Project Title: Missouri Headwaters – Mountain Watershed and Aquatic Habitat Response to Climate Variability and Change

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Project Summary: The US Geological Survey (USGS) proposes to develop a precipitation-runoff model for the 14,669 sq mi Missouri Headwaters basin above Toston, MT. The Precipitation-Runoff Modeling System (PRMS) model will enable users to calculate streamflows in the Upper Missouri River and major tributaries given daily inputs of precipitation and temperature. Streamflows under future climate scenarios will be simulated using the model; these simulated flows will be used by FWP biologists to manage fisheries resources in the Missouri Headwaters basin. ***This project falls under the Great Northern Landscape Cooperative Center (GNLCC) categories "aquatic integrity" and "climate".***

Need: The Missouri River begins in the Rocky Mountains of southwestern Montana at the confluence of the Jefferson, Madison, and Gallatin Rivers. Approximately 740 square miles of crops and pasture are irrigated by the rivers in this Missouri Headwaters basin (fig. 1). These same rivers also support diverse communities of fish and are an important recreational and commercial destination for anglers and boaters.

Figure 1. Missouri Headwaters basin.

Several efforts are underway in the Missouri Headwaters basin to manage scarce water supplies to sustain fish habitat and meet the needs of irrigators, ranchers, boaters and anglers. Water users in the Big Hole basin are working with state and federal agencies to keep water in the stream for fish habitat, notably for Arctic Grayling recovery. The Jefferson River has been on the Montana FWP "chronically-dewatered" stream list since 1988; irrigators in the Jefferson River basin have been working together to keep water flowing, creating one of the first streamflow drought plans in the state in 2000 (http://www.jeffersonriverwc.org/Restoration_Plan/Measureable_Accomplishments.pdf). In addition, under the Ruby River Task Force water users have voluntarily managed flow diversions to meet minimum targeted stream flows in the Ruby since 1996.

General Circulation Models (GCMs), developed under the auspices of the intergovernmental Panel on Climate Change, simulate physical processes in the atmosphere, ocean, cryosphere, and on the land surface for a wide range of possible future climate scenarios. Output from GCMs as well as examination of historical and recent precipitation and temperature cycles indicate that warmer temperatures occurring across the western United States could continue into the future. Scientists have shown that warmer temperatures will produce more precipitation as rainfall instead of snowfall at lower and middle elevations and cause most of the mountain snowpack to melt earlier. These changes would tend to increase streamflows throughout the winter and spring and decrease streamflows in the summer. Decreased summer flows will negatively affect management of surface water resources in the Missouri Headwaters and the capacity of the system to support agriculture, recreation, and fisheries.

The Missouri Headwaters Partnership was formed in 2009 to "…create a regional collaborative organization that promotes economic and ecologic sustainability by supporting the natural resource integrity, water quality, water quantity, and economic and ecologic values of the landscapes and communities of the Missouri River headwaters basin." The Missouri Headwaters Partnership and other local, state, and federal agencies have identified a requirement for better tools for water supply and fisheries management within the Missouri Headwaters basin.

The proposed PRMS model will be developed in cooperation with the Missouri Headwaters Partnership, local watershed groups, the Montana Department of Natural Resources and Conservation (DNRC), Montana Fish Wildlife and Parks (FWP), the Natural Resources Conservation Service (NRCS), the Bureau of Reclamation (Reclamation), the US Forest Service (USFS), and PPL Montana. Streamflow under projected climate scenarios from regional climate models will be simulated.

The precipitation-runoff model will provide an increased understanding of watershed dynamics in the Missouri Headwaters basin and help users quantify the relative importance of snowmelt, rainfall, evaporation, and tributary flows during different times of the year. The model will serve as a tool for understanding the effects of varying climate conditions on streamflow and fisheries habitat. PRMS can be paired with water management software such as RiverWare to help water users plan for and adapt to variable water availability and changing irrigation demands. PRMS can also be coupled

with existing and proposed groundwater models to further understand surfacewater-groundwater interactions and effects of changing irrigation methods on streamflows. Modeling future climate scenarios will enable planners and water users to estimate streamflows 10, 20, 40, 50, and 90 years into the future based on projected climate conditions. Correlating model results with fisheries data will allow scientists and managers to estimate potential impacts to fisheries and to develop management strategies to mitigate those impacts.

The PRMS model can be an integral part of the State Water Plan directive for the Missouri River basin, especially the plan's stated objective to provide "An analysis of the effects of drought and increased depletions on water availability." Future streamflow scenarios information is also critically important to Montana Fish Wildlife and Parks as they plan fisheries management options for the Missouri River and its tributaries. The PRMS model and results can also inform/be informed by other hydrology work in the larger Missouri River basin, including the climate modeling by the University of Washington Climate Impacts Group and the decadal variability modeling led by the Center for Research on the Changing Earth System (CRCES; http://www.decvar.org/MRB_project.php). Since the Missouri Headwaters basin is similar to other mountain basins in the western United States, methods and results from the modeling and fisheries analyses can be applied to other areas in the GNLCC.

