PROJECT PROGRESS REPORT

PROJECT TITLE: An interactive and participatory optimization tool for supporting community learning and collaborative design of adaptation action plans in watersheds

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I. PRELIMINARY MATERIALS

A. Research project objective. This proposed one year project will create a climate-focused WRESTORE framework for stakeholders in central Indiana. WRESTORE (Watershed REstoration using Spatio-Temporal Optimization of REsources) is a novel, interactive and participatory optimization framework that has been developed by the investigators of this project for the purpose of designing alternatives (or solutions, adaptation action plans, etc.) for watershed planning and management problems. In this project, we will continue to engage with partners and stakeholders at every step of the process and collaboratively achieve the proposed objectives:

1) Develop a multi-objective methodology for optimizing adaptation action plans based on conservation practices, in watersheds impacted by future hydrologic extremes,

2) Investigate the various learning, decision components, visual and informational user-interface display factors, and anticipation processes of stakeholders, and

3) Test and disseminate WRESTORE tool use for adaptation planning in a Midwestern watershed.

B. Stakeholders and decision makers.

i. Jill Hoffman (Coordinator, Upper White River Watershed Alliance; President, Empower Results LLC)

ii. John Ulmer (Chair, Eagle Creek Watershed Alliance)

iii. Kimberly Neumann (Acting State Conservationist, USDA-NRCS, Indianapolis, IN)
C. Approach
The main underlying motivation behind this research is to transform complex and specialized design tools based on optimization algorithms (which are generally used only by experts) into tools through which communities can easily participate and help in the design of climate-resilient and adaptation strategies for watersheds. Below is an outline of the various proposed tasks that are being implemented to attain our project goals.

Task 1. In this task, we will build a modeling framework that will provide watershed communities a science-based assessment tool for analyzing the effect of climate change and their actions (via adoption of adaptation strategies/alternatives/action plans) on the flood and low flow events in their river systems. Eagle Creek watershed community, where this framework will be used, has been actively engaged in the past in using science-based assessment tools, such as use of hydrologic models (Bhaduri et al., 2000; Babbar-Sebens et al., 2010), for developing alternatives to manage hydrologic impacts. A coupled climate-hydrology modeling framework will enable the community to incorporate a climate focus in their efforts, and test the effectiveness, reliability, and resilience of their action plans in future climate scenarios.

• Task 1.1. Climate Data: Since the main goal of this research is to incorporate existing climate change data in the planning of adaptation strategies, we will (a) use North American Regional Climate Change Assessment Program (NARCCAP), which is funded partly by NOAA, to obtain various climate change data for the Midwestern region, and (b) engage with local agencies and groups (e.g., USDA-NRCS at Indianapolis, Eagle Creek Watershed Alliance, etc. (see Task 4 for details)) to assess the community’s data needs and perceptions of climate trends and variability in their region.

• Task 1.2. Hydrologic Model: Predictions of current and future daily precipitation and temperature from completed runs at NARCCAP will be used as inputs to the hydrologic model (Soil and Water Assessment Tool) to estimate multiple realizations of hydrographs for the current and future time periods, respectively.

• Task 1.3. Extreme hydrologic flow events: Four aspects (frequency, seasonal distribution, duration, and magnitude) of flood events (via, peak flows) and low flow events (important for aquatic water quality and ecosystems) in current and future climates will be assessed using established statistical techniques.

Task 2. Stochastic, and multi-objective optimization formulation and methods for design of adaptation alternatives (addresses objective 1, 2, and 3) at local watershed scales will be developed in this task.

• Task 2.1. Formulation of adaptation alternatives for watersheds: A policy, in this context, is defined as a spatial distribution of conservation practices in a watershed that help achieve a desired state of peak flows and low flows, in addition to any other benefits (such as, water quality benefits, etc.). The baseline current time period 1971-2000 and the future time period 2041-2070 will be examined for management periods, and stakeholders will have the option to explore “plan for now” and “plan for the future” approaches.

• Task 2.2. Stochastic and multi-objective optimization algorithms: In the proposed work we will investigate decentralized, multi-agent versions of such algorithms for optimization of
conservation practices as adaptation strategies to overcome or mitigate the potential and uncertain extreme flow impacts in the future.

