Scenario-Based Scoping and Modeling: A Deschutes River Basin Case Study

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The goal of the Basin Scale Opportunity Assessment (BSOA) project is to identify opportunities for hydropower generation *and* environmental benefit, while avoiding impacts to other water uses. To examine tradeoffs among hydropower, environmental and other water uses, we developed a daily river/reservoir water balance model for the Deschutes River Basin and operated the model under a suite of alternative water resource use scenarios and scoping levels/management actions. The modeled scenario outcomes can be visualized via a web-based tool to provide a common basis for understanding the implications of different water resource management actions.

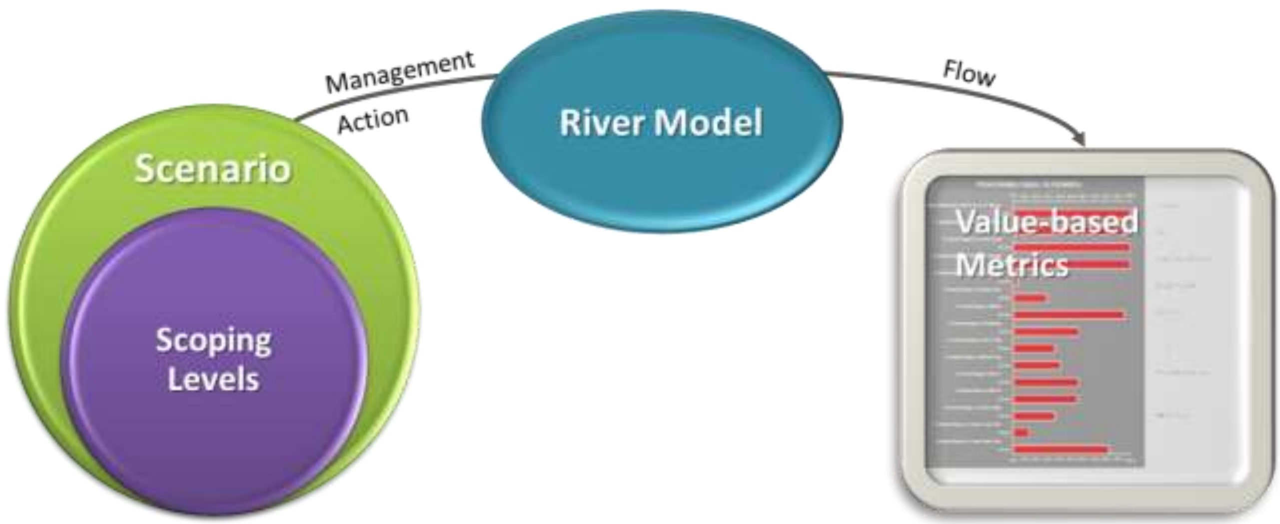

Figure 1. Diagram of the relationship among key concepts

Scenario-based modeling is not intended to provide all of the answers to all of the questions important to stakeholders in the basin, but can be used as a means to explore different water use/water management options. Scenario modeling, in this project, involves determining and applying scoping levels in a mass-balance model specific to the Deschutes and Crooked River basins. Scenario scoping is the process of identifying actions, measurements, and resource levels that expose opportunities and tensions in the system.

Scenario Modeling: Applying scoping levels in a mass-balance model specific to a basin

Pacific Northwest National Laboratory (PNNL) and Oak Ridge National Laboratory (ORNL) worked with stakeholders and modeling experts in the Deschutes Basin to develop an initial set of water resource use and management scenarios and run a mass-balance model for these conditions. These scenarios are intended to examine the interaction between several key hydro power and environmental opportunities and demonstrate functionality of the tool. Alternative scenarios and model runs could be developed to further clarify opportunities and tensions, or explore additional opportunities. The power of collaborative scenario-based modeling is the ability to continue to refine tools and add additional data as needs arise and data are available.

