9.0 Recommended Potential Improvements for 2016 Forecast

The model developed and used for this study represents current state-of-the-science technology. However, there are areas that could be improved upon to reduce uncertainty and risk. This section consists of recommendations by the WSU research team on how to improve the 2016 Forecast. The recommendations are based on discussions with stakeholders, Ecology and the WSU research team. This section also includes some initial suggestions on how to achieve the improvements. While Ecology will consider and evaluate the suggestions provided here, ultimately, the breadth and scope of the 2016 Forecast will be influenced by many factors including technology, staffing, data availability, budget, timeline, and overall importance to Ecology's strategic plan and mission.

9.1 Water Management Data Collection and Processing

9.1.1 Expand Water Rights Data

There are two primary areas where additional data are needed: 1) percent of irrigation demands associated with groundwater sources versus surface water sources, and 2) water rights associated with Surface Water Source Limitations. Ecology would need to evaluate the best way to acquire these data.

9.1.2 Collect and Verify Diversion Records

Collection and quality assurance/quality control of metered diversion data at the Columbia River scale as well as the watershed scale would allow WSU to evaluate the performance of the integrated model help calibrate the model to better represent actual conditions. Such evaluations are currently lacking due to a lack of data.

9.2 Data Verification and Model Evaluation

9.2.1 Verify Irrigated Areas

The recently released 2011 WSDA Cropland Data Layer expands coverage of irrigated pasture. This will significantly improve the coverage of irrigated agriculture in future models. However, given the large discrepancies between acreage reported by several of the irrigation districts and WSDA, independent field verification of the data could be conducted to reduce uncertainties. This verification could be carried out in the Walla Walla, Yakima, and Okanagan drainages initially and could be expanded depending on the level of agreement between WSDA estimates and the checked acreages.

9.2.2 Improve Information on Surface/Groundwater Sources to Understand Conservation Implications

Conservation is a complex issue in terms of whether or not it improves water quantities in streams and rivers. Diverting less water through use of improved irrigation efficiencies could actually reduce return flows (via shallow groundwater flows). This may in turn increase total consumptive water use and may adversely impact critical season stream flows currently benefitted by less efficient conveyance and irrigation technology.

An increased understanding is needed on how conservation actions may affect return flows, consumptive use and stream flows. Improved knowledge of the local surface/groundwater interface is also needed to evaluate the potential positive and negative impacts of conservation efforts. Seepage studies of water quantity, observation wells, and ion analysis can be used along with models of the Spokane, Yakima, and Walla Walla to improve understanding of the implications of conservation programs.

9.2.3 Field Verify and Expand Irrigation Practice Information

WSDA information was used to determine irrigation efficiencies throughout the State of Washington. This information needs to be field verified (in collaboration with validation of crop types and irrigated acreage). In addition, the database of irrigation efficiencies needs to be expanded to include information from Canada and larger water diversions in Idaho, Oregon, and Montana. This would facilitate the evaluation of conservation practice impacts.

9.2.4 Use Evapotranspiration Remote Sensing Application of Consumptive Use Requirements

The University of Idaho and the Idaho Water Resources Department have been using remote sensing images from LandSat (Thermatic Mapper) to determine evapotranspiration from agricultural areas primarily in southern Idaho. The procedure called "Mapping Evapotranspiration at high Resolution and with Internalized Calibration" (METRIC) is a modified version of the European approach known as SEBAL. A similar version for Washington crops, soils, and climate with field information on soil moisture, precipitation, temperature, and relative humidity at several key locations throughout the watershed could be developed. This information, along with a database of GIS layers of remotely sensed images could be combined with data collection efforts already occurring at AgMet stations throughout the region. In combination with water right diversion records, VIC-CropSyst water demands, and WIG estimates, this information would enable significantly improved evaluation of crop water demand, current groundwater recharge, conservation potentials, and long-term cost savings as ultimately metering of water diversions may not be necessary.

9.2.5 Expand Model Evaluation

Model evaluation could be improved in subsequent Forecasts. The 2011 Forecast has uncertainty in off- and on- farm water use efficiency as well as population expansion patterns. Differences between competing model estimates are difficult to resolve without improved measurement of *in situ* processes at relatively large scales. Even small discrepancies can amount to significant quantities of water over a watershed and provide some degree of overall uncertainty. For example, the Washington Irrigation Guidelines (based on ASCE) and CropSyst (based on United Nations Food and Agriculture Organization) compute evapotranspiration somewhat differently. As illustrated in Figure 217, when alfalfa harvest events (clipping) are considered, crop evapotranspiration evolution throughout the growing season between the two methods are clearly different. Additional information is needed to resolve parameter issues such as these as well as to verify the entire VIC-CropSyst model. This information can be collected through extensive data monitoring of on-farm practices, subsurface return flows, irrigation ditch diversions and losses, streamflows, and climate drivers or from remote sensing with some in-field verification.