Task 3. This task will investigate factors involved in stakeholder decision making, learning, and preference elicitation within climate-focused WRESTORE. In this study we will use the Graphical User Interface that WRESTORE supports to observe and identify the various scenarios of human behavior and learning that can potentially arise when stakeholders are presented with (a) climate change impact predictions, and (b) multiple choices/alternatives for adapting their watershed landscape to manage the predicted impacts. We will construct metrics, cognitive models, and techniques to observe these behavior and learning scenarios, via single user experiments.

Task 4. This task will test and assess proposed interactive optimization methods and the use of visualization interfaces, via stakeholder engagement (addresses objectives 1, 2, and 3). We will test the climate-focused WRESTORE system for its usability, reliability, and success in including stakeholder preferences and meeting stakeholder goals and expectations. Testing will be done in a workshop environment and will involve standard surveys. We will partner with natural resources facilitators at Empower Results, LLC, and other groups such as the Eagle Creek Watershed Alliance, Upper White River Watershed Alliance, United States Department of Agriculture- Natural Resources Conservation Services at Indiana, United States geological Survey (USGS), etc. to enhance participation in using and testing this system, support us in the design and creation of evaluation tools and training materials, and support the process for tool adoption and dissemination.

D. Matching funds/activities descriptions, including in-kind, used in this project.
   None

E. Partners
   Eagle Creek Watershed Alliance, Upper White River Watershed Alliance, USDA Natural Resources Conservation Service (NRCS), and US Geological Survey (USGS)

II. ACCOMPLISHMENTS
A. Project timeline and tasks accomplished
   - Task 1 (completed): We evaluated the long-term performance of a set of potential wetlands, one of the conservation practices, as adaptation solutions for reducing impacts from a range of high flows estimated by future climate scenarios. This study used the SWAT hydrological model forced with an ensemble of bias corrected climate projection datasets from NARCCAP. The analysis performed in this research focused on the Eagle Creek Watershed in Indiana as a case study and built on the previous study by Babbar-Sebens et al. (2013), which identified 2953 potential wetland locations in 108 of the 130 sub-basins.
     In using the NARCCAP data for a hydrological impact study, it was found that the minimum and maximum temperatures for the watershed were well simulated by the climate models. However, the climate models did not accurately represent the variance and seasonal trends in precipitation for the watershed, confirming findings from previous studies showing the necessity for bias correction of precipitation projection data. Four bias correction approaches and the raw climate models, resulting in 40 climate datasets, were investigated and evaluated for
several error metrics. The bias correction methods that did not improve the precipitation data were removed, leaving 27 climate realizations, which was further narrowed down to 11 realizations with a streamflow analysis in SWAT.

The final ensemble of climate realizations was input into the calibrated SWAT model to simulate watershed hydrology in projected future climate scenarios. A land use change analysis was performed to estimate the impacts of urban development on streamflow. Urban growth projections for 2050 produced very minimal effects on streamflow output for the future time period (2041-2070) and were not incorporated into the subsequent analyses. The hydrological response to the future climate projections (2041-2070) was also compared to that of the past climate projections (1971-2000) in a streamflow analysis and an extreme event analysis. In general, the climate models predicted a slight increase in long-term mean monthly streamflow in the winter and a slight decrease in the summer from past to future. The extreme event analysis results showed that out of the 11 climate realizations, 6 projected an increase in the frequency of the historic Q05 value and 5 projected an expected decrease in the future. The ensemble tended to agree that overall, high flow events are anticipated to increase in frequency in the winter and decrease in the spring and summer.

The performance of potential wetlands was evaluated with an extreme event analysis and a peak flow reduction analysis. For both the past and future time periods, implementation of wetlands resulted in a reduction in the magnitude of the 5% exceedance streamflow (Q05) value of about 0.5-1.5 m$^3$/s across all climate realizations. While it was shown that the high flow events would decrease in size, very little change in the seasonal distribution of the Q05 events was seen with the wetlands. The maximum peak flow reduction was calculated across all sub-basins in the watershed for each climate realization. When wetlands were implemented, the watershed saw maximum peak flow reductions between 20 and 60 m$^3$/s in the past time period and 24 to 44 m$^3$/s in the future, or 15-20% of the peak flow without wetlands in the past and 15-19% in the future. The distributions of peak flows above the Q05 streamflow value was also assessed. When wetlands were implemented, the median value, or event with a probability of occurrence of 0.5, saw a decrease in magnitude of 0.85 to 2.25 m$^3$/s. This reduction means that, overall, the size of events expected at certain frequencies will be reduced when wetlands are installed, or that the frequency of high peak flow events will be reduced.