> *The power of collaborative, scenario-based modeling is the ability to continually refine understanding*

Because water, hydropower and environmental issues in places like the Deschutes Basin are extremely complex, it is important to understand that the models and tools developed and applied in this opportunity assessment are not intended to provide a single answer or set of recommendations. Scenario-based modeling requires collaboration between modelers and stakeholders to **explore** issues of interest in a transparent and coordinated way, so that model results are understood within the context of data limitations and uncertainty.

Here, we provide background on opportunity scenarios, the modeling software (RiverWare), data visualization architecture, and next steps.

The Scenarios

Deschutes River Scenario

The Deschutes River scenario focuses on opportunities for enhancing instream flow, conserving water, and adding hydropower generation at upstream reservoirs, irrigation canals and conduits in the Deschutes Basin. Enhancing instream flow in the Deschutes River has been identified as an environmental goal in the basin (NPCC 2004, Golden & Aylward 2006). Under this scenario, flow enhancement in the upper Deschutes River is enhanced by simulating step-wise increases in discharge from Wickiup Dam during the

> *Example Scoping Action: Increase local instream flow by a discrete number of levels to assess the effect on other uses*

non-irrigation season (mid-October through mid-April), as well as testing the effect of water conservation measures in the form of generalized demand reductions. Scoping levels for flow enhancement were implemented in the model by incrementally increasing the minimum flow for this reach from the current average minimum flow of 25 cfs (baseline) to 350 cfs. A total of five such "flow cases" were examined: 25, 100, 175, 250 and 350 cfs). Demand reduction measures were then simulated by reducing model diversion requests. Demand reduction levels were set to 0 (baseline), 10, and 20%.

Crooked River Scenario

The Crooked River scenario examines operating conditions before and after pending legislation (H.R. 2060 "Central Oregon Jobs and Water Security Act"), which proposes increasing the minimum flow requirement below Bowman Dam from 10 cfs (pre-legislation) to 17 cfs (post-legislation). This potential change was simulated in the model by setting the average minimum flow below Bowman Dam to 10 and 17 cfs. For these model runs, operations in the Deschutes River were held at baseline conditions (i.e., 25 cfs minimum average flow below Wickiup Dam and 0% water demand reduction).

The Model

RiverWare software was used to create a daily water-balance model for the Deschutes and Crooked River basins. This model was based on the structure of a monthly MODSIM model originally developed by Oregon Water Resources Department (La Marche 2001) and then expanded to include groundwater components, the Crooked River, and improved inflow hydrographs by the U.S. Bureau of Reclamation and PNNL (under review).

The model was calibrated using naturalized monthly inflows for Deschutes basin from 1929 to 2008 (Johnson 2009). Monthly inflows were disaggregated into a daily sequence (Acharya, A. and Ryu,

RiverWare Model Facts

- Daily water balance model for Deschutes and Crooked Basins
- Based on the structure of monthly MODSIM model
- 5 Dams
- 28 Diversion/water user accounts
- 8 Inline hydropower objects
- 2 Pumping systems
- Groundwater returns at diversions with 50-year lag

J. 2012) and the model was calibrated to observed monthly flows. Model inflow locations include upstream of Crane Prairie, Wickiup, Crescent Lake, Bowman and Ochoco dams, significant tributaries including Little Deschutes, Tumalo Creek, Whychus Creek, and the Metolius River. Significant side flows including those above Benham Falls on the Deschutes River and below Opal Springs on the Crooked River were included in the model architecture.

Dams included in the model are Crane Prairie, Wickiup, Crescent Lake, Bowman, Ochoco, and Opal Springs dams. Each dam was identified as a hydropower object, along with eight, existing and proposed in-canal hydropower developments (Siphon, Juniper Ridge, Ponderosa, Monroe Drop, Mile 45, Mile 51, and NC-2). To model water use, twenty eight diversion/water user accounts were identified, including those from Arnold, Central Oregon, North Unit, Ochoco, Three Sisters, Swalley, Lone Pine, and Tumalo irrigation districts. We included two major pumping systems in the model: Ochoco Relift and Barnes Butte Plant.

Groundwater seepage and recharge are major components of the hydrology in the Deschutes Basin. Groundwater returns were found to have a 50-year lag and were implemented at each diversion. Groundwater returns are distributed throughout the model (J. Johnson, personal communication, June 26, 2012).

