 9/30/2008, (\$214,541) B. Lamb, H. Westberg, and T. Jobson. Our biocomplexity grant was aimed at the development and evaluation of novel disjunct eddy covariance (DEC) and disjunct eddy accumulation (DEA) methods for measuring fluxes of volatile organic compounds (VOCs) and other trace gas species using aircraft and towers. WSU conducted urban pollutant flux measurements during the March 2006 Mexico City MIRAGE campaign (ATM-0531273) for a variety of organic pollutants and CO₂ (Velasco et al., 2005a,b; Velasco et al., 2009). These were the first VOC fluxes measured from an urban environment. In addition to these research projects, LAR has current NSF support through a Research Experience for Undergraduates (REU) site program (Lamb et al., \$276K) which is hosting 14 undergraduate researchers during summer, 2009.

Yager: CAREER: A Mechanistic Understanding of Sediment Transport in Mountain Streams with Applications in River Restoration and Science Education, # 0847799, 6/1/09-5/31/14 (\$455,000). The goal of this project is to improve understanding of flow and sediment transport in steep channels at the fundamental level of the interaction between flow turbulence and sediment motion. The field measurements were used to develop and test a simple field proxy for the local sediment supply to steep channels (manuscript currently under review at the Journal of Natural Hazards).

Barber, Beall, Boll, Gaffney, Norton, Rosa have not had NSF funded projects in the past 5 years