2016 Washington State Legislative Report

Columbia River Basin

Long-Term Water Supply and Demand Forecast

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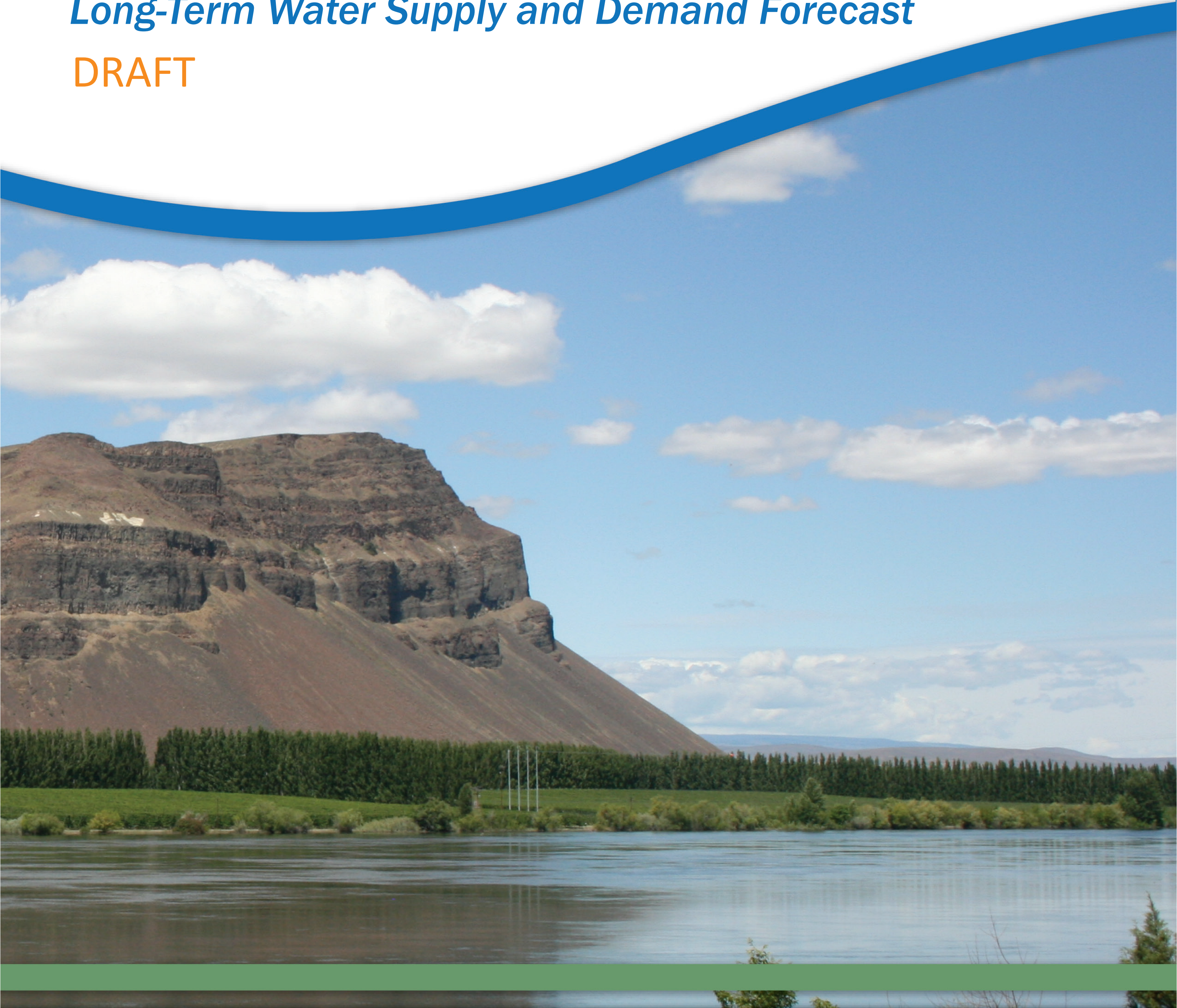

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Definitions of Water Supply and Water Demand Terms

Water Supply

Surface Water Supplies reflect the total amount of surface water generated in a watershed, quantifying the water available for in-stream and out-of-stream uses. Supplies reflect water availability prior to accounting for demands. They should not be compared to observed flows, which do account for demands through withdrawals for irrigation and other out-of-stream uses (see Flows definition, below). Regulated supplies represent water that has been stored and released from reservoirs, whereas unregulated supplies have not. Supplies were estimated using an integrated modeling framework that incorporates the impacts of operations of major reservoirs on the Columbia and Snake Rivers, as well as the major reservoirs in the Yakima basin. Water supplies at the watershed (Water Resource Inventory Area, or WRIA) level are "natural supplies", without consideration for reservoirs, with the exception of the Yakima watershed (WRIAs 37, 38, and 39).

Groundwater Supplies reflect the amount of groundwater (from aquifers) available to meet different water demands. Groundwater supplies were not modeled or quantified in the 2016 Forecast. Certain assumptions about existing groundwater supplies were made, described in the Groundwater Irrigation Demand definition, below. due to resource constraints. To address groundwater supply limitations in future Forecasts, we created an inventory of areas within the state where groundwater levels are known to be declining (see Integrating Declining Groundwater Areas into Supply and Demand Forecasting).

Historical Supplies indicate surface water supplies modeled for 1981-2011, based on historical climate data. To characterize variability in supplies, historical supply curves are provided for low, median, and high supply conditions. As supply cannot be straightforwardly measured, these different conditions were based on flow measurements. Low, median, and high flow conditions were determined as the 20th, 50th, and 80th percentile flows in the historical record, respectively.

Forecast Supplies indicate forecasted supplies for the year 2035. Models to quantify supply were run using projected climate information from the global Coupled Model Intercomparison Project Phase 5 (CMIP5) as inputs. These projections include results from seven global climate models, obtained using two different assumptions as to how greenhouse gases in the atmosphere are expected to increase, leading to ten different future climate scenarios. Major reservoir rules were assumed not to change in response to changes in forecasted (2035) water supply.

Water Demand

Agricultural Water Demand represents the water needed to fulfill the needs of crops, often referred to as "top of crop". This includes water that will be used consumptively by the crops, as well as irrigation application inefficiencies (such as evaporation, drift from sprinklers, or runoff from fields), but does not include conveyance losses (see definition, below). This demand can be met by groundwater or surface water. In the case of surface water, it is considered an out-of-stream use, as water is diverted from rivers to croplands.

Conveyance Losses denote water that is lost as it travels through conveyance systems, which can occur to varying degrees in everything from unlined ditches to fully covered pipes. These losses vary widely and are difficult to assess, but have been estimated to average about 20% across the whole Columbia River Basin. Because of the greater uncertainty associated with these estimates, conveyance losses have been treated and shown separately from "top of crop" demands.