Modeled System Operation

Irrigation water demands were based on monthly values in the MODSIM model. The RiverWare model required daily values so the monthly demands were divided to estimate daily demands.

In the Crooked River Basin, Bowman and Ochoco Dams were modeled with three major operations: flood control, water demand during irrigation season, and minimum environmental flows. Flood Rule Curves designated by the Bureau of Reclamation were used to set model storage level requirements and releases during the non-irrigation season (Johnson 2009).

Upper Deschutes Basin dams included Crane Prairie, Wickiup and Crescent Lake. Crescent Lake dam is operated by Tumalo Irrigation District and, therefore, releases are only made to meet minimum flow criteria and Tumalo irrigation demand. Non-irrigation releases may occur if the reservoir is full and must pass inflow.

Wickiup Dam is operated in tandem with Crane Prairie dam by North Unit Irrigation District. Because of significant seepage, in wet years Crane Prairie is permitted to fill to maximum while releasing minimum required flows. During dry seasons, Wickiup is filled first followed by Crane Prairie. Irrigation water rights from Crane Prairie are transferred through Wickiup. Crane Prairie non-irrigation releases above minimum flows only occur if the reservoir is full (Inter-District Contract Agreement 1938).

Model Outputs

Model outputs include discharge, storage, pool elevation, seepage, groundwater fractional return flows, diversion requests, diversion shortages, and energy production. To visualize the effects of actions we rely primarily on daily flow at diversion points and dams, and daily power at hydropower locations.

> *When considering the implications of model scenarios one must acknowledge sources of model uncertainty.*

Model Validation and Current Limitations

The RiverWare model is currently being validated by comparing aggregated daily flows to the MODSIM monthly output. Daily stream gauge data will be used to further validate the model at a daily time-step.

A model, as a mathematical representation, can never fully replicate reality. Though the RiverWare model developed for the Deschutes River Basin is quite complex, certain interactions, inputs and operations are unknown with the granularity required to perfectly replicate the water system.

- Water accounting is not yet automated
- The current model is based on daily inflow estimated from monthly inflow data. Daily flows are in the process of being generated and implemented within the model.
- Power calculations were implemented with general efficiencies. More data will be collected to provide more precise energy predictions to have a better understanding of feasibility of hydropower development
- Irrigation district-level lateral canal demand is not known and therefore not represented in the model

The Dashboard

Critical data for examining scenario outcomes were extracted from the RiverWare outputs and made available through the BSOA visualization web portal. The BSOA visualization system is a web-based interface developed to provide users access to geographic, tabular and model simulation data and deliver an intuitive means of assessing the opportunities and trade-offs between different management actions. The interface consists of three main components: (1) an interactive map, (2) opportunity evaluation tools, and (3) scenario exploration tools.

The interactive map allows the user to tailor the map with customizable GIS overlays. The opportunity evaluation tool includes site cards showing the location and details on hydropower and environmental opportunities. Scenario exploration tools include a description of scenarios, assumptions and scoping variables and a dashboard for visualization of and interaction with model outputs. The dashboard system architecture consists of a relational database containing metadata for individual model nodes and their associated model outputs (flow, reservoir level, etc.). The model output data is queried via interface control for dynamic chart creation. There are three levels of data available for user interaction and drill down: value-based metrics, annual summaries and raw data. Data can also be downloaded for more in-depth analysis.

VBM Class	VBM Example	Note
Hydropower	Percent of total potential power generated during water year	Calculated for individual power nodes
	Percent of water year where total inflow to Lake Billy Chinook is between 4400 and 4600 cfs	Total inflow from all streams in the model
Environmental	Wickiup flow as a percent of 300 cfs during non-irrigation season	Non-irrigation season defined as Oct 15- Apr 15
	Percent of summer days that flow exceeds 250 cfs at DEBO gauge	Summer defined as Jun 1 - Aug 31
Water User	Percent of North Unit Irrigation District diversion request that was received	
	Percent of water year where Prineville Reservoir remains above 92,000 acre feet	

