ANNUAL PROGRESS REPORT: EPS 1135483

CI-WATER: Cyberinfrastructure to Advance High Performance Water Resource Modeling

The CI-WATER project, which is a cooperative agreement between the US National Science Foundation and a consortium of the Utah and Wyoming NSF EPSCoR jurisdictions, has completed its first year. This report summarizes consortium-wide activities, and breaks contributions down by project objective, and university. The CI-WATER project started Sept. 1, 2011. We were given notice by NSF of the cooperative agreement in the latter half of that month. Recruiting for graduate students and staff started in October, 2011, but most positions were not filled until the summer of 2012. For this reason, all consortium universities have considerably underspent salary during the first project year. Cyberinfrastructure acquisitions are primarily occurring at the University of Utah and the University of Wyoming. The Utah acquisition is a mass storage system, while the Wyoming acquisition is a large computational cluster. In the first year, the University of Wyoming wrote specifications, issued a request for bids, and selected a vendor for the cluster. Funds have been obligated, and the Wyoming cluster will be installed in September, 2012. The consortium decided to postpone initial acquisition of the Utah mass storage system until the first half of project year 2 to allow installation of the Wyoming compute cluster, and to obtain more favorable pricing on the mass storage system. For this reason, the University of Utah has underspent equipment funds in project year 1, but will do so in the first half of year 2. Despite the delay in taking on graduate students and hiring staff, we report that progress along most milestones is on schedule.

I. Research Activities and Findings

The objectives of the CI-WATER Project Consortium are (from the proposal):

1. Enhance cyberinfrastructure facilities.
2. Enhance access to data- and computationally-intensive modeling.
3. Advance high-resolution multi-physics watershed modeling.
4. Promote STEM learning and water science engagement.

Accordingly, we have organized this section based on these four objectives. Activities designed to enable completion of our goals and objectives are assigned to four research and education/outreach teams. Each team contains one or more members from each participating institution.

Objective 1. *Enhance cyberinfrastructure facilities*

Consortium-wide progress

The consortium has initiated monthly teleconferences between Utah and Wyoming high performance computing staff and PIs, and this group held two face-to-face meetings, one in Salt Lake City and the

other at SC11 in Seattle. Participants have included Steve Corbató, Julia Harrison, Guy Adams, Brian Haymore, Sam Liston, Court Strong, and Wayne Bradford of Utah and Tim Kuhfuss, Jeff Lang, Fred Ogden and Tim Brewer of Wyoming. Recent discussions have focused on the Internet throughput and overall performance between the Center for High Performance Computing at the University of Utah and the University of Wyoming (UWyo) Computational Cluster. Other topics addressed include the technical details of the Wyoming HPC procurement document, hardware architecture, use of Graphical Processor Units (GPUs), network interconnects including Infiniband and 10 Gigabit Ethernet, batch scheduling software, and cluster management. We have also initiated discussions regarding access to the UWyo Compute Cluster and the NCAR-Wyoming Supercomputing Center (NWSC) by Utah CI-WATER investigators, through the Wyoming NWSC allocation, for the atmospheric science research team of Prof. Court Strong.

We have initiated file transfer speed tests of the fiber-optic connections between the Universities of Utah and Wyoming. Results of these speed tests will help guide year 2 allocation of resources by determining if network speed is sufficient for the transfer of multi-Terabyte files is possible in a reasonable time frame (hours not days).

Contributions from Utah

Acquisition of the mass-storage device at the University of Utah has been delayed until early in year 2, owing to the recently completed selection of the UWyo compute cluster. Discussions are already underway on strategies to link the IBM-based system in Laramie with the HP-based IBRIX storage system in Salt Lake City. A small amount of storage (10 TB) was acquired in year 1 to support Utah research in the interim. An additional reason to delay this purchase until the second project year was that the floods in Thailand in 2011 caused both storage system shortages and a significant spike in hard disk prices in early 2012. Prices now are returning to earlier levels, and we will be able to procure considerably more storage for the same amount of money in the second project year with two year's funding. Meanwhile, the University of Utah has completed the state-of-the-art Downtown Data Center (DDC) in Salt Lake City to house this storage capability, and the new Research@UEN optical network in Salt Lake City is now operational to connect the campus with the DDC and the high-performance Internet2 national network in support of high-speed file transfer.

In collaboration with USU Information Technology we are developing the specifications for a Virtualized Host system infrastructure to serve the data service development, prototyping, and hosting needs of this project. Given that we are evaluating and planning to use a number of software technologies that are hosted on a variety of computer platforms (e.g., Windows- and Linux-based software), this virtualized infrastructure will enable us to quickly spin up virtual machines that implement different operating systems and platforms using shared computational and storage resources rather than requiring a physical machine for each purpose. A purchase of hardware that implements our design is anticipated within the month and the purchased hardware will be hosted within the USU Enterprise Data Center.

Contributions from Wyoming

In the first CI-WATER project year, the University of Wyoming put into place the necessary cyberinfrastructure and personnel to support the needs of the CI-WATER project using internal funds. These include:

- Hired of a Director of Research Computing.
- Developed a Research Computing Support team, currently consisting of a User Support director and a HPC engineer and administrator. Two to three additional support positions will be filled over the next two years.
- Applied for and gained membership in the Coalition for Academic Scientific Computation (CASC).
- Took a leadership role in the Front Range Consortium for Research Computing.
- Established a graduate minor in interdisciplinary scientific computing.
- Upgraded power and cooling systems in the UWyo Information Technology Building to support the new computing cluster.

In addition, the CI-WATER group at UWyo secured an allocation of 2.4 million core hours on the NCAR-Wyoming Supercomputing Center to support the computational research in this project.

A request for proposals for High Performance Computing (HPC) & High Performance Storage (HPS) system was issued by UWyo in December, 2011, and nine proposals were reviewed by three teams: 1) technical experts; 2) computationally-oriented researchers; and, 3) management. The objective of this evaluation strategy was to identify the vendor with the best long-term value for the university's research needs. After a thorough review and vetting process, IBM was selected to provide the initial installment of an HPC/HPS system at UWyo to support the computational aspects of the project, as well as enhance computational research throughout the university. The systems will be installed in mid-September and available for research use this October. The UWyo system will run the same operating system as the Yellowstone machine at the NCAR-Wyoming Supercomputing Center, Red Hat Enterprise Linux.

The initial HPC configuration consists of 74 nodes built with dual Intel E5-2670 Sandy Bridge (2.66 GHz) CPUs and 1 TB local disk storage connected by FDR Infiniband. The GPU nodes use NVidia Tesla model M2090. The system will initially run at around 32 teraflops computational speed. The number of nodes of different types is:

- 58 Thin nodes with 32GB memory
- 3 Thin GPU nodes with 32 GB memory
- 8 Fat nodes with 64 GB memory
- 5 Fat GPU nodes with 128 GB memory.

The initial HPS configuration is built upon a GPFS File System with 350TB useable storage that will be scaled to 3 PB in coming years. This storage was purchased by the University of Wyoming using funds other than CI-WATER, for use by all campus users.

The total cost of the initial cyberinfrastructure installation, including infrastructure upgrades to the UWyo IT center, is slightly over $1M. The CI-WATER project contribution was $333,000, with additional contributions from the University of Wyoming, and faculty grants and start-ups. UWyo has pledged contributions from internal funds of $700K/year and $200K/year in CI-WATER project years two and three, respectively, to continue to build and ensure the sustainability of the University of Wyoming's

cyberinfrastructure capabilities. CI-WATER project funds in year one were used solely for the acquisition of computational nodes.

Objective 2. *Enhance access to data- and computationally-intensive modeling.*

Consortium-wide progress

Even though we spent much of the year recruiting project staff, graduate and undergraduate students, we made significant progress on this objective. We conducted several planning meetings involving all four institutions. These consisted of face-to-face meetings, conference calls, and webinars. We have outlined a strategy that will allow us to leverage the unique strengths of each institution in a synergistic fashion that will result in a number of high-quality research products and tools. The work done by this team will also produce tools of broad interest to the water research and management communities.

Contributions from Utah

Due to the length of this section, we delineate contributions from each institution to promote clarity.

Brigham Young University

After receiving funding (September of 2011), our initial efforts during the next six months included coordinating with other project members, recruiting graduate students, and performing detailed planning for the project. We conducted an extensive recruiting effort and were successful in forming a strong team of researchers including a post-doctoral researcher, two Ph.D. candidates, and a Masters candidate. The post-doctoral researcher is Kris Latu who is in the process of finalizing a Ph.D. at the University of Melbourne in Australia. His Ph.D. research focused on model integration and coupling water resource models with financial analysis for long-term water resource planning and management. Since Kris has unique skills that will greatly benefit our research, we adjusted our budget by reducing faculty summer support and hiring fewer MS students to bring him on board as our initial budget did not include a post-doctoral researcher. The two Ph.D. students are Nathan Swain and Scott Christensen. Both Nathan and Scott have strong programming backgrounds and have a deep interest in water resource management. Nathan and Scott were hired in May of 2012 and Kris was hired in July. The Masters is Michael Burns. Michael started work in late 2012, but did not start pursuing his research activities in earnest until May or June. Everyone on the team is fully engaged and is making excellent progress. We have identified three additional Master's students who will be engaged in our project beginning this fall and we have identified two additional Ph.D. students that we would like to hire in January of 2013, providing we can find some additional funds to supplement the CI-WATER grant. We are pursuing several options in that regard, and we are confident that we will be able to bring them on the team.

The BYU team will provide input and support to all four of the CI-WATER project objectives, but our primarily focus is on Objective 2: *Enhance access to data- and computationally-intensive modeling*. We have assembled a team with significant background and unique skills in this area that will allow us to make a successful contribution. We have two decades of experience conducting research in water resource model development, geographic information systems (GIS), visualization, and development of web tools. We also have worked closely with the US Army Corps of Engineers and other federal agencies to develop tools for water resource modeling and we have been personally involved in a number of large real-world

modeling projects. These projects have given us insight into the modeling process and helped us to understand the barriers that can make it difficult and expensive to apply high-performance modeling and computations to day-to-day water resource planning and management.

During our planning process we discussed issues related to data- and computationally-intensive modeling with other researchers, with officials from various state and federal agencies, and reviewed research in this area. In going through this process, and based on our prior experience, we have concluded that one of the most important challenges when attempting to enhance access to computationally-intensive modeling is not only extraordinary model complexity, but that each model has unique parameters, options, criteria evaluated, and other model-specific features. It is impossible to develop a simple solution that can be directly applied to all high-performance models with no modification. Our objective is to develop a system that is implementable using the CI-WATER resources, yet it is flexible enough to be adapted to almost any modeling application. To achieve these goals, we are planning to develop a system that will implement tools that leverage vast amounts of spatial data to perform cloud-based simulations with simple web interfaces and intuitive 3D visualization and mapping of model results.

The results from this initial planning effort are a three-part approach to achieve these goals. These tasks are as follows:

Task #1 – Develop geoprocessing toolkits for high-performance models

This task will involve developing a scripting environment or toolkit for a set of water resource models. This toolkit will make it possible to write custom scripts for processing complex spatial data into the formats required by the model, modify model input files, run the model, and process the output. The toolkit will be developed in a GIS environment, facilitating the use of databases, SQL queries, and a large library of existing geoprocessing tools for coordinate projection, spatial analysis of vector and raster data, and mapping and visualization. The geoprocessing tools will be written using a COM interface, which will make it possible to use them in almost any programming language. However, we expect that it will be most commonly used with Python.