Non-Consumptive Return Flows are estimates of the water that is not consumptively used by crops (including irrigation application inefficiencies and conveyance losses), that percolates through the soil and returns to the groundwater or surface water system. Such flows may be available to users downstream, although the time-lags vary considerably both in time and location. Some of the upstream water demand will be counted towards supply downstream of the original place of use.

Groundwater Irrigation Demand represents the agricultural water demand that was met by groundwater supplies. Because this Forecast did not model groundwater supplies, the assumption was made that groundwater supplies would be sufficient to meet a fixed percentage of agricultural water demand, and that percentage would remain constant through 2035. The exception to this assumption was for the Odessa Subarea, where future groundwater supply was forecasted to decrease to zero. There is a recognition that these assumptions are not realistic everywhere, as watersheds with closed or regulated surface water bodies likely have limited groundwater supplies. being limited and likely not available for new appropriation. The inventory of areas with declining groundwater levels (see Integrating Declining Groundwater Areas into Supply and Demand Forecasting) is a first step towards better incorporating groundwater into future forecasts.

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Unmet Irrigation Requirements represent the difference between agricultural water needed for crops planted in a typical year to achieve maximum yield, and the water supply available for agricultural irrigation. For those time periods when agricultural requirements exceed available water, three different curtailment scenarios were explored: 1) all crops were fallowed proportionately so that supply met irrigation requirements; 2) lower value crops were fallowed first, increasing the fallowed acreage until irrigation requirements were equal to supply; and 3) deficit irrigation, as well as fallowing, were used to reduce irrigation requirements to meet available supply. The economic impact under these scenarios was explored for three WRIAs in eastern Washington. Municipal Demand includes estimates of water delivered through municipal systems, as well as self-supplied sources.

Municipal demand was only estimated within Washington State. For each county in a WRIA, estimates of municipal demand were computed as the sum of water for domestic, commercial and industrial demands, as reported by the U.S. Geological Survey. The source of water can be surface or groundwater. Municipal demand also has a consumptive portion and a non-consumptive portion. The non-consumptive portion includes water that is lost through system leakages and water that returns for wastewater treatment. Together, the consumptive and the non-consumptive portion represent municipal demand.

Instream Water Demand was incorporated into water management modeling through state and federal instream flow targets. Within Washington's watersheds, the highest adopted state and federal instream flows for a given month were used to express current minimum flows for fish in both historical and 2035 forecasted instream demands. State and federal instream flows along the Columbia River mainstem were also compared to historical and future supplies.

Hydropower Water Demand represents the total amount of water that needs to flow through the dams to so as to generate the electricity needed by the entities managing those dams to fulfill their clients' needs. This demand is not estimated with the integrated model, and accurate data to estimate hydropower demand is lacking.

Total Water Demand is the water needed for different instream and out-of-stream uses, including agricultural demand, conveyance losses, groundwater demand, municipal demand, and instream flow requirements. It is important to note that this does not include all existing demands for water. For example, it does not quantify water needed for hydropower, recreation, and navigation.

Historical Water Demands indicate demands modeled for 1981-2011, based on historical climate data. Low, average, and high demand conditions were determined as the 20th, 50th, and 80th percentile demands in the historical record, respectively.

Forecast Demands indicate demands projected for the year 2035. These demands are expected to be strongly affected by climate change impacts on crops' water requirements, by trends in agricultural production, and by water management policies. The climate change effects were explored by modeling demands under ten climate change scenarios (described in the **Forecast Supplies** definition, above). The baseline is defined to include medium domestic economic growth, medium growth in international trade, and no changes in water pricing or water supply capacity. The effects of trends in agricultural production were explored by modeling two additional scenarios: 1) assuming the current crop mix remains unchanged, and 2) under a projected crop mix that was developed by using a statistical model to extend recent trends in crop mix into the future. In both these scenarios the irrigated land base in agriculture is assumed to remain the same. The Forecast does not incorporate improvements in irrigation efficiency or changes in crop mix that might be adopted by producers in response to limitations in water availability. Finally, the effects of water management policies were explored by modeling different water capacity scenarios (see overview in the Changes Explored in the 2016 Forecast section).

Stream Flows represent streamflow conditions at specific locations in a watershed, as would be observed by a streamflow gauge. Flows at a particular location reflect the balance between supply and demand in the watershed upstream of that location. Whereas supply is the total amount of surface water generated in a watershed and does not account for the impacts of water use and withdrawals (see **Surface Water Supplies** definition, above), flows do account for consumptive use of water upstream of the specified location.

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Meeting Eastern Washington's Water Needs

The Columbia River Basin, the fourth largest watershed in North America in terms of average annual flow, is intensively managed to meet a range of competing demands for water, including hydropower generation, irrigation, navigation, flood control, protection of salmonid species, municipal and industrial use, tribal treaty commitments, and recreation. Reliable access to water is essential for existing and future regional economic growth and environmental and cultural enhancement. Variations in water supply and demand across the Basin are increasingly leading to localized water shortages as populations grow, the climate changes, and regulatory flow requirements increase. Managing these multiple demands for fresh water resources requires understanding how future conditions will alter water supply and demand, and strategically investing in projects that meet competing water management objectives.

The water supply systems within the Columbia River Basin were built to reliably deliver water under historical conditions. Future changes in water supply and demand, therefore, have the potential to stress the system. This 2016 Long-Term Water Supply and Demand Forecast provides information that will help legislators, water managers, industry, and agency professionals plan for future conditions that will likely be quite different from those we have experienced in the past.

Many factors that influence water supply and demand—agricultural market conditions, input costs, production decisions, global trade conditions, temperature and precipitation patterns, water management policies, water storage capacity—need to be projected into the future. This 2016 Forecast explores three broad types of changes that are expected to occur:

- ***Climatic:*** Changes in precipitation and temperature affect water availability, agricultural growing conditions, and the season during which crops require water. The Pacific Northwest is expected to experience increasing temperatures and shifts in precipitation, leading to wetter winters and springs, drier summers, declining snowpack, earlier snowmelt and peak flows, and longer periods of low summer flows. Increasing temperatures also result in an earlier shift in the irrigation season. Meanwhile, increased concentrations in carbon dioxide also influence crop water requirements through increases in water- and energy-use efficiencies. These climatic changes were explored using the results of global climate models downscaled to a regional level to represent the projected climate for 2035.
- ***Economic:*** Water demand depends on the mix of crops in the region, which in turn is responsive to consumer tastes, domestic food demand, export and import trends, and production technologies, among other factors. While some crop groups have seen relatively large changes within existing cropland, the relative acreage share for the region is expected to remain stable, with forage crops covering the most acreage. Changes in crop mix were explored through using a statistical model to project to 2035 the trends in crop mix that are currently being observed.
- ***Water management:*** Changes in water availability, storage capacity, and cost of water supply development passed along to users affect water use. Increases in water storage capacity from planned water storage projects can supply water to new uses, including the development of new irrigated acreage. Such water management changes were explored using scenarios that simulate expanded irrigated acreage.