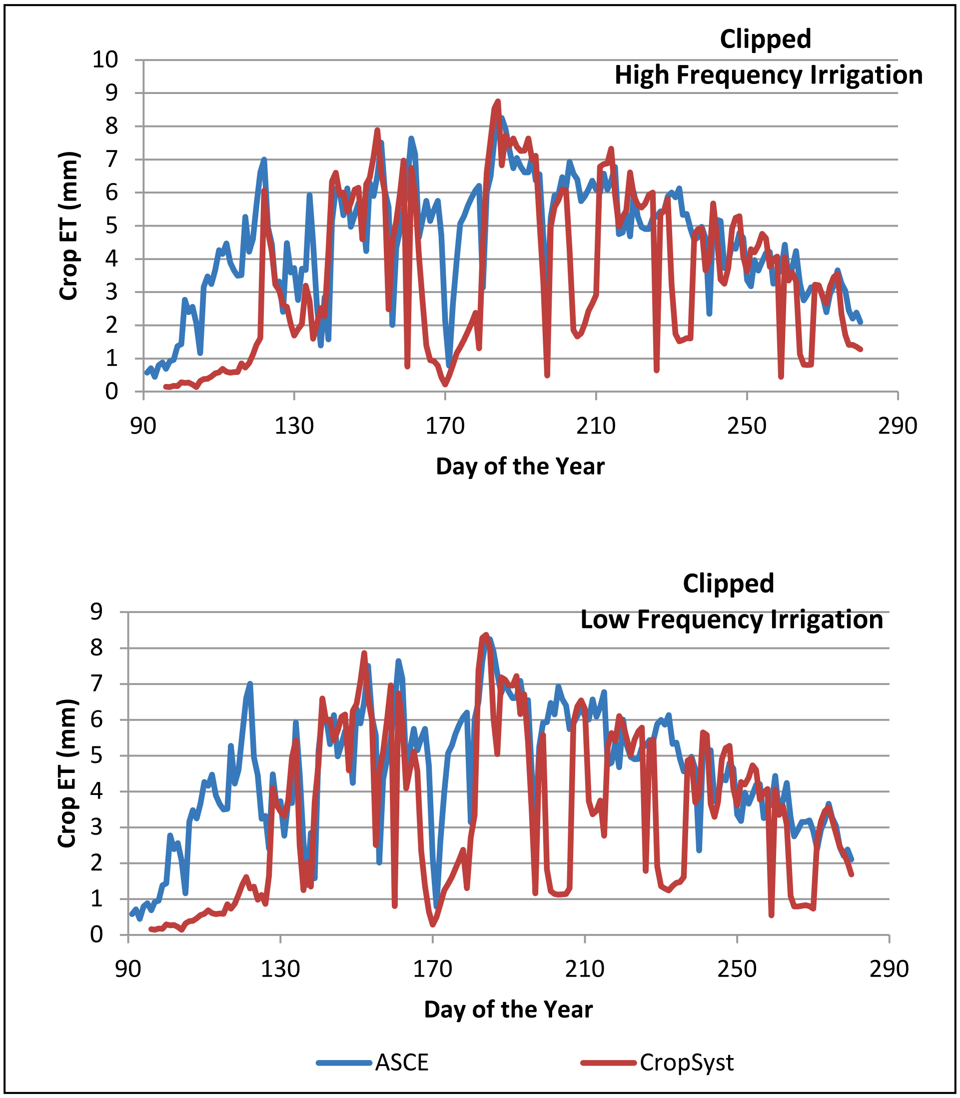

Figure 217. Comparison of estimates of evapotranspiration for alfalfa from the Washington Irrigation Guidelines (based on ASCE) and CropSyst (based on United Nations Food and Agriculture Organization).

9.3 Improvement of Biophysical Modeling

9.3.1 Incorporate Deep Groundwater Dynamics

Several watersheds rely substantially on groundwater pumping to support domestic and agricultural demands. Other areas rely on supplemental groundwater to augment surface supplies. A USGS study showed that these supplemental wells are in some areas now used every year rather than for drought mitigation purposes (Vaccaro and Sumioka 2006). Pumping of groundwater also ultimately reduces return flows back into streams in many instances although the timing may be considerably different. The current VIC-CropSyst model does not incorporate this information. To address this, the model would be expanded to include 3 or 4 areas where sufficient information on groundwater is known. GWATER or MODFLOW would be linked with VIC-CropSyst primarily through the spatially-explicit recharge layer.