Wetlands were found to be a reliable alternative to reducing peak flows. The peak flow reductions in the future time period were similar to the reductions that would have occurred if wetlands had been implemented in the past, showing that wetlands performance will be consistent in the future. The robustness of wetlands as a method for peak flow reduction was analyzed. Robustness is defined as a solution that meets the desired goals while being insensitive to uncertainties, or in this case, the variance across the climate realizations. The expected maximum peak flow reductions were similar across all climate realizations, which tells us that they are insensitive to the climate projections. To further analyze the robustness of the wetlands, streamflow reductions were analyzed across models within certain ranges. Streamflows within 0-50 m$^3$/s, 50-100 m$^3$/s, and 100-150 m$^3$/s, produced very similar streamflow reductions across the climate realizations. More variation in expected streamflow reductions occurred for streamflows above 150 m$^3$/s, but for the majority of flows, which occur below 150 m$^3$/s, wetlands show a robustness, or insensitivity to the climate projections.

Managing the expected changes in streamflow due to climate changes is a challenge and has become more important as flows increase in magnitude and frequency. Wetlands creation is a key strategy in management plans designed to withstand the effects of climate change and
provide streamflow management benefits. This study focused on long-term projection of wetland performance for reducing peak flows and wetlands were found to reduce both the magnitude and frequency of peak flow events. By implementing wetlands occupying about 1.5% of the watershed, maximum peak flow reductions of 15-20% can be obtained. This study highlights the benefits gained from wetlands in flood conditions and reinforces the need for climate change-integrated conservation plans. The methods established here can be applied to other watersheds or other conservation practices to conduct better long-term land management studies and decisions.

- **Task 2 (commenced, completion expected Oct 2015):** The Graphical User Interface (GUI) in WRESTORE is currently being updated to enable stakeholders to visualize results of simulation models forced by climate projections. The GUI will enable users to evaluate and assess effectiveness of conservation practices (such as wetlands) in both current and future climates, thereby testing the resilience of these practices as adaptation alternatives. The learning-based optimization environment in WRESTORE is also being updated in this interface to enable interactions between machine-based, algorithmic agents and human agents, with capability to engage in mutual learning from one other.

- **Task 3 (commenced, completion expected April 2015):** Single-user experiments are currently being planned for testing with students and other volunteers in October 2015 and groups of stakeholders in Indiana in Feb 2016. These experiments will investigate factors affecting stakeholder preference elicitation and learning in WRESTORE’s GUI environment when users view performance of practices predicted by simulation models forced by historical climate versus ones forced by future climates.

- **Task 4 (not started yet):** This task will be conducted during the user and stakeholder workshops.

**B. Application of your findings to inform decision making**


**C. Planned methods to transfer the information and lessons learned from this project.**

Data sharing will involve presentation and workshops at national scientific meeting(s), presentations and workshops at local watershed community events (e.g., White River Festival (http://whiteriverfestival.org/)), and peer-reviewed publications. Since the main focus of this research is to rapidly disseminate the research tools to the end users, we will also network via our partnering communities and agencies to share the data and tools with interested parties.

**D. Significant deviations from proposed workplan.**

Since the project started late, we are slightly behind the earlier schedule. Also, distribution of some of the funds was modified in order to support a student. The program manager has been notified, and approval has been obtained.
E. **Completed publications, white papers, or reports (with internet links if possible).** These can be either non-peer reviewed or peer-reviewed. For peer-review publications, please list either **published** or in **press**, but **not** “in review”.
  

III. **GRAPHICS: PLEASE INCLUDE THE FOLLOWING GRAPHICS AS SEPARATE ATTACHMENTS TO YOUR REPORT**
  
  Not yet.

IV. **WEBSITE ADDRESS FOR FURTHER INFORMATION (IF APPLICABLE)**
  
  Decision Support System website: [http://wrestore.iupui.edu/](http://wrestore.iupui.edu/)

V. **ADDITIONAL RELEVANT INFORMATION NOT COVERED UNDER THE ABOVE CATEGORIES**
  
  N/A