Other types of changes were beyond the scope of this Forecast, often because available data were not sufficient to develop feasible scenarios. By developing specific scenarios representing these three dominant types of changes, however, this Forecast quantifies the likely range of water supply and demand across the Columbia River Basin in 2035, paying particular attention to the portion of the Basin in eastern Washington State.

Overview of the 2016 Forecast

Surface water supplies reflect the total amount of surface water generated in a watershed. Water demand is the total amount of water needed for total instream uses—including hydropower and instream flow requirements—and out-of-stream uses, including agricultural demand (the dominant out-of-stream use), conveyance losses, groundwater demand, and municipal demand.

Water supply and demand impact each other. Out-of-stream diversions reduce supply downstream, while water that is diverted but not consumptively used—such as water that is lost through leaks in municipal systems or return flows from irrigated fields—may return to the system and provide water supply downstream.

The 2016 Forecast team simulated surface water supply and agricultural irrigation demands with an integrated computer model that captures the relationships between climate, hydrology, water supply, irrigation water demand, crop productivity, economics, municipal water demand, and water management for three different geographic scopes:

- **The entire Columbia River Basin** upstream of Bonneville Dam, across seven U.S. States and one Canadian Province.
- **Each watershed in eastern Washington,** as delineated by eastern Washington's 34 Water Resource Inventory Areas (WRIAs).
- **Washington's Columbia River mainstem,** from the Canadian border to Bonneville Dam.

The model used in the 2011 and 2016 Forecasts integrates and builds upon three existing models—VIC, CropSyst, and ColSim—that have been used independently in various published studies to simulate conditions in the Columbia River Basin. What distinguishes this 2016 Forecast from previous efforts is that:

- The hydrological (VIC) and crop production (CropSyst) models are more tightly integrated, so that the interactions between the hydrological cycle and crop growth processes are better captured. This improves the simulation of crop water requirements, particularly during drought conditions.
- Newer climate change projections (CMIP 5) and improved downscaling methods were used, so that future climate scenarios are more appropriate for the region, and are better able to capture changes in temperature and precipitation extremes, in addition to changes in average temperatures and precipitation.
- Improved historical climate and crop data were available, reducing the number of assumptions that were needed to model historical supply and demand across the region.
- Only one 2035 crop mix was projected, simplifying the assumptions made about future domestic economic growth and international trade. The 2011 Forecast demonstrated that scenarios based on varying economic growth and trade have relatively little effect on the future crop mix.
- Improved modeling of the impacts of water rights curtailment modeling was created using the results of

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surveys from, and discussion with, watershed water masters about water management in response to the 2015 drought. Improvements included modeling curtailment at weekly (rather than monthly) time-steps, modeling curtailment of non-interruptible water rights, and using Yakima RiverWare to better simulate prorationing in the Yakima River Basin.

- Two scenarios of responses to water shortages were captured. In the first scenario, all crops suffer curtailment equally. In the second scenario, farmers fallow lower value crops first. These two scenarios provide upper and lower estimates, respectively, of the negative impacts of reduced water availability on production and profitability.

In addition to the abovementioned improvements, five exploratory modules were conducted, to inform future modeling updates and water management decisions. These modules involve the exploration of methods and data complementary to yet distinct from the core modeling of supply and demand, and are meant to either provide a foundation for expansion in future forecasts (geographically, or to other sources of water, such as groundwater), or provide better data or assessments, to inform effective water management and policy decisions by the Office of the Columbia River. These modules are:

1. *Integrating Declining Groundwater Areas into Supply and Demand Forecasting:* Where is it critical to integrate groundwater supply modeling into future Forecasts? Is there sufficient data available in those areas to do so?

2. *Pilot Application of METRIC Crop Demand Modeling in Washington State:* Can agricultural water demands, non-consumptive return flows, and stream discharges be estimated at finer scales, to better inform future Forecasts and OCR's focus for developing water supplies?

3. *Water Banking Trends in Washington and Western States:* What can be learned from water banking across the West, that can help facilitate and increase the efficiency of water banking in Washington State?

4. *Effects of User-Pay Requirements on Water Permitting:* What impacts do different user-pay systems for water right permitting have on the demands for water?

5. *Western Washington Supply and Demand Forecasting:* Is it feasible to extend the modeling approach to western Washington, as the foundation for a complete Washington State Water Plan?

The Washington Department of Fish and Wildlife also updated and expanded the Columbia River Instream Atlas (CRIA), focused on instream water needs and priorities for conserving salmonid species in Washington State.

Feedback received on the previous Forecast (2011) along with interactions with the Columbia River Policy Advisory Group, the Water Resources Advisory Committee, the agriculture, hydropower, and municipal communities, and local, state, federal, and tribal governments in the intervening years were essential for planning for the 2016 Forecast.

Dalles Dam, Vancouver, WA

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Significant Findings

Columbia River Basin Water Supply

Forecasts for 2035 suggest that there will be an overall increase in annual water supplies across the Columbia River Basin, and a shift in supply timing away from times when demands are the highest. Unregulated surface water supply between June and October is projected to decrease 10.6% (±5.8%[1]), on average. Meanwhile, an average increase in unregulated surface water supply between November and May of 28.6% (±7.4%) is expected. These changes combine to produce an overall increase of approximately 11.7% (±6.5%) in average annual supplies relative to historical (1981-2011) supplies (Table ES-1) across the entire Columbia River Basin. This shift in timing is in response to warming temperatures, which will result in a smaller snowpack, with more precipitation falling as rain and less as snow, and an earlier snowmelt peak. Even with an overall increase in annual water supplies, it is possible that this shift in supply away from the season of highest water demand has the potential to cause increased water scarcity in portions of the Columbia River Basin, depending on the months when irrigation is required.

Annual surface water supplies entering Washington will increase approximately 14.1% (±2.0%) by 2035, on average. This includes inflows into Washington along the Similkameen, Kettle, Columbia, Pend Oreille, Spokane, Clearwater, Snake, John Day, and Deschutes Rivers. Most of the rivers show only increases in supply, regardless of the climate scenario used. The only exception was the Kettle River, where the direction of change was unclear (on average, supply decreased 0.2±3.8%).