This work will be patterned after ongoing work involving groundwater modeling associated with the Arc Hydro Groundwater (AHGW) data model and tools. The AHGW data model is a schema for representing groundwater data in an ArcGIS geodatabase. It includes all types of groundwater data used in a groundwater project, such as wells, monitoring wells, aquifers, boreholes, cross sections, etc. It also includes a “Simulation Feature Dataset” that provides features for storing groundwater simulation models in a GIS environment. The Simulation Feature Dataset is used to store model grid cells and basic relationships between cells. An extension to the Simulation Feature Dataset called the MODFLOW Data Model was developed to store MODFLOW simulations in a geodatabase. MODFLOW is a groundwater model developed by the USGS and it is the most widely used groundwater model in the world. The MODFLOW Data Model is a relational database design that allows each of the MODFLOW input files to be decomposed into a set of GIS tables. This exposes the MODFLOW data to the full range of database querying and geoprocessing available in the GIS environment. This data model was then used as the foundation for the development of a toolkit called MODLFOW Analyst. This toolkit supports geoprocessing tools to import, query, modify, and export MODFLOW files and tools for launching MODFLOW models. In other words, it is a complete scripting environment for MODFLOW, from which powerful applications involving groundwater simulations can be constructed.

In our case, we intend to extend this concept to integrated surface water/groundwater models. The first model we have selected is the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model. GSSHA was first developed by Fred Ogden and is now maintained and supported by the US Army Engineer Research and Development Center in Vicksburg, Mississippi. GSSHA supports a wide range of modeling applications including flooding and inundation mapping, sediment and nutrient transport, urban storm drain modeling, snowmelt, and others. GSSHA is physics-based model capable of representing the entire hydrologic cycle through long periods of time and is ideally suited to evaluate temporal changes both in landscape meteorology. GSSHA is a good candidate for this project because it is a sophisticated yet relatively highly-used model with a broad range of capabilities. We are currently in the process of designing a GSSHA Data Model. As was the case with the AHGW Data Model, the GSSHA Data Model is a schema for storing an entire GSSHA simulation in a geodatabase. Once this design is completed, we will develop a suite of geoprocessing tools for loading data from a native set of GSSHA input files to the geodatabase and vice versa. The toolkit will also include tools for modifying the geodatabase using spatial and temporal data, running the model, and processing the model output. This toolkit will make it possible to develop custom scripts for GSSHA models.

Once the GSSHA data model and tools are complete, we will develop similar systems for other existing models in use by other CI-WATER project investigators. We will also adapt these tools to support the parallel watershed simulator being developed under Objective #3.

Task #2 – Develop API for cloud-based modeling environment

In this task we will develop an Application Programming Interface (API) that can be used to take the modeling scripts developed in Task #1 and host them in user-friendly web interfaces. The custom scripts will run on a server and the web interface will manage the scripts and process the model outputs for post-processing and visualization. In some cases, the scripts will use Monte Carlo-style simulations requiring multiple processors. The API will include a suite of tools for setting up and managing this type of simulation using cloud-based distributed computing resources such as the Amazon or Microsoft cloud. It will also support “big iron” shared-memory supercomputer simulations. The API will interact with the custom scripts to run the simulations and archive the model results. It will include mapping and visualization tools such as Google Earth to browse the model results and present the model results using static and dynamic (animated) images.

Task #3 – Develop web-based applications

Tasks 1&2 are currently under development. When they are completed, we will use the geoprocessing toolkits from Task 1 and the API from Task 2 to build custom web-based applications for water resource planning and management. Again, the AHGW system can be considered a prototype for how this will work. We have used the AHGW data model and tools as part of a previous project to develop a customized system for the state of Utah Division of Water Rights (UDWR) for automatically simulating the impact of proposed new wells or changes in approved pumping rates for existing wells. Historically, the UDWR has not been able to perform MODFLOW simulations to analyze groundwater withdrawal permit applications on all cases due to the lack of expertise in agency staff and due to the fact that it is cost-prohibitive to outsource all such cases to consultants. With this new system, they are able to set up a new simulation in seconds and launch a custom script on a remote server that makes all of the

modifications to the model and runs the model and processes the results to analyze drawdown of the water table at key locations and potential impact to surficial springs and streams. The results are all displayed using a Google Earth plug-in.

In a similar fashion, we will use the geoprocessing tools and the API to develop a powerful suite of web-based simulation tools. Based on our initial planning, we have identified the following tools as candidates for this task:

Water Level Mapper for Drought Analysis: In 2011-2012, the state of Texas saw the worst one-year drought on record. Fluctuations in gravity measured by GRACE satellites indicate that as much as 100 cubic kilometers of water was lost during this period. Much of this came from reservoirs and shallow soil moisture, but a significant amount came from aquifers. In response to this crisis, a Texas Drought Technology Steering Committee (TDTSC) consisting of academics and water managers was formed to develop new tools and strategies to assist the state in monitoring, predicting, and responding to drought events. We are currently developing an automated water level mapper as part of this effort. While this system does not use the GSSHA or MODFLOW toolkit, it is allowing us to develop and test the API being developed as part of Task #2. The system is based on the Texas Water Development Board (TWDB) groundwater database, but can be adapted to use other databases as well. The system involves a set of ArcGIS workflows running on a server with a web-based front end and a Google Earth plug-in. A temporal interpolation geoprocessing tool was developed to estimate the piezometric heads for all wells in a given region at a specific date using a regression analysis. This interpolation tool is coupled with other geoprocessing tools to filter data and interpolate point elevations spatially to produce water level, drawdown, and depth to groundwater maps. The web interface allows users to generate these maps at locations and times of interest. A sequence of maps can be generated over a period of time and animated to visualize how water levels are changing. The time series regression analysis can also be used to do short-term predictions of future water levels.

Snowmelt Simulator: A tool that simulates snowmelt and runoff. In some years, high amounts of snowmelt and rapid melting patterns have resulted in massive flooding problems in the Western United States. This tool will automatically collect snowpack data from SNOTEL stations and feed the data into the GSSHA model along with an ensemble of historically probable temperature profiles. The tool will then run GSSHA in stochastic mode using the GSSHA snowmelt model and calculate the probability of exceeding selected flooding thresholds. The potential flooded areas associated with different levels of risk will be displayed on the web-based map.

Burned Area Analysis: Forest fires can dramatically affect the hydrologic characteristics of watersheds. With this application we will make it possible to input (or collect from the web) spatial data describing burned areas within a watershed and run a watershed runoff model to predict the impact the fire will have on a set of pre-defined storm events.

Additional applications will be developed as the project proceeds. We will also continue to work with state water officials in Utah, Wyoming, and elsewhere to identify needs.

System Benefits

The system we are developing has a number of important benefits.

1. Since it is based on a scripting library and an API, it allows for efficient adaptation and customization for individual projects and applications.
2. The system supports distributed and HPC environments, thus fulfilling our objective of enabling high-performance cyberinfrastructure for water resource modeling.
3. The code will be public domain which will enable widespread distribution and utilization.
4. We hope to be able to leverage the system for other research projects. We are already planning to use it in support of the Utah EPSCoR Track-1 project and we are planning to use it in support of an upcoming NSF Critical Zone Observatory proposal.

Utah State University

We have instantiated a number of HubZero virtual machines as part of the process of evaluating HubZero as an implementation environment for our science data gateway. An immediate need identified is the upgrade of the HubZero platform to Debian LINUX version 6, as the current implementation in version 5 does not meet USU Information Technology security requirements. We are awaiting the release of Hubzero on Debian LINUX 6 (Due Sept 25, 2012) to continue our evaluation.

We have been studying the process of model preprocessing and setup in the context of building hydrologic models for the Little Bear River. To date we have used the Soil Water Assessment Tool (SWAT) and Penn State Integrated Hydrology Model (PIHM) models. These span a range of hydrologic model use cases as SWAT is a subbasin and hydrologic response unit model while PIHM uses an adaptive mesh of triangular elements. We are working to get a better handle on the data requirements, access, pre-processing, and manipulations needed to run common hydrologic and water resources models that we want to support in CI-WATER. We are approaching our investigations from a couple of perspectives. First, can we automate the data access, pre-processing, and manipulation steps for some existing models by capitalizing on the fact that most models have similar data requirements (for which we could use existing or build standard services). Accomplishing this requires that we accommodate the fact that models all have a bit different data resolution, segmentation, and ways of pre-processing data, challenges that we are currently working to address. Next, since the data requirements of many models have many elements in common, can we generalize the staging of model input data and execution of model setup steps to better automate this process?

We have also begun to investigate iRODS as a distributed file system that can help us with data staging, and model preprocessing and execution functions. New functionality emerging in iRODS will enable iRODs micro services to better define modeling workflows, and the fact that iRODs is distributed means that we may more easily be able to move a model and/or data to computational resources when needed.

University of Utah

The UU project participants for research contributions to Goal 2 were Steve Burian, Courtenay Strong, and Christine Pomeroy. This team comprised of an atmospheric modeler (Strong), an urban stormwater modeler (Pomeroy), and an urban water system modeler (Burian) is developing research capacity to

enable access to data- and computationally-intensive modeling for the specific application of urban water management. Specifically, the team is linking in a one-way connection climate modeling with urban water supply system modeling and urban stormwater modeling. The one-way connection initially will be based on regional dynamic downscaling of global climate modeling results at the spatial and temporal resolution necessary for use in urban water system modeling. The team conducted a search for student and post doc support and was able to hire towards the end of the first project year an advanced post doc in atmospheric sciences and a new PhD student in civil and environmental engineering.

Overall, the team in the first year has been developing a conceptual framework through cross-disciplinary discussions to create a research capacity that provides climate to water management water research capacity to support water management. Initial tasks have included compiling databases for climate modeling, downscaling, urban water system modeling, and urban watershed modeling. In addition, climate modeling data analysis, and regional scale model simulations have been performed by Strong. Court Strong worked on configuring and tuning the Weather Research and Forecasting (WRF) model for use in simulating future precipitation variability over the Wasatch Range. As part of this process, the model was ported to Ember (one of the newest supercomputers at the University of Utah), and a one-year validation run was conducted by boundary forcing WRF with historical observations from the Climate Forecast System Reanalysis (CFSR). Following experimentation with resolution and various parameterization packages, results were obtained that compared favorably with hourly snow observations in the Utah SNOTEL database. Strong and his post doc are working on format conversions and interpolation methods needed to prepare boundary condition data sets projecting to the year 2100, and have started to evaluate the effectiveness of various physical and statistical schemes for removing model biases from these boundary conditions.