Table 1. Summary of Value-Based Metrics (VBM) computed from the daily model

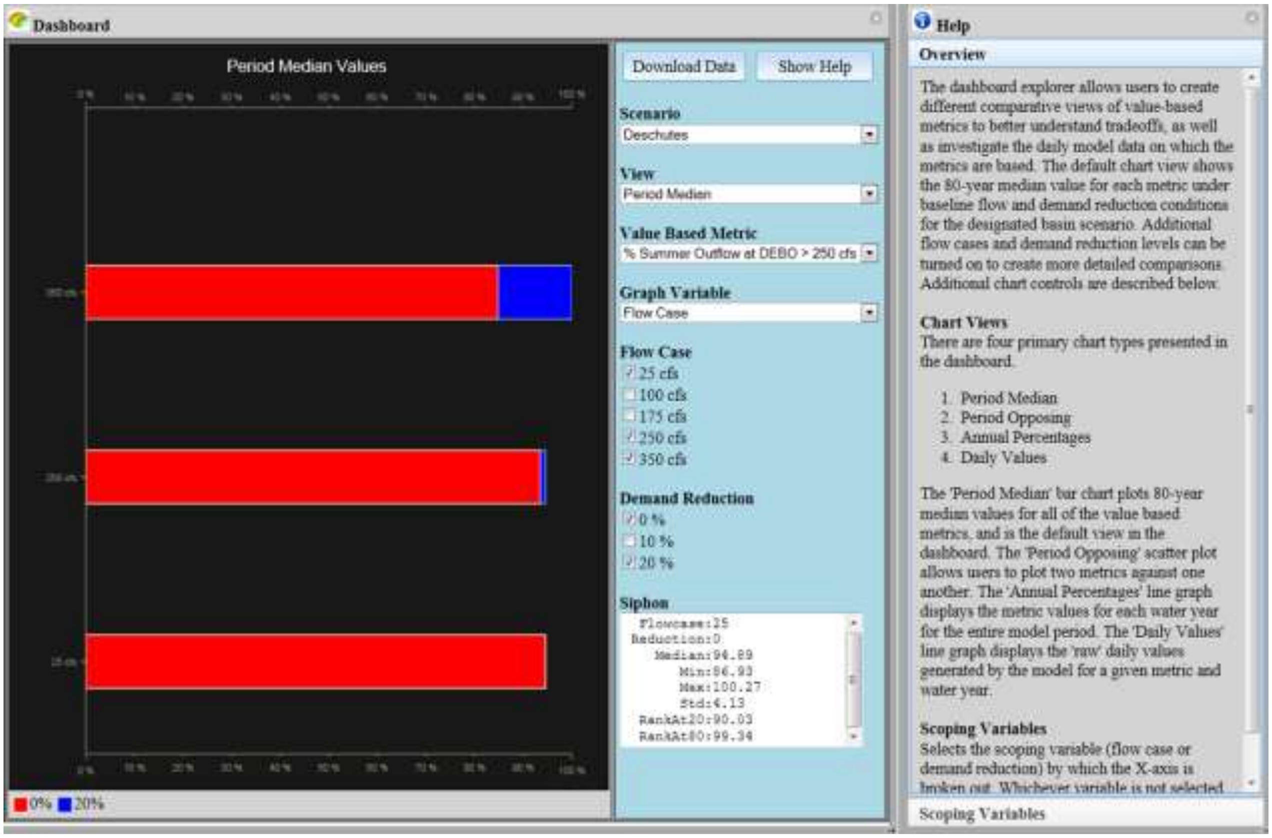

Figure 2. Example Dashboard View

Summary and Next Steps

The BSOA project has created a daily water model to explore a suite of scenarios and scoping levels for the Deschutes River Basin. The model is being refined, validated and fitted with water accounting rules to provide increasing functionality for scoping other scenarios. The basin scale dashboard architecture currently provides the structure and flexibility to view the implications of any number of scoping actions that may be explored in future efforts. Some refinements to look and feel of the dashboard are planned, including: font sizes, tool tips and color coding changes.

Acknowledgements

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