Annual surface water supplies generated within the Washington portion of the Columbia River Basin are smaller than elsewhere in the Basin, being expected to increase approximately 4.0% (±1.7%) by 2035, on average. This calculation includes the major watersheds of the Walla Walla, Palouse, Colville, Yakima, Wenatchee, Chelan, Methow, Spokane, and Okanogan Rivers. While most rivers show increases in supply regardless of the climate scenario used, three watersheds—Colville, Chelan, and Okanogan—showed mixed results, ranging from increasing to decreasing supplies, depending on the climate scenario used. The changes in supply for the Washington portion of the major rivers ranged from 7.1% (±2.7%) for the Spokane watershed to 50.7% (±2.7%) for the Methow watershed. As with the supply forecast for the entire Columbia River Basin, these rivers will experience shifts in timing of stream flow. The rivers experiencing the greatest shift in supply timing are those for which streamflow was predominantly derived from snowmelt during the historical period, such as the Methow River.

Columbia River Basin Water Demand

Even as water supplies are forecast to increase by 2035, agricultural water demand—which accounts for approximately 79.4% of total out-of-stream demand (agricultural plus municipal)—is forecast to decrease by approximately 4.9% by 2035, across the entire Columbia River Basin. This decrease is somewhat greater within Washington, where it is forecast to reach 7.1% (Table ES-2). These decreases in demand are due to a combination of projected changes in climate, which is expected to be warmer and slightly wetter, leading to an earlier and wetter beginning to the growing season, and to projected changes in crop mix, where crops with lower water use are projected to replace high-water-use pasture. These results are also supported by current trends in agricultural water demand for non-drought years, which have shown reductions in diversions for irrigation. It is worth noting, however, that current trends may also be responding to changes in irrigation technology, a factor that is not included in the model, and therefore not contributing to the forecasted decrease in agricultural water demand. Such technological changes, as well as production changes—such as double cropping, cover cropping, or shifts to higher water use crops, for example—may lead to demand decreasing less than projected, or even demand increases.

Demand for energy generated at hydropower facilities across the Columbia River Basin is anticipated to increase by 2,200 to 4,800 megawatts (MW), on average, by 2035 (accounting for distribution and transmission system losses). Quantifying the demand for instream water at existing dams (or at points where future reservoirs could potentially be built) is challenging, as such a "conversion" of flows to energy produced depends on many factors, including dam design, peak power needs, efficiency, and availability of other energy sources. A preliminary conversion was attempted, with an estimated power-to-water conversion factor of approximately 16 ac-ft/MW, leading to projections of increases in hydropower water demand of 750,000 ac-ft per year by 2035.

1 Numbers within parentheses (e.g. ±5.8%) represent confidence intervals on this estimate. That is, though we cannot be sure the forecast value is 10.6%, we are 90% certain that the value will lie between 4.8% (10.6 minus 5.8) and 16.4 (10.6 plus 5.8).

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Demands within Washington State

Within the Washington State portion of the Columbia River Basin, historical (1981-2011) out-of-stream diversion demands for municipal and agricultural irrigation water (excluding irrigation conveyance losses) were estimated to be in the range of 3.7 (±0.1) million ac-ft. By 2035, out-of-stream water demands across eastern Washington are forecast to decrease by 22,900 (±24,200[2]) ac-ft per year. The Forecast anticipates the following changes in water use or need, by sector (Table ES-3):

- 272,100 (±29,200) ac-ft decrease in total (ground and surface) agricultural irrigation water demand annually. This number assumes no change in irrigated acreage, and no additional water supply development. In addition to the demands for both surface and groundwater to be applied to crops, this number also represents the additional water needed due to irrigation application inefficiencies. Ongoing modeling is exploring the impact of further water supply development on agricultural demand. It is important to highlight that, though there is a decrease in overall agricultural demand, additional surface water will be needed annually in the future, to replace demand currently being met by groundwater in the Odessa Subarea.
- 80,000 ac-ft in additional total diversion demands for municipal and domestic water annually, which represents an 18% increase over 2015. This increase in municipal and domestic demand is due to a 17% increase in population expected between 2015 and 2035. Although some new municipal demands will likely be met by deep groundwater supplies, others will likely come from shallow groundwater or surface water.

Consistent with the results of the 2011 Forecast, the greatest concentrations of current and future agricultural irrigation and municipal water demand are in the Rock Glade (WRIA 31), Walla Walla (32), Lower Snake (33), Yakima (37, 38, 39), Lower Crab (41), Esquatzel Coulee (36), and the Okanogan (49) watersheds. The forecast shift in peak flow to earlier in the spring will decrease water supply during the summer season in the future. This shift in timing is dominant in north central and northeastern Washington watersheds—including the Wenatchee (WRIA 45), Entiat (WRIA 46), Methow (48), Middle Lake Roosevelt (58), Colville (59), Upper Lake Roosevelt (61), and the Pend Oreille (62)—as well as more southern watersheds such as the Klickitat (WRIA 30), Walla Walla (WRIA 32), Palouse (WRIA 34), and Yakima (37, 38, 39) watersheds. Although annual irrigation demand is forecast to decrease in the future, increases in early season irrigation demand are projected to occur in central Washington watersheds: the Rock Glade (WRIA 31), Walla Walla (32), Esquatzel Coulee (36), Lower Crab (41), Grand Coulee (42), Lower Yakima (37), Naches (38), and the Upper Yakima (39) watersheds. Forecast out-of-stream demand values for 2035 do not include potential improvements due to water conservation measures.

The forecasted changes for out-of-stream water demands can be expected to lead to changes in instream conditions by 2035, including:

- Almost 660,000 ac-ft per year of unmet tributary instream flow water demand, and 13.4 million ac-ft per year of unmet Columbia River mainstem instream flow water demand, based on observed deficits during the 2001 drought year.
- In many rivers in eastern Washington, including the mainstem Columbia River, stream flows are below state or federal instream flow targets on a regular basis, particularly in late summer. Surplus water exists in many of these same rivers at other times of year.
- Decreases in surface water supplies in tributaries in summer and early fall may lead to more weeks when instream flows are not met by 2035. This may result in a higher frequency of curtailment of interruptible water right holders in basins with adopted instream flow rules.
- An evaluation of fish, flows, and habitat in twelve fish-critical subbasins, available in the Columbia River Instream Atlas (Ecology Publication in preparation), will help target investments to maximize the positive impact on fish populations.

The greatest concentration of current and future demands—dominated by demand for irrigation—in Washington are in the south-central Washington. Ongoing modeling is exploring the impact of curtailment of interruptible and pro-ratable water rights on unmet agricultural requirements at the watershed scale

2 Note that in this case, the confidence intervals overlap zero. The uncertainty in this forecast, therefore, determines that we cannot say with any confidence that out-of-stream water demands across eastern Washington will indeed decrease by 2035.