The urban water team of Burian and Pomeroy has been compiling urban water system data and urban watershed data in partnership with Salt Lake City Public Utilities. The team created a general data request document for water managers to use in the collection of water infrastructure (e.g., reservoirs, diversions, conveyance, control, treatment facilities). The reservoir information sheet was distributed to personnel in Salt Lake City Public Utilities to acquire data on physical geometry and configuration of reservoirs and outlets, water surface elevations data, rules that govern system operations, upper and lower bounds or thresholds that trigger policy actions, water use data, maintenance schedules, and information used for forecasting and decision making. This information is currently being used to create a systems model of the Little Dell and Mountain Dell reservoirs that provide significant surface storage capacity for Salt Lake City metropolitan area. GoldSim is being used as the systems model because of the team’s familiarity with the model and the potential to partner with a similar NOAA-funded project being performed with water utilities in Dallas, TX and Snohomish, WA. Accompanying the GoldSim model of the reservoirs the team has also initiated a hydrologic model of the Wasatch Front in an effort to simulate the water budget of the Salt Lake City metropolitan area. The work has focused on modeling evapotranspiration and streamflow from the Wasatch Front Canyons using RHESSys and stomrwater and snowmelt runoff from the urban watershed using SWMM. The objective with the water modeling is to provide the means to study water supply implications (RHESSyS, GoldSim), urban watershed management implications (SWMM), and integrated urban water management implications (all models) of climate variability.

At this stage in the project, UWyo is less involved this objective than the other institutions due to our primary focus on Objective 3. However, we have been involved the planning and tool design discussions because we intend to use many of the tools described above with the CI-WATER HPC watershed model we are developing. For example, we intend to use the geoprocessing and web-based modeling tools currently being developed at BYU as a scripting environment for launching model simulations and viewing simulation output. This interaction will become more involved in years two and three of this project once the CI-WATER HPC model is operational.

Objective 3. *Advance high-resolution multi-physics watershed modeling.*

Consortium-wide progress.

Our first meeting with our collaborators was held November 14, 2011, at the National Center for Atmospheric Research in Boulder, Colorado. We had two participants from the US Army Corps of Engineers, Engineer Research and Development Center (USACE-ERDC) attend the meeting in person, and several others attended by telephone. The primary topic of this meeting was identification of the best existing code to use as a starting point for the CI-WATER HPC model development. We considered several options, and agreed to use a version of the USACE-ERDC ADaptive Hydraulics (ADH) code as a starting point. USACE-ERDC agreed to provide the CI-WATER project with the computational kernel of the ADH model, reduced to an easy to implement starting point for our model development. The ADH model offers several advantages for our project, including the fact that it was developed expressly for use on high-performance massively parallel computer systems. A second advantage is that it operates on an unstructured (triangular) mesh, which is more efficient for simulation of large areas with variable resolution. The ADH code includes shallow water flow and full 3-D unsaturated zone flow and heat transport solvers. USACE-ERDC also agreed to provide our project with mesh generation, visualization, pre- and post-processing tools that are compatible with the ADH code. Finally, USACE-ERDC agreed that the code they provide our project shall become public domain.

We had our second collaborator meeting at the Information Technology Laboratory of USACE-ERDC in Vicksburg, Mississippi, Feb. 14-15, 2012. The objective of this meeting was to work out the details regarding the ADH computational kernel that is to form the basis of the CI-WATER HPC model and how it can be tailored to suit the objectives of our project. We were given demonstrations of the mesh generation, visualization, pre- and post-processing tools that we will use to support our model development activities. A third collaborator meeting is planned for October, 2012.

Contributions from Utah

As noted above under Goal 2 we have developed the capability to apply both the PIHM model and the SWAT model, initially to the Little Bear River. This includes the capability to do PIHM preprocessing and triangle mesh generation. In developing the high resolution multi-physics model, we are drawing upon functionality in other models to the maximum extent possible. Additionally, while the high resolution multi-physics model is under development, the PIHM and SWAT model implementations that we have developed are serving as use cases for: 1) examining the processes involved in developing input datasets to drive hydrologic models; and 2) examining the process and potential options for packaging

model input datasets and model code for execution on remote computational resources (e.g., assembling a SWAT model package and sending it to a remote computer cluster for execution).

Our SWAT and PIHM modeling use cases are also being used to examine the capabilities of existing, state-of-the-art hydrologic models for representing human built infrastructure and human water management. These important components of western watersheds have been inconsistently implemented within existing models (if they have been implemented at all), and examining use cases from existing hydrologic models is necessary for identifying the required process representations, datasets, and data structures needed to adequately represent human mediated hydrology.

Contributions from Wyoming

We initiated searches for students and project staff positions in October, 2011. The University of Wyoming had no job classification suitable for our senior programmer position. We worked with the university Human Resources department to create a list of essential duties and qualifications to create this position, which was completed in February, 2012. The search was initiated immediately. The post-doctoral research associate position was advertised in December, and we interviewed candidates in February and March of 2012.

The CI-WATER project hired two undergraduates majoring in mathematics and computer science in the summer of 2012 to perform workflow related tasks. Working under the direction of the P.I. they have explored geospatial coordinate systems and transformations, set up parallel programming environments on project computers in the Linux environment, and tested existing codes for watershed delineation, stream identification, and geospatial data processing.

The post-doctoral research associate hired to work on the CI-WATER HPC model development started work in July, 2012. Dr. Wencong Lai earned his Ph.D. in Civil Engineering in May, 2012 from Clemson University, where he conducted research on the application of the discontinuous Galerkin method for mixed finite-element and finite-volume modeling of flowing water. His skill set is perfect for the position. Since starting, Dr. Lai has been working on multi-layered multi-physics unsaturated zone flow algorithms, and a combination multi-physics approach to simulate downslope flow through shallow soils coupled with overland flow.

Modeling at the scale of the Upper Colorado River basin using a high-resolution physics-based approach has never before been done. As a result we are blazing new ground in terms of examining approaches and evaluating the suitability of existing tools to meet our needs.

Findings to date focus on workflow- the process of creating input data for the CI-WATER HPC model. We have findings to report with respect to map projections, watershed delineation and stream identification from Digital Elevation Models, and mesh generation.

An in-depth evaluation of different goespatial coordinate systems revealed that the “interrupted sinusoidal map projection” is an excellent choice for simulating the hydrology of large areas. The word “interrupted” in this name indicates that the central meridian of the map projection can be placed at any meridian, such as the center of the study watershed. The “sinusoidal” map projection is a straightforward mathematical transformation, and offers advantages that area is perfectly preserved, azimuth distortion is easily corrected, and lines of latitude remain horizontal lines. This map projection is suitable for describing

areas of the earth that are up to 40-degrees in longitude wide with minimal distortion. Note that 40-degrees of longitude is large enough to contain the Amazon watershed, which is the largest river basin on Earth. We have identified and implemented software to convert geospatial data to/from this coordinate system and other widely used coordinate systems.

Watershed delineation and stream location identification is an important component of our input generation workflow. We have implemented the TauDEM watershed and stream delineation software in a parallel computing system. TauDEM was developed by Utah State University collaborator Prof. David Tarboton.

The CI-WATER HPC model will run on an unstructured triangular mesh. Having variable mesh resolution is desirable for computational efficiency. We have envisioned a mesh with very high resolution in certain portions of the watershed such as in high altitude areas where topography affects snowfall accumulation, redistribution, sublimation and melt. We also hypothesize that we can use considerably lower resolution in broad-flat valley floors. We have performed a detailed review of both the literature and existing mesh generation software. To date we have found no example that solves the variable mesh resolution problem over a large watershed. We have identified key examples from the literature, and sample codes that might serve as a starting point for development of our own mesh generation tool. Our cooperators at USACE-ERDC have provided a base mesh generator for us to modify and test.

We have developed a conceptual design to incorporate water management systems such as reservoirs and trans-basin diversions as well as urbanization effects within the CI-WATER HPC model. This design will include linkages to existing models identified in Objective 2.

Objective 4. *Promote STEM learning and water science engagement.*

The CI-WATER outreach and education team has been actively working to enhance STEM learning and water science engagement as outlined in Objective #4 of the CI-WATER proposal and documented on the CI-WATER website at http://ci-water.org/.

Consortium-wide progress.

Both Utah and Wyoming have initiated programs that implement the trajectory of STEM at each of three target levels shown in Figure 2 of the proposal, including K-12, higher education and adult learners. A collaborative outreach/education team has held monthly coordination webinars to guide our work and meet the timelines and milestones indicated on page 15 of the proposal.

Contributions from Utah.

Efforts this year focused on development and launch of the CI-WATER website http://ci-water.org/and general broadcast program to introduce the project. UEN hired graduate student Jenn Gibbs, and BYU hired undergraduate Sara Hall to support outreach projects. USU is slated to hire an outreach student in the coming year. May 2012 marked Water Week outreach activities in both states. The first CI-WATER symposium was moved from May to September in order to accommodate schedules of key speakers. Additional coordination with Track 1 projects began when iUTAH EPSCoR was announced in the summer. Other than moving the dates for the 2012 symposium, all projects continue on schedule.

Contributions from Wyoming.

Specific programs developed over the last year include (1) teacher training programs through toolbox development and workshops, (2) public outreach and communication programs and (3) diversity building through interactions with the Wind River Indian Reservation. To oversee these activities, Beth Cable was hired by WY EPSCoR in May 2012 as Wyoming's Track-2 Education Outreach and Diversity (EOD) Coordinator. Beth brings extensive experience working with the Wyoming school system through her prior role as Science Fair Coordinator for the Science Math Teaching Center (SMTC) on the UWyo campus. We were fortunate to attract Beth to join the WY EPSCoR team.

Together, the outreach and education milestones are moving forward. We have good processes for coordination and have expanded our partnership to include museum and school partners. Highlights of our progress in education, outreach, and engaging diverse audiences is outlined below.

(1) Focus on Education

1a. Hydroinformatics Course. Researchers involved with CI-WATER developed a collaborative course, Hydroinformatics, offered for graduate students beginning August 28, 2012. The course is jointly taught by faculty from USU, UofU, and BYU, with plans to expand to UofWY next fall. In addition to providing new content and opportunities for interaction among students at all three institutions, this is the first time for most faculty to teach using the UEN Interactive Video Conferencing (IVC) system. The course will be recorded using software currently in a pilot phase of adoption at Utah State and UEN is monitoring their feedback closely to test the software's applicability to other courses. The course combines synchronous video lectures with asynchronous student discussions, assignments, and grading using a new Learning Management System called Instructure Canvas. UEN coordinated several planning calls with faculty and campus faculty assistance centers to initiate the course. Instructors include Jeff Horsburgh (USU), David Rosenberg (USU), Dan Ames (BYU), Jim Nelson (BYU), Steve Burian (UU), Christine Pomeroy (UU). Enrollment (and demographics) for the course is as follows:

USU – CEE 6930: Hydroinformatics; 7 Male, 1 Female, No Disability, 3 white Males, 2 Palestinian males, 1 Chinese female, 1 Ethiopian male, 1 Nepalese male
BYU – CEEn 594R Hydroinformatics; 15M, 0F, no disability; 11 white U.S., 4 Latino
UU – CVEEN 7920 Hydroinformatics 4M, 2F, no disability; Two Chinese, two Iran, two white
UU - ATMOS 6910 Hydroinformatics 1F, no disability, white

1b. CI-WATER toolboxes. Instructional toolboxes for K-12 classrooms were designed during the first year and are nearing completion. The toolboxes focus on CI-WATER topics, contain specimens and print materials that support hands-on, relevant classroom instructions and preparation for field experiences. The toolboxes were designed to support both Wyoming and Utah state standards. Wyoming EPSCoR is collaborating with the Natural History Museum of Utah and The Science Zone in Casper to create and develop two toolboxes for distribution to The Science Zone, a non-profit science museum in Casper WY, and to a selected rural school in Wyoming. The Water Modeling Toolbox includes water-–oriented experiments and hydrology modeling computer programs. The toolboxes will be completed during the last week of August, 2012 and will be available for checkout through both museums' teacher lending programs. These toolboxes will be distribute through The Science Zone, to local schools and will offer direct in-classroom access to water modeling resources.