9.3.2 Expand Water Right Modeling

To demonstrate types of management strategies that could yield improved asset allocation, a water right priority allocation model could be applied to the Yakima River Basin. This would create a framework for analyzing other watersheds in the future. With the completion of the current adjudication of the Yakima River Basin, a comprehensive list of surface water right information will be available on which to build a model of the watershed. This model would be linked with demand and return flow information from VIC-CropSyst to evaluate yield changes due to specific watershed strategies, new reservoirs, changes in current operations, and allow assessment of curtailment of individual rights. This tool could also form the basis for water marketing exchanges in the future. It would also enable addressing finer scale questions.

9.3.3 Evaluate a Variety of Reservoir Management Scenarios

The 2011 Forecast assumed historical reservoir operations to carry into the future. In fact, future operations are likely to evolve, adapting to changing climate and changing demands. For the 2016 Forecast modeling can create an optimization based reservoir management model that can evaluate multiple sets of operation rules.

In addition, the 2011 Forecast had a simplified reservoir model for Yakima that treated the entire system of reservoirs as a group and did not include specific operations for individual reservoirs. The US Bureau of Reclamation has a detailed reservoir model for Yakima which can be used for the 2016 Forecast by purchasing the required software.

Lastly, all the reservoir models could also be implemented at a weekly or daily time step instead of the monthly time step that was used for the 2011 Forecast. This will allow the model to match the time scale in which curtailment decisions are made.

9.3.4 Include Effects of Crop Rotation

The 2011 Forecast used a single snapshot of crop mix as a data layer for base case conditions. Actual farm practices often involve rotation of crops from year to year and the increasing use of alternative management strategies, such as cover cropping. Each of these could impact the demand and the economics of future crop selection. Factoring in crop rotation would give better long-term soil moisture conditions, improve water budgets, and allow more accurate assessment of economic impacts.

9.3.5 Account for Sensitivity of Forests under Climate Change

The next version of VIC-CropSyst could include improved modeling of the forest hydrology implications of climate change. There is a growing body of evidence indicating significant changes in runoff is occurring due to large-scale infestation of pine bark beetles. Parts of BC are reportedly seeing road and bridge flooding due to rising groundwater tables and reduced evapotranspiration from land surfaces.

9.3.6 Improve Population Growth Projections

On the biophysical side, estimates of population growth projections could be improved by evaluating twenty year trends of population growth locations within the county rather than assuming uniform distributions across each region. The latter approach tended to move people surrounding the city limits to parts of the country not necessary likely to experience the same growth. A more thorough review of water system plans to separate those systems that have separate irrigation feeds could also be conducted in order to more accurately assess total per capita water demand.

Lastly, the 2016 Forecast could carry out municipal demand forecasting in other states' portions of watersheds that extend outside of Washington's borders (e.g. Oregon, Idaho, Montana). This would make the Forecast's Tier II results more relevant by including other states' municipal demands.

9.4 Improvement of Economic Modeling

9.4.1 Include Land Assessments for Expanded Agriculture

Utilization of GIS maps that show potentially viable areas for irrigated agriculture would enable Ecology to better estimate where future demand for new water would likely be the greatest.

Land availability is an important factor because it informs model specification, shaping how land use can change within and across sectors. This is key for understanding the productivity of non-irrigated land that may become irrigated, or land moving from irrigated to dryland agriculture. It will also inform where there is little land available to move into agriculture, such as is the case in parts of Chelan County. Characterizing the entire land base is also significant for capturing the impacts of urban expansion. Incorporation of city ordinances, zoning laws, and other land use regulations such as protected forest land, urban growth boundaries, and development easements that restrict land use change could similarly be important.

9.4.2 Provide a Richer Representation of Factors that Influence Agricultural Productivity

There are two categories of factors influencing agricultural productivity that could be included in future Forecasts. The first is to forecast changes in productivity that are due to technological change that happens as a result of factors such as improved plant breeding. The second is farm level responses that model how producers can substitute between inputs in response to changes in factor prices and resource constraints. This is critical for many reasons including the ability to more accurately determine the impact of water curtailments that occur during drought conditions. This could be achieved by using a multi-input multi-output optimization model to represent the agriculture sector.