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Conclusion

The results of the 2016 Forecast suggest that overall seasonal shifts in timing of water supply and demand will be a dominant issue, and will likely require area-specific management and adaptation strategies in the future. However, irrigation demand was forecast to decrease on average, due to wetter springs and a shifting of the growing season into the spring, when rain is projected to be more plentiful. Under warming temperatures, some crops will also reach maturity faster, thus decreasing irrigation demand later during the irrigation season. This decrease in demand will help to alleviate a reduction in summer water supply, at least in non-drought years.

Two important considerations that highlight the complexity of water management in the region are:

- Producers with existing water rights will likely respond to the decreased demand of crops, and anecdotal references already suggest increases in double-cropping and cover cropping are occurring. Actual irrigation demand in 2035 may therefore not decrease to the extent projected in this Forecast. The Washington Department of Agriculture data do not distinguish these double-cropping patterns, so estimating this trend is not currently straightforward.
- Vulnerability of agricultural production to future changes in climate will be most apparent in drought years, which are expected to occur more frequently as the climate changes, with droughts also becoming more severe. Ongoing curtailment modeling may provide additional information on the extent of this vulnerability.

This Forecast improves our understanding of future surface water supplies and instream and out-of-stream demands. Unfortunately, it cannot answer all questions related to water supply and demand in the Columbia River Basin. However, it does provide projections 20 years into the future and highlights the main changes that can be expected in water supply and demand. It can therefore serve as a capital investment planning tool to help OCR and others make decisions that contribute to maintaining and enhancing the region's and eastern Washington's economic, environmental, and cultural prosperity

Table ES-1. *Modeled water supply in the historical (1981-2011) and forecast (2035) periods for the entire Columbia River Basin. Estimates are presented for average years (50th percentile), with the range in parentheses representing low supply (20th percentile) and high supply (80th percentile) years..*

	Historical (million ac-ft per year)	2035 Forecast (million ac-ft per year)	% Change
Entire Columbia River Basin	132 (113-151)	136 (122-161)	3.03%

Table ES-2. *Agricultural water demands, excluding conveyance losses (known as "top of crop"), in the historical (1981-2011) and forecast (2035) periods. Estimates are presented for median years, with the range in parentheses representing low demand (20th percentile) and high demand (80th percentile) years. Note that these demands could be met with surface or groundwater.*

	Historical (million ac-ft per year)	2035 Forecast (million ac-ft per year)	% Change
Entire Columbia River Basin	10.1 (9.2-10.9)	9.6 (9.1-10.1)	-4.90%
Washington Portion of the Columbia River Basin	4.2 (3.9-4.4)	3.9 (3.7-4)	-7.10%

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***Table ES-3.** Summary of changes in demands in eastern Washington between the historical (1981-2011) and forecast (2035) periods for different uses. Additional information on demands that will need to be met with surface supplies, that are not currently being met from this source, or not reliably, are included to provide context.*

Water Use or Need	Estimated Volume (acre-feet)	Source
Projected changes in Agricultural Demand by 2035[a]	-301,300 to -242,200	WSU Integrated Model
Projected changes in Municipal and Domestic Demand (including municipally-supplied commercial) by 2035	80,000	Municipal Demand Projections
Projected changes in Hydropower Demand by 2035[b]	35,000 to 75,000	Review of Projections by Power Planning Entities
Water Use or Need to be Met with Surface Supplies		
Unmet Columbia River Instream Flows[c]	13,400,000	Ecology data, McNary Dam, 2001 drought year
Unmet Tributary Instream Flows[d]	659,918	Ecology data, tributaries with adopted instream flows, generally for the 2001 drought year
Unmet Columbia River Interruptibles	40,000 to 310,000	Ecology Water Right Database (depending on drought year conditions)
Yakima Basin Water Supply (pro-ratables, municipal/domestic and fish)[e]	450,000	Yakima Integrated Water Resource Management Plan (April 2011)
Alternate Supply for Odessa[f]	155,000	Odessa Draft Environmental Impact Statement (October 2010), adjusted based on consultations with teh East Columbia Basin Irrigation District
Declining Groundwater Supplies (other than in the Odessa Subarea)[g]	750,000	*See Integrating Declining Groundwater Areas into Supply and Demand Forecasting* posters

a Additional agricultural demands were modeled assuming the land base for irrigated agriculture remains constant, and climate change is moderate (RCP 4.5 scenario). Projected changes in irrigation demand were estimated as a decrease of 272,100 ac-ft, with a confidence interval of ±29,200 ac-ft. The confidence interval reflects that, though we cannot be sure the projected change is exactly-272,100 ac-ft, we are 90% certain that the value will lie between-301,300 (-272,100 minus 29,200) and-242,200 (-292,100 plus 29,200). These decreases in demand were due to the combined impacts of climate change (wetter in the early growing season) and crop mix (projected shift to crops that use less water).

b Hydropower projections are based on an average need of 2,200 to 4,800 MW by 2035. This demand is historically expressed as a nonconsumptive water use. Net power generation and water right data for Grand Coulee, Rocky Reach, Rock Island and Lake Chelan were averaged to develop an approximate power-to-water conversion factor of approximately 16 ac-ft/MW. Because this projection is based on existing dams as opposed to new projects, and because these average numbers do not account for peak power needs, actual demand may be higher. Alternatively, if this demand is met via conservation, efficiency improvements, or non-hydro sources, the demand projections could be lower.

c Unmet Columbia River instream flows are the calculated deficit between instream flows specified in Washington Administrative Code (WAC) and actual flows at McNary Dam in 2001 under drought conditions. 2001 is the only year when Columbia River flows were not met and interruptible water users were curtailed.

d Unmet tributary instream flows are the combined deficits between current instream flows specified in WAC and actual flows for the driest year on record at the following locations: Walla Walla River at East Detour Road, Wenatchee River at Monitor, Entiat River near Entiat, Methow River near Pateros, Okanogan River at Malott, Little Spokane River at Dartford, Spokane River at Spokane, Colville River at Kettle Falls. All deficits are for drought year 2001, with the exception of the Little Spokane and Colville Rivers, where the greatest unmet flows were in 1992, and the Walla Walla River, where data collection started in 2007. Data on the 2015 drought year are being evaluated, to determine whether 2015 should be used to adjust this estimate for the final report.

e Multiple water projects planned in the Yakima River Basin, as part of the Yakima Integrated Water Resource Management Plan, are expected to lead to decreases in the estimated volume needed by the 2021 Forecast. Examples include: Yakima Aquifer Storage and Recovery (ASR), Cle Elum Reservoir, and the Kachess Drought Relief Pumping Plant.

f Reports of Examination state that 164,000 ac-ft are needed to serve 70,000 acres. The East Columbia Basin Irrigation District is currently serving 3,000 acres of groudwater replacement via the Columbia Basin Project. Assuming these acres are served with an average 3 ac-ft/ac, the volume still needed was estimated. Two additional sources are expected to contribute to this alternate supply, the Odessa Subarea Special Study and the Lake Roosevelt Incremental Storage Releases Program. As the contributions of these two additional sources were not quantified at the time of this report, the volume estimated here should be considered a conservative estimate.

g This estimated need was calculated on the following basis: approximately 230,000 acres of irrigated under water rights within areas affected by unreliable and/or declining groundwater supplies, an assumed average irrigation rate of 3 ac-ft/ac, and an approximate affected population of 200,000 with an average use of 200 gpcd. This estimate does not include the Odessa Subarea. Significant uncertainty exists in this estimate related to the geographic extent of the affected areas and other factors.