Beth Cable initiated several interactions with UT collaborators to bring toolboxes as a new activity to Wyoming EPSCoR. She travelled to the Natural History Museum of Utah to collaborate with Madlyn Runburg during mid-June, 2012, and to learn about toolbox structure and development. The group participated in a Stanford Innovation Studio Design Thinking and 21st Century Learning workshop as a platform for CI-WATER toolbox development. The workshop focused on learning as active problem-solving that encourages creativity, critical thinking, communication and collaboration, which will be part of the toolbox goals. During the visit, Beth also met with the Museum's toolbox manager, Heather Paulsen, and reviewed their existing, successful toolboxes and program. Heather, Madlyn, and Beth continue to collaborate and communicate on toolbox development via email and conference calls.

Beth Cable travelled to The Science Zone and collaborated with Carrie Schroeder and Jennifer Wistisen during mid-August, 2012. In addition to providing feedback, input and ideas about toolbox development, The Science Zone will promote the CI-WATER toolkits through their after-school, Mad Science, High School Explainer, and professional development programs. The Science Zone will also house a permanent display related to water modeling for the general public. Planning for this display development is underway. Upon training of toolbox curriculum and implementation, The Science Zone staff and volunteers will actively promote the toolkits to their teachers and outreach programs.

Beth Cable collaborated with Heather Paulsen in late August, 2012 at the Natural History Museum of Utah to attend a workshop, plan, shop and construct the toolboxes. These boxes focus on providing information about the quality and availability of water resources based on natural and man-made population, climate, and land use changes through water-based experiments, computer programs, and problem-solving. Distinct sets of lessons and curriculum guides are being developed for each grade level including grades K-2, 3-4, 5-6, 7-8 and 9-12. The boxes include all related resources, including books, videos and field equipment and are self-explanatory. A plan for deployment includes visits with the toolboxes by EPSCoR staff to teachers in Wyoming with follow-up visits.

The toolboxes will be displayed at the September CI-WATER Symposium in Utah and promoted at the Wyoming Science Teachers' Association meeting, the Math and Science Teacher's Conference and the Wyoming After-School Alliance meeting. The toolbox will also be promoted at the Casper Museum Consortium.

1c. K-12 Workshops. In conjunction with the CI-WATER Symposium in August, UEN scheduled workshops for science teachers and students at four high schools in Salt Lake City and also with undergraduate and graduate students from the University of Utah, Salt Lake Community College, and Westminster College. The workshops feature Dr. Christopher Emdin discussing *Science for the Hip Hop Generation* in an effort to build science interest among urban youth. The workshops will be video-recorded, live streamed for Wyoming teachers, and and adapted into online course materials for teachers in both states. Planning is underway for the science teacher workshops slated for summer 2013 with the Genetic Science Learning Center at the University of Utah taking the lead on that effort.

1d. Mt Everest toolbox: a new opportunity. Wyoming EPSCoR strives to remain communicative with surrounding EPSCoR jurisdictions to leverage resources and share ideas. This year we partnered with Montana EPSCoR by placing a National Geographic-sponsored toolkit into a fifth grade Wyoming classroom, promoting outreach and teaching in basic STEM areas. The Everest toolkit was associated

with a National Geographic-sponsored climb of Mt Everest by UWyo Writer-in-Residence, Mark Jenkins, which included a live internet feed from the climbers to a website where students and teachers could interact with the climbers during the mountain ascent. Teachers were provided science-based activites for students related to human physiology, mountain geology and snow distribution. The toolkit was placed in Kurk Aegerter's fifth grade classroom (Beitel Elementary) in Laramiw, WY. He and his students visited the climbers' updates daily and studied the landforms of the Himalayas. This activity, and EPSCoR's involvement, was written in the University of Wyoming news, the local Laramie Daily Boomerang, and students and Mr. Aegerter presented the experience to the Albany County School District. It was shared with 32 students - 18 girls, 14 boys, 1 Native American and 5 Hispanic students. Along with the toolkits, curriculum and lessons were available online (http://www.montana.edu/everest/resources/lessons.htm) and the teachers and students could follow the climb directly at http://adventure.nationalgeographic.com/adventure/everest/. The teachers were able to keep the materials so that the lessons and the climb could live on.

According to the evaluation conducted by Montana, 38 schools (36 in Montana and one each in Wyoming and Utah) received teacher's kits, each with approximately $500 worth of equipment including a GPS unit, a time-lapse camera, maps, a pulse oximeter, rock samples, climbing gear, maps, and a weather station. Over 2,000 students used the teacher kit materials (approximately 290 of which were Native American and 150 of which were children with disabilities). Over 1,000 adults were exposed to the teacher kit materials. Almost all (78%) of the teachers shared the materials with other classes or audiences. Over 95% of the teachers who received teacher's kits agreed or strongly agreed that the materials enhanced their students understanding of geology, climate change, geography, human physiology and the tools and equipment used in research.

1e. Code Camps. Addressing cyberlearning is also a key goal for CI-WATER. UEN sponsored the first Utah High School Supercomputing Competition in March 2012 and is supporting outreach efforts for Research Network @ UEN, a Track II NSF EPSCoR project led by Dr. Steve Corbato. Working with faculty from the University of Utah School of Computing, UEN is producing four short films featuring Utah's technology history to be aired in conjunction with the Supercomputing 2012 conference this November in Salt Lake City. The technology history films will be distributed to area schools and used to recruit students for the CI-WATER High School Coding Camps planned for summer 2013.

Planning is underway for code camps, which are designed for undergraduate students at our consortium universities, community and tribal colleges and HBCU's. We will run a five day course on water management open to undergraduates. We will actively recruit students from Hampton University, Winston-Salem State University, Jackson State University, and North Carolina Agricultural and Technical State University. We will teach the students to use water management models developed as part of the CI-WATER project and existing models. We will run the course by the end of May, 2013.

(2) Focus on Outreach

2a. Public Media partnerships: Both Wyoming PBS and UEN broadcast water themed programming and short segments introducing the project to statewide viewers in Utah and Wyoming. Broadcast Water Week in Utah included 18 hours of programs and corresponding promotion. Utah produced programs were also shared with Wyoming for localization and broadcast through Wyoming PBS. In collaboration with Wyoming PBS, WY EPSCoR initiated a state-wide "water night" planned for airing regularly on

Tuesdays at 7 PM. A water documentary, *Liquid Assets*, was broadcast on Wyoming PBS on May 21, 2012 coinciding with Utah's Water Week. Dr. Fred Ogden, PI for the CI-WATER grant, provided a one-minute introduction to the project. A program from Utah called *Green River: Divided Waters* was broadcast on August 14, 2012 with the same introduction by Dr. Ogden. Planning is underway for broadcasting *Glen Canyon: A Dam, Water and the West* with a new, updated introduction by another scientist and for a live water call-in show with project scientists. All of these programs are in coordination with the Utah Education Network (UEN).

2b. Social media engagement: Utah and Wyoming students are taking the lead on social media efforts including blogs, Twitter, and Facebook pages accessible from the main CI-WATER website. Jenn Gibbs, a University of Utah graduate student hired to assist with this effort has worked closely with Kali McCrackin, UWyo undergraduate student, who was hired by WY EPSCoR to create, update, and maintain social media networks, In collaboration with the Utah Education Network and the CI-WATER team, Jenn and Kali created and shared a CI-WATER social media plan. Kali subsequently created a WY EPSCoR social media plan, including active involvement with and updates on both CI-WATER and WY EPSCoR Twitter and Facebook pages, and social media efforts have extended to the UT EPSCoR Track 1 project called iUTAH. Kali has also created a successful "test" blog initially about the Student Research Apprentice Program (a program funded by Track-1 funding). At last record over 100 followers from 8 countries were following the blog. This blog is now being transitioned to become a general WY EPSCoR blog and will include a CI-WATER component. A fall edition of an all new WY EPSCoR newsletter is currently under construction. This newsletter will be both paper and online, which will include an interactive portion for all participants. Utah is also planning to engage Twitter extensively during the CI-WATER symposium using the #ciwater hashtag.

2c. CI-WATER symposium: The first annual CI-WATER Symposium, *Managing Water in an Uncertain Future: Harnessing New Computational Power*, will be held September 5-6, 2012 at the Natural History Museum of Utah. September 5th includes a keynote address and industry and CI-WATER team leader panel discussions. September 6th is scheduled as a project partner work session. Additionally, an educational event called *How do we get kids to love science? STEM and the Hip Hop Generation.* This event will be directed by Dr. Laura Hunter from UEN and features Science Education specialist Dr. Chris Emdin speaking during an evening event for 150 guests at the Utah Museum of Natural History . This Symposium has been collaboratively planned with UT and Wyo participants through bi-weekly meetings. Beth Cable also participated in a planning walk-through on August 22, 2012 at the Natural History Museum of Utah with the Utah participants. Patti Carpenter from the Museum and Rich Finlinson from UEN have coordinated a press package to accompany the symposium week events, and secured a radio interview with Dr. Emdin on Utah NPR station KCPW. A press release for local media, on-air interstitials promoting the events, and posters for campuses and K-12 schools have been widely distributed.

2d. Outreach to potential CI-WATER HPC model collaborators, user community and Upper Colorado River Basin stakeholders

The University of Wyoming team has given or scheduled a number of presentations to potential stakeholder groups. These completed or scheduled presentations include:

Invited presentation to Utah State University "Spring Runoff Conference on CI-WATER HPC model, Logan, Utah, April 3, 2012.

Invited presentation to the biennial meeting of the Consortium of Universities for the advancement of Hydrologic Science, Inc. (CUAHSI) on the CI-WATER HPC model, NCAR Green Campus, Boulder, Colorado, July 16, 2012.

Presentation at Front Range High Performance Computing Symposium on the CI-WATER HPC model development, August 13, 2012, Fort Collins, Colorado.

Briefed NCAR Executive Committee at the NCAR-Wyoming Supercomputing Center, August 21, 2012, on the objectives of CI-WATER Objective 3. The NCAR Executive Committee consists of the Director of the Universities Corporation for Atmospheric Research, the Director of the National Center for Atmospheric Research and the Directors of the NCAR research divisions. Fred Ogden summarized the CI-WATER project during this meeting. Several NCAR Lab directors expressed interests in the CI-WATER project, and in particular, the potential of coupling existing regional climate models with the CI-WATER models under development. Action items from the meeting include organizing annual joint NCAR-Wyoming research meetings to foster collaborations amongst UWyo researchers and researchers in NCAR's various labs.

Invited abstract submitted to “Future” session of the conference “Fifty Years of Watershed Modeling: Past, Present, and Future”, September 24-26, Boulder, Colorado. The participants in this conference will include stakeholders and a veritable “who's-who” in watershed modeling.

Scheduled seminar Oct. 2, 2012, to Wyoming Water Forum, Cheyenne, Wyoming, on CI-WATER HPC Modeling Objectives, entitled “Hydrologic Modeling of the Upper Colorado River Basin on the NCAR-Wyoming Supercomputer”. The Wyoming Water Forum is hosted by the Wyoming State Engineer's Office, and is attended by personnel from all water-related agencies in State government.