Objectives: The objectives of this project are to 1. Develop a precipitation-runoff model to provide an increased understanding of watershed dynamics in the Missouri Headwaters basin and help users quantify the relative importance of snowmelt, rainfall, evaporation, and tributary flows during different times of the year; and 2. Quantify potential changes in the amount and timing of streamflow and resulting changes in aquatic habitat in the Missouri Headwaters under future climate scenarios, so that local and state water and fisheries managers can find solutions to share this limited resource. ***These objectives contribute to the LCC objective "decision support tools/systems or science applications for focused resource conservation" and "Inventory of resource (streamflow) conditions or trends."***

Methods: The USGS will develop a PRMS model for the Missouri Headwaters basin above Toston, MT (fig. 1). The development will follow procedures and protocols being used by the USGS National Research Program for other large-scale PRMS models being constructed for the Yellowstone Basin, the Great Lakes Basin (http://cida.usgs.gov/glri/projects/accountability/responses_future_change.html), and the Apalachicola-Chatahoochi-Flint Basin (http://ga.water.usgs.gov/nawqa/).

The USGS Precipitation-Runoff Modeling System (PRMS) is a numerical precipitation-runoff model that can be used to simulate daily streamflows given inputs of daily precipitation and daily minimum and maximum temperature. PRMS is a physically-based, distributed-parameter precipitation-runoff model (Leavesley and others, 1983; U.S. Geological Survey, 2007) that has been rigorously developed and garnered the approval of the precipitation-runoff modeling community. PRMS is currently being used in Montana and throughout the United States for investigating watershed scale responses to climate change (Markstrom and Hay, 2009; Chase et al, 2009). The proposed modeling

work will take advantage of the GNLCC Geospatial Data Management Infrastructure, a separate ongoing cooperative project being undertaken by the USGS and USFWS. The GNLCC data management plan includes a data acquisition and delivery framework, a data model, and a complementary storage solution for the GNLCC. The GNLCC Infrastructure will provide access to PRMS datasets for any specified area, and then will capture model outputs as a set of related data files bundled into a single virtual file. This "distribution dataset" will consist of all data variables for a given model run, including model metadata.

The PRMS model will be calibrated to historical streamflow data as well as solar radiation, evapotranpiration, and snow-covered area data. Then, daily precipitation and temperature data from an existing regional climate model (RegCM3) developed by Steve Hostetler, will be used to simulate streamflow under future climate scenarios. RegCM3 simulates climate on a 12-kilometer grid for 1) present day equilibrium (100 yr), 2) transient CO_2 extending out ~50 years into the future, and 3) equilibrium under doubled CO_2 (100 yr). RegCM3 is being used in Montana and across the western United States by USGS, USFS, the Bureau of Land Management, and other agencies for understanding effects of projected climate changes on riverine and terrestrial systems.

The USGS will work with personnel from local watershed groups, Montana Department of Natural Resources and Conservation (DNRC), Montana Fish Wildlife and Parks (FWP), and the Natural Resources Conservation Service (NRCS) to assure that the data input to the model are appropriate and the data produced by the model are useful for management objectives. We will also coordinate with the USFS and their ongoing watershed vulnerability assessments in the Gallatin National Forest as well as hydrologic climate projections produced by the University of Washington Climate Impacts Group for USFS Regions 1 and 6 across the Rocky Mountains. The Bureau of Reclamation and PPL Montana will be consulted as well. The Jefferson Watershed Group coordinator will provide in-kind support to assist with this coordination.

FWP biologists will correlate the model output with fisheries and stream temperature data to help guide management decisions and prioritize stream reaches for restoration and other aquatic habitat enhancement work. FWP will continue to monitor streamflow and fish populations to assess the health of the rivers in the Missouri Headwaters basin.

Deliverables: The USGS will prepare a draft Scientific Investigations Report document documenting the PRMS model, and post the model and results to a portal accessible to other modelers and scientists.

Letters of Support: Letters of support from FWP, DNRC, the Missouri Headwaters Partnership, the Jefferson and Madison watershed groups, and Golden Sunlight Mine demonstrate support from state agencies and local land owners and resource managers; these letters are included with this proposal.

Schedule:

Task	FY 2011				FY 2012			
	1	2	3	4	1	2	3	4
Meet in July 2011 with partners regarding model inputs, calibration targets, and calculation nodes				X				
Gather, review, synthesize input data and parameters: precip, streamflow, topo, veg, soils				X				
Construct, calibrate model					X	X		
Preliminary Model Presentation to partners						X		
FWP biologists correlate model output with fisheries and stream temperature data						X	X	*X**
Simulate streamflow for projected climate scenarios						X	X	
Final Model Presentation to partners September 2012								*X**
Report – funding and timeline under this proposal includes writing and initial editorial/layout work. Draft for college review by March 2013; available online by July 2013				X	X	X	X	*X**

* Funding for 4rth Quarter FY 2012 not included in this proposal