INTEGRATING DECLINING GROUNDWATER AREAS INTO SUPPLY AND DEMAND FORECASTING


Drilling near the Dalles Municipal Airport, Klickitat County

In both the 2006 and 2011 Water Supply and Demand Forecasts, groundwater supplies were presumed not to be limiting when supplying water rights, mainly due to modeling constraints. As a result, the economic implications of groundwater limitations were also not considered. Groundwater is declining in some areas in Washington, which could result in curtailment of water rights, delayed impacts on surface water sources in hydraulic continuity with groundwater, denial of groundwater right applications, and resulting changes in water right holder uses in response to an interruptible supply.

Ten areas of Washington State with groundwater declines documented by the Department of Ecology and the United States Geologic Survey were evaluated. Study of the groundwater areas included summaries of groundwater declines, geographic extent of the groundwater body, aquifer cross-sections and descriptions, groundwater model information, water right data, and supply-side and demand-side options to reducing groundwater declines.

Key findings:

- Declining groundwater areas should be incorporated into the 2021.
- Greater monitoring of the declining groundwater areas is warranted, including aquifer levels, metering data, stream gages, and pump testing.
- Public outreach to water right holders in declining groundwater areas should be implemented to incentivize demand-side conservation measures.
- State and County government should consider whether existing policies and regulations are sufficient in these areas to protect public water supplies and prevent unintended economic consequences.
- The State should consider water supply projects that could stabilize, reverse, or offset declining groundwater supplies.

Additional groundwater development is already limited in all areas in Washington where there are regulated or closed surface water bodies. The current focus on documented areas of decline is therefore a first step towards identifying the places where is it critical to integrate groundwater supply modeling into future Forecasts.

PILOT APPLICATION OF METRIC CROP DEMAND MODELING IN WASHINGTON STATE

Agricultural water use largely corresponds to evapotranspiration (ET), which is the sum of evaporation from the ground plus transpiration from plants. The aggregation of ET values across a watershed can be used to calibrate the integrated models used in the 2016 Forecast. Evapotranspiration is usually estimated using data from weather stations and making assumptions on stages of crop growth. Stages of crop growth vary significantly across a watershed, though, due to factors such as soil, management, and topography. To address this problem, a model—METRIC, which stands for Mapping EvapoTranspiration at High Resolution and Internalized Calibration—was developed to calculate evapotranspiration using Landsat satellite images. This model has been successfully used in Idaho, California, New Mexico and other regions to monitor water rights, quantify net ground water pumping and to determine irrigation uniformity. The first objective of this exploratory projects was to develop and calibrate METRIC to estimate crop water use in three pilot watersheds in Eastern Washington: Okanagan, Walla Walla, and Yakima.

A major drawback in using Landsat images for METRIC is that the satellite provides images every 16 days, or less frequently if some images are blocked by clouds. The second objective, therefore, was to develop an algorithm to compare crop water use between CropSyst (the crop production model used in this Forecast) and Landsat-derived-METRIC. If the use values are consistent, this would allow the crop model to estimate crop water use between the dates for which images are available. CropSyst could then be used to model scenarios with changes in irrigation practices, crop management, crop rotations, and to evaluate the effects of changes in water supply (e.g. curtailments) on crop water use during droughts.

Key Findings:

- METRIC was applied to apple orchards in the Roza Irrigation District, Yakima County. A similar analysis will be done for major crops in these three watersheds.
- Apple water use estimates from METRIC in Roza ranged around the value provided by the Washington Irrigation Guidelines (WIG) for apples, as the METRIC estimates capture the range of water use values specific to particular conditions (soil, slope, basin orientation, etc.) (Figure ES-1). For example, METRIC estimates quantify the difference in water used by apples in the upper Yakima relative to the lower Yakima WRIAs.
- CropSyst, if well-parameterized, can estimate crop growth—estimated using Leaf Area Index (LAI)—quite accurately (Figure ES-2).
- The METRIC model is now developed and calibrated for Eastern Washington using freely or generally available software (Python and ESRI ArcGIS functions). Removing the platform dependence of the original model will make it easier and cheaper for users interested in water use in Washington to use this model.
- Automation of various processes involved in METRIC has reduced the necessity of highly trained expert to run this model. It has also made the model easier to use and less time consuming.

Comprehensive modeling of the dominant crops' water use across Washington's WRIAs using METRIC could help Ecology:

- Identify areas where the best solutions to water scarcity would be to invest in conservation projects versus areas where additional storage projects would be needed.
- Quantify the amounts of water needed based on where the land is located within the WRIA, and
- Improve model estimates of consumptive use in future long term supply and demand forecasts.