Scheduled seminar Oct. 4, 2012, to U.S. Army Corps of Engineers, Engineer Research and Development Center, Coastal and Hydraulics and Information Technology Laboratory, Vicksburg, Mississippi, on CI-WATER HPC model development and collaboration.

Abstract submitted on CI-WATER HPC model to Upper Colorado River Basin Water Conference to be held November 8-9, 2012, in Grand Junction, Colorado. This is a key conference, as many Upper Colorado River Basin water stakeholders will be in attendance. This forum will provide us the opportunity to make contacts with stakeholders throughout the UCRB that we do not normally interact with. http://www.coloradomesa.edu/watercenter/UpperColoradoRiverBasinWaterForum.html.

(3) Focus on Increasing Participation and Diversity in STEM

3a. Workshop on the Arapahoe Ranch, Wind River Indian Reservation: Coordinating with Kelsey Beck, Instructor of Science at the Wind River Tribal College (WRTC), WY EPSCoR is planning a Natural Resource Monitoring Workshop for the coming Track-2 award period, 2013. Organizers include Beth Cable, Ginger Paige, Kelsey Beck and other participants form WRTC, WY EPSCoR and ENR (Environment and Natural Resources Department at UWyo). The workshop will be held either in spring or summer of 2013 and will be modeled after a test workshop that is currently being conducted in October 2012 (funded by WY EPSCoR Track-1). The Track-1 “test” workshop held this October aims to increase

understanding of the principles of natural resource monitoring for Wind River Tribal College environmental science students, junior and senior Ft. Washakie High School students, land managers, regulatory officials, and interested community members. Topics will include field methods, water resources data types and collection, and traditional knowledge of water. The next Track-2 workshop will dovetail with the first workshop by introducing modeling and computational methods to the students. We aim to leverage the overlapping but also distinct traits of the Track-1 and Track-2 activities to produce a series of connected and consecutive workshops. These workshops will be developed for credit and will ultimately articulate between WRTC and UWyo (and UT).

3b. Establishing an American Indian Communication Network: To facilitate communication and planning with the Wind River Indian Reservation, WY EPSCoR is collaborating with the American Indian Studies program at UWyo. Over the last year, UWyo researchers, professors and partners were surveyed to identify the various types of ongoing projects between UWyo with the Wind River Indian Reservation. Data has been collected and analyzed and the results are being synthesized. The information will be available on University website by the end of August, when the new redesigned WY EPSCoR website will be released. . A symposium to share and communicate regarding future collaborations is currently being planned and UT participants will be invited. This information will be valuable for professors and researchers to learn what is being done on the Wind River Indian Reservation, how efforts can be combined and avoid overlap. Additionally, incoming and current students can use the information as a resource to connect with persons or subjects of their interest. This is a new opportunity that WY EPSCoR is following up on to facilitate communication and planning with the reservation.

3c. Diverse Learners. The selection of Dr. Emdin as a keynote speaker for the CI-WATER symposium evening event was intentional. His research focuses on the intersection of science and tenants of hip hop culture. Most young people, and particularly urban youth, view Hip Hop artists as role models. We hope to engage them in science with equal fervor by pointing out the similarities and shared characteristics of science and hip hop. Four Salt Lake City area high schools were selected to host Dr. Emdin for the CI-WATER *Hip Hop Science* presentation based on their urban locations and diverse student body and include Highland High general biology students (Mr. Doug Jorgensen), West High Physics Students (Mr. Enrique Arce-Larretta), Salt Lake Center for Science Education all students (Mr. Larry Madden), and City Academy Charter School afterschool students (Dr. Sonia Woodbury). The workshops are also co-sponsored by the Urban Institute for Teacher Education at the University of Utah. The workshops will be recorded for use by additional teachers in Utah and Wyoming.

Additionally, the CI-WATER website meets ADA accessibility standards and all programs broadcast by Wyoming PBS and UEN during Water Week are close captioned for the hearing impaired.

II. Training and Development (this can apply to training within the group as well as target audiences)

Consortium-wide progress.

On July 17-19 the BYU CI-WATER team attended the US Army Corps of Engineers sponsored training on the “Introduction to Distributed Hydrologic Modeling with GSSHA using the Watershed Modeling System (WMS).” This course was hosted at the University of Wyoming and the instructors included project Co-PIs Jim Nelson and Fred Ogden. The objectives of the course were to learn the basic spatial

data required to parameterize GSSHA distributed models and the basics of the WMS interface which allow for the development of gridded GSSHA models. We learned how to locate necessary information, set up basic models, execute and visualize results. Once we could master the basics we spent some time on applications that included land use changes, incorporation of hydraulic structures, and long term simulations that included snowmelt runoff. This workshop was attended by ten CI-WATER project co-I's, post-docs, and graduate students.

The education and outreach partners received training on use of the Wimba web conferencing system to hold our regular planning meetings.

Contributions from Utah.

On August 22-23, 2012, many of the faculty, staff, and students from the Utah institutions attended an NSF workshop held in Salt Lake City entitled: “Science: Becoming the Messenger”. The workshop was taught by Emmy award winning television producer Joe Schreiber, former PBS executive Dan Agan and bestselling science author Chris Mooney. Through the workshop we learned how to communicate with the media, how to use new dissemination technologies such as Twitter, and how to best formulate and organize blog articles, presentations, and videos related to communicating science.

We have developed and initiated a graduate level course on Hydroinformatics and modeling that will is being offered for the first time during Fall Semester 2012. This course is being offered simultaneously across all three Utah campuses using distance learning technology supported by project partners at the Utah Education Network. Jeff Horsburgh and David Rosenberg (USU), and Dan Ames (BYU), and Steve Burian (UU) are the instructors for the course. This course will be offered across all three Utah campuses using distance learning technology.

Faculty involved in the new Hydroinformatics course received training on the Interactive Video Conferencing System and the course Learning Management Software called Instructure Canvas. Training for the course systems was provided by personnel from UEN, the U of U Technology Assistance Center and the Utah State Faculty Assistance Center.

Contributions from Wyoming

WY EPSCoR has significantly benefited from the established and highly successful training programs available through our UT partners. A major effort since hiring Beth Cable is to provide training for her in toolbox development and museum display. Frequent online webinars and meeting with UT have been very significant and helpful as evidenced by the cooperative toolboxes, which are nearly ready for deployment.

In the Spring semester of 2012, P.I. Ogden offered a short course on C programming which was attended by other co-I's, graduate, and undergraduate students. This ad-hoc course was necessitated by the lack of suitable scientific programming courses on campus to prepare students for work in writing massively parallel code.

The CI-WATER principals have initiated discussions with UWyo Provost Myron Allen and Vice President for Research Bill Gern regarding campus-wide instruction in high performance computing. In the Fall

semester of 2012 we will prepare a proposal together with Bryan Shader, who is special assistant to VP Gern for High Performance Computing. We will propose a sequence of course modules that could be offered through the UWyo Outreach School to our collaborating institutions and others that will focus on: 1) structured programming; 2) data types; and 3) writing code for parallel computer systems to solve scientific and mathematical problems.

P.I. Fred Ogden and post-doctoral associate Wencong Lai attended the 2nd annual Front Range High Performance Computing Symposium, August 13-14, 2012. The first day consisted of presentations on the state of the art in HPC, while the second day consisted of lectures on parallel programming.

P.I.'s Ogden and Craig Douglas, together with post-doctoral associate Wencong Lai made arrangements to attend ADH code and operations training at USACE-ERDC October 3-5, 2012.

III. Outreach Activities

The major outreach activities for Utah and Wyoming are described in the Focus sections above. Social media outreach goals were also added to our project. CI-WATER launched Facebook, Twitter, and Blogger sites this summer. Interactions from social media into the CI-WATER website from May 1, 2012 to August 1, 2012 indicate 26 visitors from Facebook, 14 from Twitter, and 8 from Blogger. Social media users typically land on the CI-WATER homepage with 24 users clicking through to subsequent pages. We will continue to monitor web and social media analytics to inform our outreach work.

IV. Award-specific reporting

In this section, we respond to the award-specific reporting guidelines that were outlined in the Programmatic Terms and Conditions (PTC) document associated with our grant. The reporting guideline from the PTC is highlighted in italics at the beginning of each section.

4.1.a Broadening participation. *The annual and final progress reports must provide the total number of participants in the activities funded by this award, including faculty, staff, students, and members of the external advisory boards. In addition, the reports must indicate the numbers of women and underrepresented groups in STEM that participated in activities funded by this award and the duration of that participation. The data must be reported in aggregate for the project, each jurisdiction, and for each participating institution. Demographic data by race, gender, and disability must be provided in addition to education level (post-doctoral, graduate, undergraduate, K-12). Progress reports must present the results of efforts to increase the participation of women and members of other underrepresented groups in STEM. Future funding will be based, in part, on the progress in increasing the number of women and underrepresented groups in STEM in activities funded by the award.*

The participants involved in the CI-WATER project during the past year are listed in the following table. The educations levels listed in column 6 represent the education level completed by the person in question. The race codes are as follows:

Race	Description
AI-AN	American Indian or Alaska Native
A	Asian
B	Black or African American
NH-PI	Native Hawaiian or Pacific Islander
W	White
H	Hispanic

Participant Name	Role	Sex	Race	Disability	Education Level	Institution	Jurisdiction
James Nelson	CoPrincipal Investigator	M	W	N	Graduate	BYU	UT
Scott Christensen	Graduate student	M	W	N	Undergraduate	BYU	UT
Nathan R. Swain	Graduate student	M	W	N	Undergraduate	BYU	UT
Michael Burns	Graduate student	M	W	N	K-12	BYU	UT
Kris Latu	Post-doc	M	NH-PI	N	Graduate	BYU	UT
Norman L. Jones	Principal Investigator	M	W	N	Graduate	BYU	UT
Sara Hall	Undergraduate student	F	W	N	K-12	BYU	UT
Laura G. Hunter	CoPrincipal Investigator	F	W	N	Graduate	UEN	UT
Jennifer Gibbs	Graduate student	F	W	N	Graduate	UEN	UT
Richard Finlinson	Technician/staff	M	W	N	Graduate	UEN	UT
Lisa Cohne	Technician/staff	F	W	N	Graduate	UEN	UT
Jo-Ann Wong	Technician/staff	F	A	N	Undergraduate	UEN	UT
Karen Krier	Technician/staff	F	W	N	Graduate	UEN	UT
Rusty Keele	Technician/staff	M	W	N	Undergraduate	UEN	UT
Landon Weeks	Technician/staff	M	W	N	Undergraduate	UEN	UT
Katie Garrett	Technician/staff	F	W	N	Graduate	UEN	UT
Michael Stack	Technician/staff	M	W	N	Undergraduate	UEN	UT
Denise Tribble	Technician/staff	F	W	N	Undergraduate	UEN	UT
Madlyn Runburg	Technician/staff	F	W	N	Graduate	UEN	UT
Jessica Anderson	Technician/staff	F	W	N	Graduate	UEN	UT
Heather Paulsen	Technician/staff	F	W	N	Undergraduate	UEN	UT
Lorie Millward	Technician/staff	F	W	N	K-12	UEN	UT
Sue Murphy	Technician/staff	F	W	N	Undergraduate	UEN	UT
Johanna Tovar	Undergraduate student	F	H	N	K-12	UEN	UT
David G. Tarboton	CoPrincipal Investigator	M	W	N	Graduate	USU	UT
Adel Abdallah	Graduate student	M	W	N	Undergraduate	USU	UT
Tseganeh Gichamo	Graduate student	M	B	N	Undergraduate	USU	UT
David E. Rosenberg	Senior personnel	M	W	N	Graduate	USU	UT
Jeffery S. Horsburgh	Senior personnel	M	W	N	Graduate	USU	UT