9.4.3 Expand Economic Model of Agricultural Production to Include the Entire CRB

Many of the agricultural commodities modeled in this study were described as having regional markets. A limitation of the 2011 Forecast was to model Washington as the entire region when the region more realistically includes surrounding states with similar growing regions including Oregon, Montana, Idaho, and California. The next Forecast could be improved by representing production in this entire multi-state region.

9.4.4 Incorporate Municipal Demand into Economic Modeling

Economic analysis could be extended to include a component for modeling municipal demand. This would include a historical analysis of population migration and urban development. By accounting for the demand for non-agricultural land and water it will be possible to estimate a willingness to pay for additional water resources for various municipalities.

9.5 Improvement of Integration between Biophysical and Economic Modeling

The 2011 Forecast's version of the model relied on sequential integration of economics and biophysical modeling where output from one model was used as inputs into the other model. Model results that were taken out of one model were exogenous in the model they were fed into. This was necessary because of the complexity of developing an integrated modeling framework that allows economic variables to be endogenously determined in the biophysical modeling and vice versa. For example, changes in the land base derived from economic factors are exogenous in the biophysical modeling. This means that crop cover does not change in the biophysical modeling in response to changes in water supply or the influence of climate on crop growth. At the same time, total physical supply of water is exogenous in the economic model and cannot change as a result of producer behavior.

The 2016 Forecast could more directly integrate the biophysical and economic modeling, to address these limitations, and to better account for the impacts of future deficits on future cropping patterns and irrigation technologies.

9.6 Improvement of Modeling Scenarios

9.6.1 Update Climate Data

In the 2016 Forecast, for future climate information, a 4-km gridded product that is based on downscaling methodology outlined by Abatzoglou and Brown (2011), the Multivariate Adapted

Constructed Analogs (MACA) methodology could be utilized. The authors are currently using MACA to downscale GCM results from the Coupled Model Intercomparison Project 5 (CMIP5) as they become available. They have done this for 3 Representative Concentration Pathways (RCPs): RCP 4.5, RCP 6.0, and RCP 8.5 (Moss et al. 2010). For historical weather information (daily maximum and minimum temperatures, relative humidity, precipitation, and wind speed), the 4-km gridded product developed by Abatzoglou (2011) for the period of 1979-2010, which is a combination of *in situ* observations and reanalysis data could be utilized.

9.6.2 Evaluate Conservation Impacts

There is considerable interest across the region in promoting agricultural and municipal conservation efforts as a mechanism for demand management. Overall effectiveness of conservation approaches in terms of improving low-flow discharges will likely be very watershed specific. Existing water demands for individual municipal systems as well as current irrigation technologies for agricultural parcels need to be factored into evaluation efforts. Quantifying overall WRIA impact will require refinement of return flow patterns, development of economic evaluations of possible conservation strategies, and evaluation of the degree of willingness to adopt conservation practices.

9.6.3 Incorporate Water Marketing in the Economic Analysis

There is evidence that water trading has been occurring at the local level but the 2011 Forecast applies deficit irrigation uniformly across low-value crops. A survey could be conducted of water users to more fully understand how water users view water markets. This will enhance the economic modeling particularly related to water shortages and local versus state-wide economic impacts.

9.6.4 Evaluate Potential Impacts of Columbia River Treaty

The Columbia River Treaty could dramatically change reservoir operations and flow timing in Washington. This could lead to changes in spill and fish requirements that will impact hydroelectric generation. Operating rules for ColSim could be updated to account for changes in flow without benefit of Canadian storage capacity.

9.6.5 Fisheries Requirements

WSU's modeling effort for the 2011 Forecast used established instream flow requirements for curtailment rules. However, as part of the Forecast, WDFW developed the "Columbia River Instream Atlas (Atlas, Ecology Publication 11-12-015) which includes instream flow conditions for eight of Washington's fish and low flow critical basins. The 2016 modeling effort could use the Atlas to determine implications for water availability at the WRIA level.