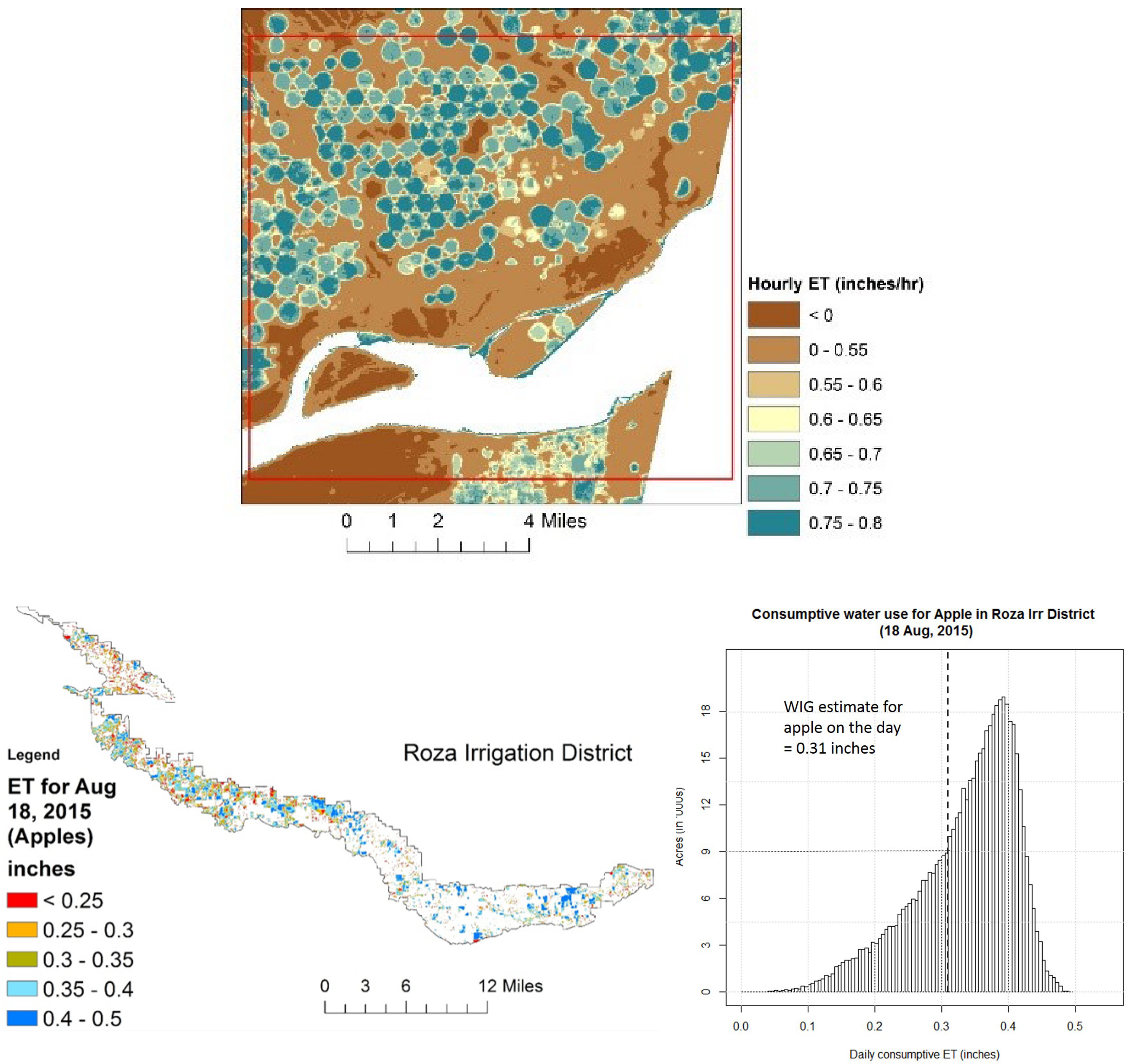

Figure ES-1: Pilot results from using METRIC in an eastern Washington Water Resource Inventory Area (WRIA). (a) High Resolution evapotranspiration (ET) maps obtained using METRIC (b) Consumptive water use for Apple orchards in Roza Irrigation District (c) About 75% of orchards are using more water than recommended by Washington's Irrigation Guidelines (WIG)

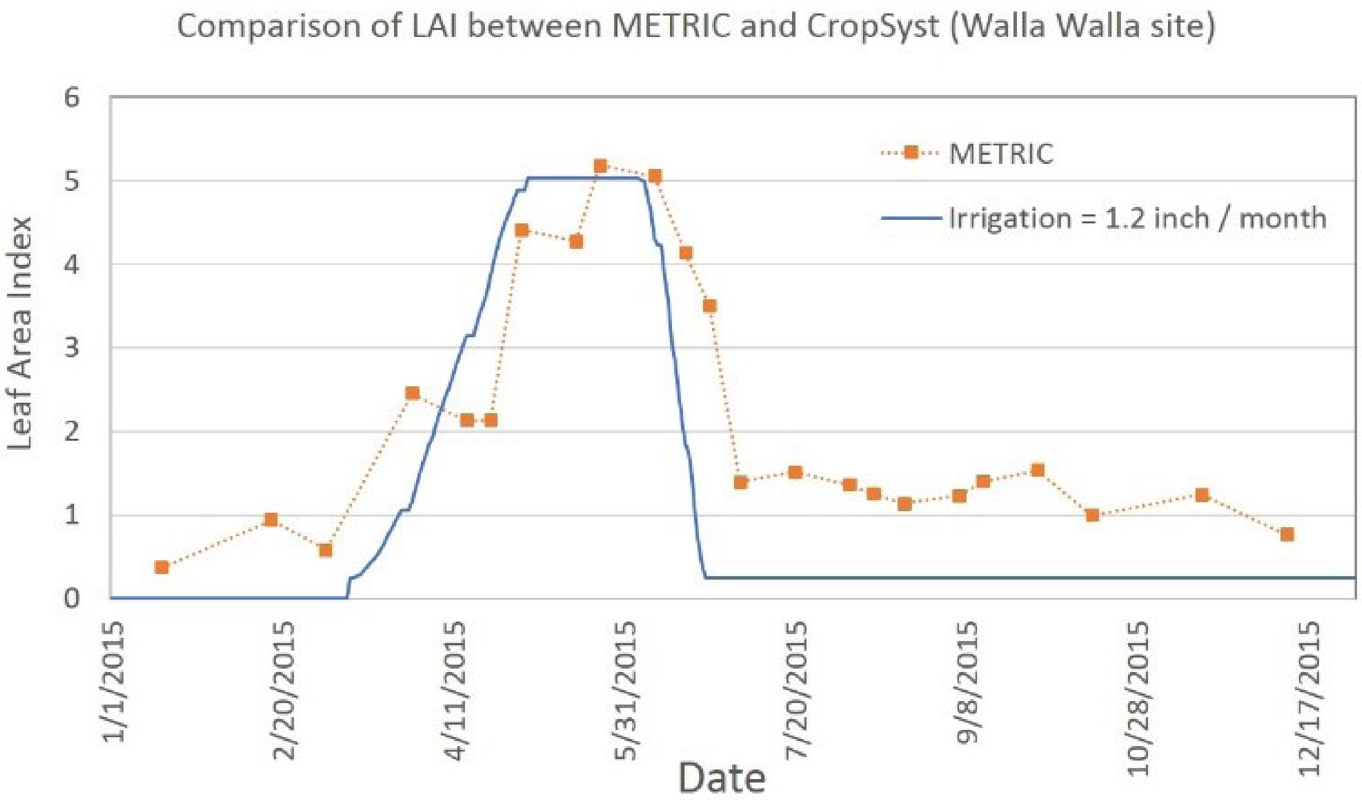

Figure ES-2: Comparison of METRIC's and CropSyst's leaf area index (LAI) estimates for a grape vineyard in Walla Walla.

Apple orchard, Yakima County

WATER BANKING TRENDS IN WASHINGTON AND WESTERN STATES

Water banks and water markets allow people and firms who face water use restrictions to purchase mitigation credits to allow water use. Water banks and markets are among the critical portfolio of tools needed to help address the complexities of water management—including drought risk, surface water-groundwater interactions, and legal and regulatory disputes and restrictions over water markets—thereby allowing scarce water resources to be allocated more efficiently.