Stephanie Reeder	Technician/staff	F	W	N	Undergraduate	USU	UT
Pabitra Dash	Technician/staff	M	A	N	Graduate	USU	UT
Steven C. Corbato	CoPrincipal Investigator	M	H	N	Post-doc	UU	UT
Hassan Tavakol-Davini	Graduate student	M	W	N	Graduate	UU	UT
Adam Kochanski	Post-doc	M	W	N	Graduate	UU	UT
Steve Burian	Senior personnel	M	W	N	Graduate	UU	UT
Christine Pomeroy	Senior personnel	F	W	N	Graduate	UU	UT
Court Strong	Senior personnel	M	W	N	Post-doc	UU	UT
Janeen Bennion	Technician/staff	F	W	N	Undergraduate	UU	UT
Jesse N. Creel	Graduate student	M	W	N	Undergraduate	UWYO	WY
Wencong Lai	Post-doc	M	A	N	Graduate	UWYO	WY
Fred L. Ogden	Principal Investigator	M	W	N	Graduate	UWYO	WY
Kristiana M. Hansen	Senior personnel	F	W	N	Graduate	UWYO	WY
Craig C. Douglas	Senior personnel	M	W	Y	Graduate	UWYO	WY
Ginger Paige	Senior personnel	F	W	N	Graduate	UWYO	WY

A summary of the demographics data organized by institution and jurisdiction is listed in the following table:

Institution/Jurisdiction	Total	Male	Female	White	Non-White	Disabled
BYU	7	6	1	6	1	0
USU	7	6	1	5	2	0
UU	8	6	2	7	1	0
UEN	17	4	13	15	2	0
State of Utah	**39**	**22**	**17**	**33**	**6**	**0**
UWYO	13	8	5	10	3	1
WYO PBS	1	0	1	1	0	0
State of Wyoming	**14**	**8**	**6**	**11**	**3**	**1**
Entire Project	53	30	23	44	9	1

Activities related to broadening participation are described in Section 3 of the Outreach section above. In addition, Wyo EPSCoR has sponsored several meetings with Marlin Spoonhunter, President of the Wind River Tribal College (WRTC), Dr. Mitchell Stone, Academic Dean of WRTC, and Lorre Hoffman, Registrar at WRTC to facilitate and promote collaboration and a working relationship. Along with the Reservation workshop previously mentioned, a UWyo and WRTC coordination meeting was held at UWyo first on May 29, 2012, including administrators of both WRTC and UWyo. A subsequent planning meeting on August 13 at UWyo will be followed by a scheduled for October 30, 2012 at WRTC. WY EPSCoR PD Sylvester and Beth Cable will be traveling to WRTC to visit classes and continue to develop plans for recruitment retention and shared workshops. At that time, we will select sites on the reservation

for deployment of the newly developed CI-WATER toolbox into a rural school on the Wind River Indian Reservation.

4.1.b. Institutional engagement. *Annual and final reports must provide evidence of broadened engagement of institutions in RII Track-2-supported activities of the consortium. These reports must also include evidence of enhanced collaboration among the consortium's universities and colleges, including non-research intensive institutions, and utilization of resources residing therein.*

This project has been effective in promoting new levels of engagement between the participating institutions. We have water scientists, staff, and students on four campuses who (for the most part) have not worked together before working together now to bring their diverse disciplinary perspectives together to the problem of water resources in this region. We have already begun discussing and moving ahead with other collaborative opportunities, including submission of a new proposal. Additional evidence of engagement is listed below:

1. We have developed four teams for the project: one for each of the four project objectives. Each team is composed of members from each of the four participating institutions. This ensures that all phases of the project will involve a high level of collaboration between institutions.
2. The management plan for the project requires frequent team meetings, ensuring ongoing collaboration.
3. The research plan developed during the first year has been designed in such a manner that the four teams/objectives will be synergistic. For example, the cyberinfrastructure for objective 1 will be used by the research activities associated with objectives 2&3. The data and modeling tools being developed for objective 2 will be utilized by the new watershed model being developed as part of objective 3. This synergy will ensure ongoing collaboration between the participating institutions.
4. The outreach activities described above involve cooperation and engagement from all four institutions.
5. The annual symposium being planned for Sept. 5-6, 2012 will involve participation from all four institutions.
6. We placed an advertisement for CI-WATER project-wide staff and student opportunities in EOS *Transactions of the American Geophysical Union* that appeared in November, 2011.
7. In the summer of 2012, we initiated monthly discussions between Utah and Wyoming HPC researchers and computational staff and management. Discussed networking needs between UWyo compute cluster and U of Utah mass storage facility. Agreed to create collaborative agreement between Utah and Wyoming on CI-WATER climate simulations and apply for time on the Wyoming portion of NWSC.

4.1.c. Linkages with other NSF projects. *Annual and final reports must include evidence of linkages, coordination and collaboration with other NSF-funded programs. The report must also show the consortium's participation in NSF programs that support research and infrastructure (human, physical, cyber) development beyond RII Track-2. These reports must also demonstrate how leveraging these programs enhances research and education competitiveness.*

Consortium-wide activities

Both Utah and Wyoming have RII Track-I projects that are complementary to the CI-WATER project. Both RII Track-I projects were given notification of funding in July, 2012. As those projects get up and running, we anticipate close coordination of efforts, identification of common objectives, and considerable synergy. We are in regular contact with the leaders of the Utah and Wyoming RII Track-I projects, and have invited them to attend the CI-WATER symposium, Sept. 5-6, 2012.

Utah activities

Goal 2 to enhance access to data- and computationally-intensive modeling is aligned well with three other national cyberinfrastructure projects in which we project members are participating.

EAR 1148453 Collaborative Research: SI2-SSI: An Interactive Software Infrastructure for Sustaining Collaborative Community Innovation in the Hydrologic Sciences. The goal of is this project is to establish an online collaborative environment called HydroShare for the sharing of hydrologic data and models. Much of the web service and user interface capability developed in for HydroSshare will be directly applicable in CI-WATER. Both CI-WATER and HydroShare are building on HUBzero and iRODS technology, so there is a natural synergy here.

EAR 1224638 Developing a Community Information Model and Supporting Software to Extend Interoperability of Sensor and Sample Based Earth Observations. This two year project is advancing the concept of a community information model for both sensor and sample based earth observations, extending the information model of the CUAHSI Hydrologic Information System to better support the type of observations derived from sampling techniques common in the Critical Zone Observatories. CI-WATER will benefit from the advances in this national data model from this project.

EAR 1153164 Integrated Data Management System for Critical Zone Observatories. Horsburgh and Tarboton are participating as subcontractor sub-awardees on this two year project to develop a comprehensive, integrated data management system for the NSF-funded Critical Zone Observatory (CZO) program, called CZOData. Much of the knowledge gleaned in this project will benefit CI-WATER and the knowledge developed in CI-WATER will benefit this project CZOData.

EAR 1038973 WSC Category 1 - Hydrologic and Ecological Impacts of Changes in Human Water Resource Management in Response to Climate Change and Urbanization. Horsburgh, Rosenberg, and Tarboton helped organize and participated in multi-disciplinary modeling workshops aimed at integrating hydrologic and agent-based models using the Open Modeling Interface.

OAI 1208732 - iUTAH-innovative Urban Transitions and Aridregion Hydro-sustainability (iUTAH project) – This is the current EPSCoR Track-1 project for the state of Utah. The project considers one of the most important problems facing the Western US, the problem of current (and future) water provision under climate change coupled with increasing urbanization and demand for water. The proposal focuses on the interactions between climate change, water rights issues and water availability within Utah. The research examines the fundamental interactions and dynamic feedbacks among hydroclimate and the ecological and human aspects of urban and montane landscapes. Focus area 3 of this project (Interdisciplinary Modeling and Visualization) provides numerous opportunities for collaboration with the

CI-WATER project. The objective of this focus area is to will develop interdisciplinary models of coupled socio-eco-hydrological systems that incorporate natural, rural, and urban ecosystem structure and function, and determine how changes in water availability, water use, and social drivers alter water quantity and quality in the western US. These models will be used to collaborate with stakeholders to explore the implications of future patterns of urbanization and alternative water management scenarios. The data and modeling tools being developed for CI-WATER Objectives 2 and 3 will be well-suited for the iUTAH project. Members of the CI-WATER team are already working closely with the iUTAH Focus 3 team. iUTAH also includes cyberinfrastructure to support integrated data storage and modeling. This is being developed in close coordination with CI-WATER. The development team includes the same people and we are coordinating software and sharing hardware wherever possible.

Wyoming activities

OIA-1208909 Water in a Changing West: The Wyoming Center for Environmental Hydrology and Geophysics. P.I. Ogden and co-I's Zhang and Miller participated in research planning activities for integrated hydrologic modeling that would operate in both projects, including shared field activities and modeling frameworks.

DGE-841298 The energy-water resources interface: A model for complex systems analysis in rural Wyoming middle schools. 5/1/09-4/30/14. P.I. Don Roth. As explained in the proposal, we have agreed to share teaching resources and educational materials.

DMS-845127 Analysis & Computing Group: Behavior of Solutions of Nonlinear Partial Differential Equations. 6/1/09-5/31/14. P.I. Gregory Lyng. Access to the University of Wyoming Compute Cluster.

MCB-846140 CAREER: Site-Specific Folding Mechanism of Elementary Protein Structural Motifs, 5/1/09-4/30/14. P.I. Jan Kubelka. Access to the University of Wyoming Compute Cluster.

EAR-944206 Refining Seismic Velocity and Attenuation Structure of the San Andreas Fault Near Parkfield, California using Full-3D Waveform Tomography, 7/15/10-9/30/13. P.I. Po Chen. Access to the University of Wyoming Compute Cluster.

EAR-1045166 Hydrogeochemical Investigation of Seasonal Transition and Land Use Change Effects on Tropical Hydrology. 5/1/11-4/30/14. P.I. Fred Ogden. This project will use the CI-WATER HPC model for hypothesis testing, and the UWyo Compute Cluster.

OCI-1054834 CAREER: Towards Scalable Error Detection for Parallel Software Systems on Emerging Computing Platforms, 6/1/11-5/31/16. P.I. Liqiang Wang. Access to University of Wyoming Compute Cluster.

EPS-1101317 Adaptation to Climate Change in the Lake Champlain Basin: New Understanding through Complex Systems Modeling, Institution: University of Vermont & State Agricultural College. Co-I Miller met with delegates of Vermont research team to discuss and plan joint modeling activities and the potential use of the Wyoming supercomputing facilities in shared hydrologic modeling efforts.