9.7 Additional Integrated Modeling Applications to Improve Forecast

9.7.1 Assess Columbia River Treaty Impacts on Supply

Managing water resources effectively and equitably among competing interests across the multitude of international, federal, state, tribal and local jurisdictional boundaries continues to represent a tremendous challenge for policy makers and scientists despite decades of collaborative efforts. Severe flooding in the U.S. and Canada combined with a growing need for hydropower prompted both countries to ratify a Columbia River Treaty (CRT) in 1964 that required construction of three large storage projects in the upper watershed in Canada (Duncan, Keenleyside, and Mica) and allowed 1 in the U.S. (Libby) that have resulted in improved water management and substantial shared benefits for both countries. For decades the shared benefit approach of the Columbia River Treaty has been held up as a model for international cooperation world-wide. The possible termination or renegotiation of the treaty in 2024 (notice can be given 10 years prior, so 2014 is the initial decision year) is sparking international debate among stakeholders on all sides as interests in prioritizing beneficial uses beyond flood control and hydropower are becoming increasingly important and provides a unique catalyst for change that often takes generations in other watersheds. In addition, the potential changes in river operation that may affect river management for the rest of the 21st century, combined with climate change and a growing population dependent on the ecological services the basin provides requires a systems approach that goes beyond the Columbia River Treaty's focus on hydropower and flood control.

As competition for scarce water resources increases and the impacts of climate change become intensified, more conflict over water supplies is expected between neighboring states as well as US-Canada interests. Future water management decisions involving the complex interactions and trade-offs between sustainable water supplies, economic development, ecosystem functions, energy, food security, societal values, recreation, navigation, laws, and cultural beliefs must be based on sound interdisciplinary and transdisciplinary science communicated to multiple audiences (Max-Neef 2005). Using the integrated biophysical modeling tool and an improved ColSim model, the potential impacts of reservoir operations on flow availability along the Colombia River mainstem could be examined.

9.7.2 Conduct Fine-Resolution Modeling Studies over Key Watersheds

The VIC model simulates the controls of climate on hydrologic processes at a relatively coarse resolution that is not necessarily fine enough to capture some of the sensitivities of the land surface to changes in climate. Therefore, for key watersheds, we plan to explore the influence of modeling scale on the sensitivity of key hydrologic processes to climate. The Distributed Hydrology Soil Vegetation Model (DHSVM; Wigmosta et al. 1994) can be applied over at least two watersheds of the CRB (the Yakima and the Spokane) at a 150 m spatial resolution to examine the finer controls of climate on snowmelt dynamics, evapotranspiration, streamflow, and soil moisture. Comparison of a full suite of states and fluxes between VIC and the process-scale DHSVM will allow a better understanding of VIC's ability to capture hydrologic variables other than streamflow. Comparison of the sensitivities of DHSVM and VIC runoff production to changes in precipitation, temperature, and land use could be done. Streamflow sensitivity to changes in precipitation can be estimated using the elasticity metric of Sankarasubramanian et al. (2001), whereas streamflow sensitivities to temperature can be estimated using the methods outlined by Elsner et al. (2010) who examined relative climate sensitivities over the Puget Sound basins. Analysis could be expanded to include examining sensitivities over the Yakima and Spokane systems. VIC and DHSVM sensitivities can be compared to each other as well as to observed streamflow elasticities. Sensitivity to land-use change can also be compared between the two models.

9.8 Stakeholder Input

9.8.1 Expand Collaboration with Conservation Districts and other Local Organizations for Targeted Preliminary Data Collection

The working water supply and demand model provided insight into specific information needs that could inform assumptions made within the Forecast (localized or basin-wide), as well as possible future applications of the model. Targeting these identified needs, the 2016 Forecast could include involvement of additional groups of informed stakeholders during the preliminary planning stages and at critical stages throughout the Forecast's development.

For example, Conservation Districts have knowledge regarding farmer practices, crop rotation, and in some cases water rights. They also regularly interact with a wide range of local stakeholders. The Okanogan Conservation District has been working with their stakeholders and evaluating claims in an attempt to better understand water supply and demand in their WRIA, and this information could improve localized modeling assumptions made within this watershed. Increased collaboration with existing local stakeholder groups can thus improve our ability to project realistic assumptions relevant to the modeling process.

9.8.2 Conduct Survey of Farm Community

Based in part on the results of initial conversations with Conservation Districts and other relevant local organizations, a survey of the farm community could be carried out. The ultimate success or failure of water policies will depend on society's willingness to adopt and implement new strategies. Water marketing, crop changes, deficit irrigation, response to incentives for conservation, etc. will all be driven by the farm community's desire and ability to adapt. Yet little is known about probable responses and economic valuation needed to promote change. As the single largest consumptive user in the Columbia River basin, understanding farmers' concerns, biases, and social/economic drivers is essential for Ecology. A survey of a representative sample of the farm community could provide information on these topics. The survey would only be identifiable by zip code so GIS interpretation of the data could be conducted. The survey would get at the heart of conservation and long-term planning goals.