Wyoming EPSCoR worked with Montana EPSCoR and Montana State University to facilitate and place an Everest toolkit into a fifth grade Wyoming classroom. This Everest project is part of a larger EPSCoR effort called CLimate in My Backyard (CLIMB) that will be launching in the fall of 2012. The online component allowed teachers to access lesson plans and activities and students and teachers to follow the climb and interact and communicate with other participating classrooms. Track 1 Bridge funding was used to plan and fund workshops on the Wind River Indian Reservation. Working with the Wind River Tribal College and the Environment and Natural Resources Program, the workshop will introduce natural resource monitoring to a diverse audience of adults and students.

4.1.d Progress on project elements. *Annual and final reports must include evidence of progress in the development and implementation of plans required for the RII Track-2 project. For RII Track-2 awards funded in response to Program Solicitation NSF 11-513, this includes: cyberinfrastructure-enabled science and engineering projects, diversity plan, dissemination and communication plan, evaluation and assessment plan, sustainability plan, and management and coordination plan.*

We will address each of the main project elements separately.

Cyberinfrastructure-enabled science and engineering projects

In this section, we will describe progress for each of the four CI-WATER objectives and reference the Milestones and Timelines graphs that were submitted with the original proposal.

Objective 1 - “Enhance Cyberinfrastructure Facilities”. As discussed in the Research Activities and Findings section for Objective 1, we decided as a consortium to delay acquisition of the mass storage device at the University of Utah until the first half of the 2nd project year. Delay of this acquisition was necessitated by two factors: 1) evaluation of HPC system bids at the University of Wyoming, which might affect the choice of storage systems; and 2) the shortage and resulting high price of hard disks in 2012 due to the floods in Thailand in 2011. The other milestones for Objective 1 in year 1 have been met. With reference to the milestones table on page 6 in the proposal:

- Establish development servers, storage resources and workstations: complete, August, 2012.
- Finalize Utah-based storage system architecture and workstations: postponed until first half of year 2.
- Establish production storage resources at the University of Utah: postponed until first half of year 2.
- Have specifications for HPC resources available for bidding: complete, December 2011.
- Functioning/additional supercomputer and associated storage resources at UWyo: Purchase complete, installation scheduled for second half of September, 2012.

Objective 2 - “Enhance access to data- and computationally-intensive modeling” Progress on milestones listed on page 9 of the proposal, are listed below. Only those tasks associated with Year 1 are listed.

- Water management components for data services
    - Develop data model design: Mostly complete. The BYU team completed a data model design for the GSSHA model that we be used by the proposed geoprocessing library.
    - Implement prototype data services: In progress. BYU team is developing web-based API

for cloud-based modeling.
- Urban data components for data services
  - Develop data model design: Mostly complete.
  - Implement prototype data services: Incomplete.
- Develop and deploy data services for datasets required by models.
- Develop a HubZero instance that interfaces with Utah/Wyoming HPC Resources: In progress.
- Develop HubZero functionality: Complete. August 2012.

Objective 3 - "Advance high-resolution multi-physics watershed modeling". With respect to the "Timelines and Milestones" Table in our proposal, we are pleased to report that we are on schedule at the end of the first year. Milestones for Objective 3, Year 1:

- Evaluate existing model codes for compatibility with project objectives: complete, February, 2012.
- Design a high-resolution, multi-process, linked regional and urban hydrology model: complete, August, 2012.
- Evaluate existing HPC API's select and/or modify: Complete. We are using the USACE Adaptive Hydraulics Model API, and are extending it as needed, August, 2012.
- Define model input data structures: Complete, and being extended as new processes added to model, August, 2012.
- Develop model interfaces that enable model subcomponents to be linked and substituted: We are working within the Computational Model Builder (CMB) framework, provided by USACE. The CMB serves as the primary user interface with the model, and enables data set creation, visualization, and post-processing, August, 2012.
- Adapt existing model codes using CI-WATER interfaces and in the HPC environment. This work has been done on a small cluster in the CI-WATER lab, August, 2012. Completion and testing on the UWyo Compute Cluster awaits installation of the cluster on campus.
- Develop new hydrologic process salvers using CI-WATER interfaces for HPC: We have completed development of novel 1-D infiltration codes, August, 2012. We have designed a 2-D mixed subsurface/overland flow routing methodology using a Finite-volume mass-conservative formulation based on the discontinuous Galerkin method. This development is ongoing.
- Build model component coupling capabilities: work on this milestone will begin in September, 2012. .

Objective 4 - "STEM Learning and Water Science Engagement". Progress on milestones, as outlined on page 15 of the proposal are detailed below.

- Teacher Curriculum Development institute at GSLC – on track for year two
- Wyoming 5-day field based environmental education program – on track for year two
- Instructional toolboxes for teachers – significant progress on this, on schedule for fall 2012 deployment to schools in Utah and Wyoming
- Annual one-day symposium – 2012 meeting moved from May to September; expanded to 2 day meeting with additional outreach events during the week and scheduled for September 4-6 at the Natural History Museum of Utah (agenda http://ci-water.org/symposium/index.html)

- Online Hydroinformatics course –designed summer 2012 and launched for Fall semester starting August 28, 2012; changed to an annual course rather than every semester in order to match school schedules and demand.
- Select and license water TV programs, produce on-air PR spots – completed May 2012
- Broadcast Water Week on UEN-TV and Wyoming PBS – completed May 2012
- Film screenings and panel discussions – eliminated; expanded symposium outreach instead
- Project website launched and updated - http://ci-water.org/ was launched April 26, 2012; 2,011 visitors since launch, top cities visiting the site are Salt Lake City, Provo, Logan and Laramie. 51.02% are returning visitors, and web visitors spend an average of 4 minutes 34 seconds on the page.
- Summer workshops for students – planning is on schedule for this 2013 activity
- Code camps/summer of code for students – planning is on schedule for this 2013 activity

Diversity plan

We are still on target for achieving our goals on the Diversity Plan. Activities/evidence from the past year:

- Recruitment for CI-WATER undergraduate, graduate, and post-doc positions included diversity offices on each campus.
- New Hydroinformatics course has 8 students representing diverse groups and 14 Caucasian students; three students are female.
- CI-WATER Symposium activities are targeted to urban youth in Utah schools with the highest socio-economic and ethnic diversity (e.g., West High, 59% ethnic minority and 15% English Language Learners)
- CI-WATER toolkits targeted to rural schools that don't have easy access to science museums and support.
- Broadcast water week programs reached viewers statewide and are close captioned for deaf or hearing impaired accessibility.
- The CI-WATER website is ADA compliant.

Dissemination and communication plan

We are still on target for achieving our goals on the Dissemination and Communication Plan. Activities/evidence from the past year:

- UEN developed a CI-WATER logo and graphics package.
- Website widgets are complete and CI-WATER partner institutions have been encouraged to place the widgets on their local sites. Widgets can be downloaded at http://ci-water.org/widgets.html
- Water industry professionals were engaged through regular email communication and invitation to the CI-WATER symposium. Four industry professionals were scheduled to speak at the meeting.
- CI-WATER undergraduate outreach assistant Sara Hall coordinated a Virtual Poster Session for the 2012 Spring Runoff conference at Utah State University. The virtual posters are featured on the CI-WATER website http://ci-water.org/community/virtal_poster_sesson.html

- UEN and public relations personnel from the Natural History Museum of Utah issued two CI-WATER press releases in May 2012 for the Water Week activities, and in August for the CI-WATER symposium.
- Local public radio station KCPW also conducted a phone interview program with Dr. Chris Emdin, a keynote speaker for the CI-WATER Symposium. http://kcpw.org/blog/cityviews/2012-08-28/cityviews-82912-the-case-for-patenting-genesscience-goes-hip-hop/

Evaluation and assessment plan.

Our evaluation and assessment plan is on schedule. Our external assessment is being conducted by two independent groups: and external advisory board and AAAS. Our external advisory board consists of the following four individuals:

Dr. Bill Michener - University of New Mexico, PI of NSF DataOne DataNet project
Mr. Ryan Britton - Managing Partner of EarthSky and Principal Investigator of the EarthSky en Español project.
Dr. Olga Wilhelmi - Head of NCAR's Geographic Information Systems (GIS) program.
Barbara Minsker – Professor at the University of Illinois. Conducts research on CI and water resources.

All four members will be attending our CI-WATER Annual Symposium on September 5-6. The first day of the symposium involves an overview of the project and some public outreach activities. On the second day of the symposium, the CI-WATER steering committee will make detailed presentations to the board in the morning and they will then discuss our project in private and then make a report to us in the afternoon. They will be reviewing our proposal and this report prior to attending the symposium.

We have also contracted with the American Association for the Advancement of Science (AAAS) to provide a second, independent level of review. We have been working **Mark Milutinovich** and **Heather McInnis** at AAAS. Heather will attend our symposium on Sept 5-6, but mostly as an observer. After learning more about our project, she and Mark will work with us to design an assessment strategy that is complimentary to, but not duplicative of, the external advisory board. They will formulate a board of experts and will revisit us in the December-January time frame to conduct a second level of review.

Sustainability plan

This information is discussed in detail in section 4.1.e of the Award-Specific Reporting Requirements

Management and coordination plan

As described in the proposal, our project will be managed using the Agile (Scrum) method of project management. The Agile method was originally developed for software development and is a widely-used and highly-efficient management approach. We are a little behind schedule on implementation, but are now in a strong position to utilize this method going forward. The agile technique requires some type of software solution to track task backlogs, task progress (burn down data), team members, etc. In this case, we need a solution that works with team members distributed at multiple locations. Accordingly, we invested some time exploring available web-based solutions for agile management. Our objective was to find something that was low cost or free and not overly complicated. We felt that a simple and elegant

solution was critical to ensure widespread usage within the project. We initially selected a free web-based system, but after testing it, we decided that the interface was too cumbersome and it was lacking some critical features we were looking for. At that point, we decided to develop our own system. BYU PI Norm Jones worked with one of the CI-WATER PhD students (Scott Christensen) to develop a custom web-based solution using HTML/PHP and a MySQL database. The system was completed in mid-July and spent the latter half of July and all of August testing and debugging the system. It is hosted at the following URL:

http://ci-water.groups.et.byu.net/agile/
*(Contact Norm Jones (*njones@byu.edu*) for a password to log on to the site.)*

We have conducted training on the system for the CI-WATER team leaders and we will begin to employ it project-wide starting in December. We believe the system will be a simple yet effective way to track progress on project tasks and to prioritize project goals and allocate resources in a systematic fashion.

4.1.e. Project Outcomes. *Annual and final reports must include a description of efforts, accomplishments, commitments, and plans to ensure that the positive outcomes of the project will be sustained beyond the duration of the award. This may include quantitative data (e.g., numbers of new hires recruited and retained, proposal submissions, award success rates, students involved in research, etc.). These reports may also include qualitative information such as descriptions of policies or programs proposed or implemented to sustain cyberinfrastructure improvements, enhance research competitiveness, integrate research and education, and promote partnerships and alliances that increase research capacity and support.*

Consortium-wide activities

Since the project is in the early stages, sustainability measures such as new proposals, software dissemination, etc. will be light. However, some notable progress has been made. We have directly engaged 50 people on the project, and many more in an indirect fashion. We have engaged three post-docs and 6-8 PhD students with additional students joining the project in the next few months. These researchers will develop a focused area of research related to this project that, along with the work of the faculty involved, will ensure that the project will influence research over a substantial period. We are also purchasing hardware and developing software tools and services that we expect will be highly leveraged in other research projects, both within and without the two jurisdictions.

Utah activities

We are early in the stage of developing software tools and data services that will form the basis of a wide variety of water resource modeling and management applications. These tools will be open source and available for wide distribution. Furthermore, we will be working with state agencies to develop applications using CI-WATER tools (see Texas water level mapping utility described above for example) that will be managed and maintained by the state agency staff going forward. These tools will also form the basis of subsequent, more advanced tools as the CI-WATER research progresses. We are beginning to work with colleagues in the region to target follow-on projects that are based on CI-WATER research products.

Wyoming activities

As stated in the proposal, the University of Wyoming is committed to the long-term sustainability of the cyberinfrastructure acquired through this cooperative agreement. The University of Wyoming has committed significant financial resources to the long-term operation and success of our computing efforts. We have hired staff, installed needed electrical and cooling infrastructure, and attracted significant funding from on-campus researchers not directly affiliated with the CI-WATER project to expand the Wyoming Compute Cluster. New faculty hires that are computationally oriented are encouraged to purchase nodes in the "Condo" model of supercomputing, rather than attempt to purchase their own clusters. The University of Wyoming is committed to providing connectivity between Laramie and the Wasatch front to enable high-speed data transfers between Utah and Wyoming in support of this project. Each of these changes represent a fundamentally new way of approaching computation at the University of Wyoming, and these changes will be supported long beyond the duration of the CI-WATER project

The University of Wyoming has hired a Director of Research Computing, and established a research computing Support team, consisting of a User Support director and a HPC engineer and system administrator. The plan calls for adding two to three new full-time support positions over the next two years in support of HPC activities on the campus of the University of Wyoming. The UWyo administration has approved all new hires, which are permanent positions, and will sustain these positions beyond the duration of the CI-WATER project.

4.1.f. Unobligated Funds: *The annual report must include, as part of the "Special Requirements" section, an estimate of the funds expected to remain unobligated at the end of the current support period. If that estimate is greater than 20% of the current year award amount, the Project Director also must include in the "Special Requirements" section a plan and timeline for expenditure of those funds.*

Consortium Wide

Notification of the cooperative agreement came at the end of September, 2011, with a start date of Sept. 1, 2011. Given notification almost one month after the start date after the start of the fall semester, we were unable to staff the project from the starting date. The CI-WATER project consortium of Utah and Wyoming Universities placed a project-wide advertisement for available positions in EOS, *Trans. of the American Geophysical Union* in October, 2011, which appeared in November, 2011. Individual advertisements were placed in appropriate media as required. Review of applicants began at various times in the first third of 2012. The start date for new hires and students varied from one to another depending on their particular situation (graduation date, required notice, etc). Most new hires started working in June, July, or August, 2012. For this reason, all Universities within the consortium have considerably under-spent the salary and fringe benefits and associated indirect costs for the first project year.

The consortium agreed to postpone acquisition of the mass storage system to be housed at the University of Utah until the first half of project year 2. This decision was deemed appropriate given that the UWyo compute cluster would not be installed until then. Secondarily, we deemed this delay beneficial to the consortium given the hard disk price spike of 2012.

Utah

The Outreach portion of our project (directed by the UEN) has proceeded mostly on schedule, except that our first annual symposium was moved from May to September. In the following years we plan to conduct the symposium in May.

Graduate students and post-docs for the Utah universities were recruited during the typical recruiting cycle where applications are submitted to the school in February and decisions are made in the spring. For BYU, most of the students were hired by the beginning of the summer (June) and for USU and UU, some of the students started in June and some are not starting until the beginning of Fall semester. Accordingly, we are behind schedule and have a substantial sum of unused funds from year one. In the coming year, we expect to fully engage our students and reach a state where we are spending funds at the rate outlined in the original proposal. We anticipate completing all of the work associated with the project and expending all of the funds, pending the approval of an extension at the end of the project.

Wyoming

The University of Wyoming had no job classification for the Research Specialist position. UWyo P.I. Ogden worked closely with the UWyo Human Resources department to create a job description and obtain permission to begin the search. This process was initiated in November, 2011, and was not complete until March, 2012. This caused a delay in the start of the search for this position.

Post-doctoral Associate Wencong Lai was hired in April, 2012, could not start until July 1, 2012, because of the need to complete his dissertation and wrap up his affairs at Clemson University.

Co-I. Craig C. Douglas was funded full time in the summer of 2012 by the King Abdullah University of Science and Technology in Saudi Arabia, as part of a pre-existing arrangement.

Graduate student support was expended starting August 1, 2012.

Cyberinfrastructure acquisition for year 1 proceeded at a rapid pace, given the amount of work required in organizing the RFP, vendor visits and presentations, solicitation of bids, selecting of final bidders, and final negotiations. The final vendor selection and negotiations concluded in June, 2012, and the CI-WATER funds for equipment in project year 1 are fully encumbered.

Once fully staffed in year two, there will be funds carried over from year 1. We have formulated a plan for spending un-obligated funds in the second year at the University of Wyoming, with the objective of not carrying over more than 20% of cumulative funds from years one and two combined. These new expenditures are given in order of preference:

1. Increase graduate assistantships (GA's). These GA's will be used to increase student involvement on the UWyo campus in the CI-WATER project. We anticipate creating two GA's and offering them to all faculty for student support aimed at CI-WATER HPC model implementation research.
2. Offering an REU in High Performance Computing during the summer of 2013. This will be a new activity that was not originally included in the original proposal because of a lack of room in the budget. Funds carried over from the first project year will enable this activity, which will build on

a previous NSF-funded REU at the University of Wyoming, DMS-755450 REU Rocky Mountain Mathematical Research and Career Experiences, P.I. Bryan Shader. Bryan has agreed to help organize this in the summer of 2013. This activity is in addition to the Code Camps that are being planned for year 2. These GA's are being offered during the fall semester of 2012.

3. Involvement of faculty not identified as senior personnel on the original proposal. Summer salary support will be provided for faculty on a competitive basis. Evaluation criteria will include: advising of students working on the CI-WATER HPC model development, testing, parameterization and applications in new areas, including socioeconomics. This competition will be announced in early 2013.
4. Sponsoring an invited speaker to the Front Range High Performance Computing Consortium symposium to be held in Laramie, Wyoming, during the summer of 2013. We will pay travel costs to invite a speaker on HPC applications relevant to the CI-WATER HPC model.

The expenditures for the first year of our project are listed below for each institution followed by the project totals. These numbers are the estimated balances at the end of the current reporting cycle (8/31/12).

BYU

Category	Budgeted	Spent	Balance	% Remaining
Salaries + Wages	$ 157,800.00	$ 53,200.00	$ 104,600.00	66%
Benefits	$ 23,394.00	$ 8,689.40	$ 14,704.60	63%
Travel	$ 5,000.00	$ 1,627.10	$ 3,372.90	67%
Equipment	$ 15,000.00	$ -	$ 15,000.00	100%
Tuition	$ 19,600.00	$ 1,625.00	$ 17,975.00	92%
Other	$ 55,000.00	$ 238.73	$ 54,761.27	100%
Total Direct	$ 275,794.00	$ 65,380.23	$ 210,413.77	76%
Indirect	$ 115,597.00	$ 29,000.00	$ 73,994.66	64%
Total	**$ 391,391.00**	**$ 94,380.23**	**$ 284,408.43**	**73%**

USU

Category	Budgeted	Spent	Balance	% Remaining
Salaries + Wages	$ 131,937.00	$ 30,000.00	$ 101,937.00	77%
Benefits	$ 33,781.00	$ 12,570.24	$ 21,210.76	63%
Travel	$ 10,000.00	$ 4,500.00	$ 5,500.00	55%
Equipment	$ 30,000.00		$ 30,000.00	100%
Other	$ 20,026.00	$ 7,000.00	$ 13,026.00	65%
Total Direct	$ 225,744.00	$ 54,070.24	$ 171,673.76	76%
Indirect	$ 80,256.00	$ 22,168.80	$ 58,087.20	72%
Total	**$ 306,000.00**	**$ 76,239.04**	**$ 229,760.96**	**75%**

UU

Category	Budgeted	Spent	Balance	% Remaining
Salaries + Wages	$123,513.00	$26,837.36	$96,675.64	78%
Benefits	$24,415.00	$9,160.66	$15,254.34	62%
Travel	$6,200.00	$3,323.17	$2,876.83	46%
Equipment	$189,749.00	$12,207.60	$177,541.40	94%
Other	$19,949.00	$16,157.70	$3,791.30	19%
Total Direct	$363,826.00	$67,686.49	$296,139.51	81%
Indirect	$86,168.00	$27,462.11	$58,705.89	68%
Total	**$449,994.00**	**$95,148.60**	**$354,845.40**	**79%**

UWyo

Category	Budgeted	Spent	Encumbered	Balance	% Remaining
Salaries + Wages	$ 205,937.00	$ 53,430.27	$ 11,642.00	$ 140,864.73	68%
Benefits	$ 72,292.00	$ 11,686.21	$ 2,893.19	$ 57,712.60	80%
Travel	$ 13,000.00	$ 3,458.22	$ -	$ 9,541.78	73%
Equipment	$ 333,333.00	$ -	$ 330,000.00	$ 3,333.00	1%
Tuition	$ -		$ 2,402.94	$ (2,402.94)	
Other	$ 77,493.00	$ 5,718.18	$ 1,823.12	$ 69,951.70	90%
Total Direct	$ 702,055.00	$ 74,292.88	$ 348,761.25	$ 279,000.87	40%
Indirect	$ 150,530.00	$ 30,829.46	$ -	$ 119,700.54	80%
Total	**$ 852,585.00**	**$ 105,122.34**	**$ 348,761.25**	**$ 398,701.41**	**47%**

PROJECT TOTAL

Category	Budgeted	Spent	Encumbered	Balance	% Remaining
Salaries + Wages	$ 619,187.00	$ 163,467.63	$ 11,642.00	$ 444,077.37	72%
Benefits	$ 153,882.00	$ 42,106.51	$ 2,893.19	$ 108,882.30	71%
Travel	$ 34,200.00	$ 12,908.49	$ -	$ 21,291.51	62%
Equipment	$ 568,082.00	$ 12,207.60	$ 330,000.00	$ 225,874.40	40%
Tuition	$ 19,600.00	$ 1,625.00	$ 2,402.94	$ 15,572.06	79%
Other	$ 172,468.00	$ 29,114.61	$ 1,823.12	$ 141,530.27	82%
Total Direct	$ 1,567,419.00	$ 261,429.84	$ 348,761.25	$ 957,227.91	61%
Indirect	$ 432,551.00	$ 109,460.37	$ 190,787.75	$ 132,302.88	31%
Total	**$ 1,999,970.00**	**$ 370,890.21**	**$ 539,549.00**	**$ 1,089,530.79**	**54%**

Due primarily to the delay in hiring graduate students, post-docs, and programming staff as described above, we were only able to spend 46% of the budget total for our first year. **However, we fully intend to complete all tasks associated with the project and we plan to spend the entire budget**. The scope of the project has not changed. Rather, the time frame has shifted by a few months due to the delayed start resulting from the misalignment with the academic year. We anticipate seeking approval for a one-year,

no-cost extension at the end of the project complete the work and spend all funding associated with the grant. This plan was discussed with the assigned program officer (Jeanne Small) by the Utah PI Norm Jones on 8/31/2012.