Understanding how water markets are working and maturing in Washington can help help guide regulatory oversight and function of water banks, and clarify how water rights will move in response to water supply shortages, curtailments, demographic changes, and climate change. These are important elements that still need to be incorporated into the economic forecasting that influences the long-term supply and demand forecast for the Columbia River. This exploratory project describes water banking activities in Washington State and across the western United States—including the various administrative forms that water banks take, and the various forms that water transactions take in the context of water banking—and provide recommendations on how to improve and provide incentives for water banking in Washington.

Key findings:

- 24 banks currently operating (including self-mitigating banks), and seven developing water banks.
- Water banking activity across 11 western States has tended to increase in the last 12 years—since the publication of Clifford et al., 2004—in terms of the number of programs, the number of transactions, and the volume of water traded, with a great deal of variation in form, function, and growth across States.
- Water banking grew from two active banks in 2004 to 24 operating banks in 2016, with an additional seven banks in development (Figure ES-3). This expansion is driven primarily by regulatory imperatives such as groundwater closures (e.g. Upper Kittitas) and Supreme Court rulings (e.g. Postema v. Pollution Control Hearings Board), and encouraged by the need to maintain instream flows for fish.
- A number of options to improve water banking and water markets more generally in Washington exist, including:
    - Seek legislative clarity on mitigation criteria for streamlined bank operation. Mitigation criteria are currently in flux due to recent Supreme Court cases (Swinomish v. Ecology and Foster v. Ecology).
    - Clarify public interest criteria necessary for forming a water bank, since Ecology resources would be used to administer it. As currently structured, each new water bank creates new unfunded obligations on Ecology that detract from other legislatively-prioritized work.
    - Identify financing mechanisms appropriate for water banking, to provide Ecology cost-recovery for bank formation and operation.
    - Identify criteria for banks whose operation depends on water rights originating outside the watershed, to prevent unintended economic impacts.
    - Explore alternatives to conventional operations and monitoring for very small uses that drive bank costs up, including for metering and certified water right examinations.
    - Explore alternative contracting options, such as computer-aided transactions and options contracts for water.

This analysis provides a broad perspective on water bank and water market developments, which can provide ideas for future developments and improvements for the State of Washington.

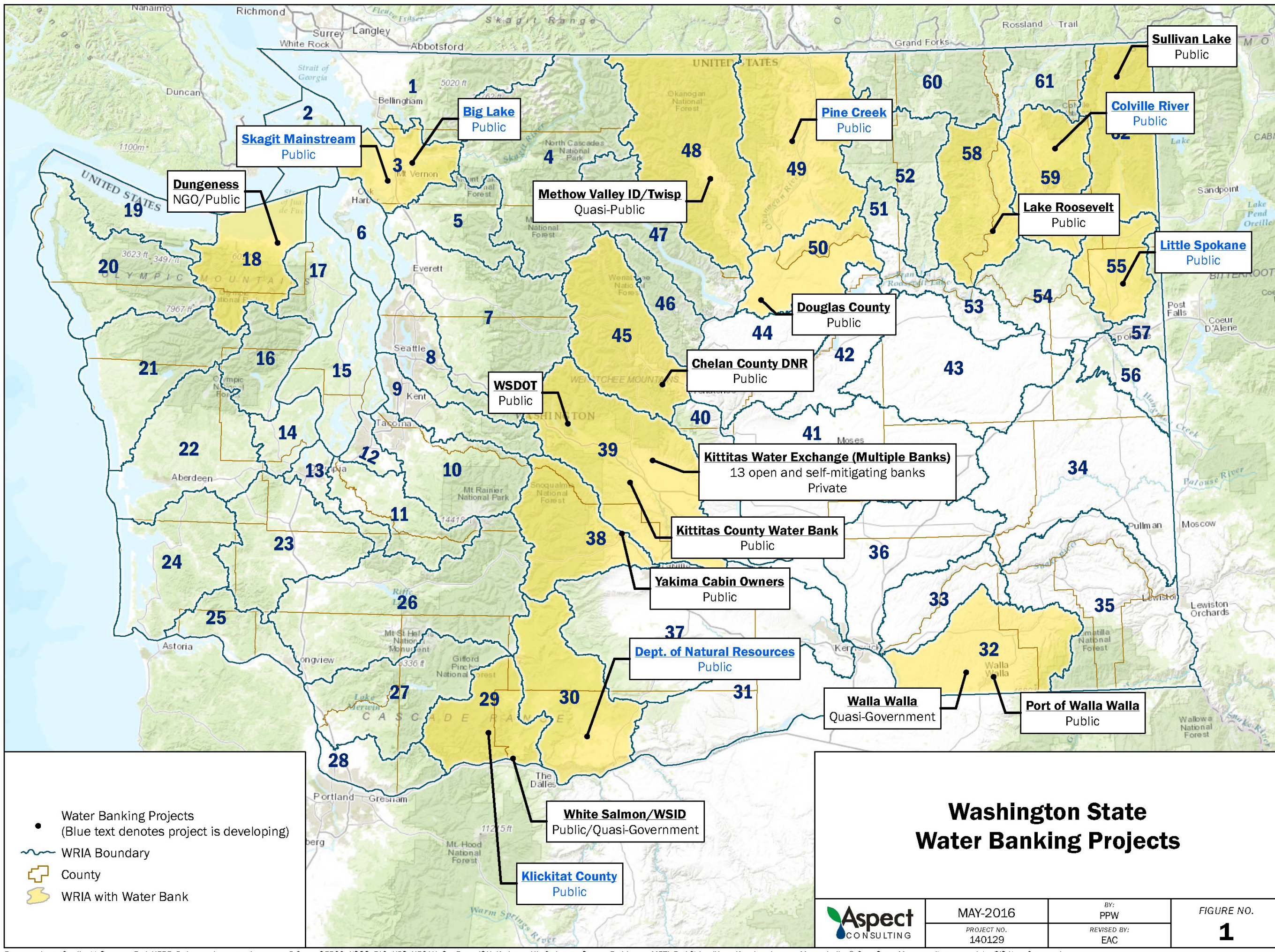

Figure ES-3. Location and extent of existing water banking projects across Washington State in 2016.

EFFECTS OF USER-PAY REQUIREMENTS ON WATER PERMITTING

Participation of applicants in water supply development cost-recovery programs affects both the extent of service provided by Ecology water storage and delivery projects, and the ability of Ecology to recover the costs of providing these services. Over the last 10 years, Ecology and OCR have offered six programs that included different kinds of cost-recovery user-pay responsibilities. These programs offer an opportunity to compare and contrast different business models and their relative successes. Fee structure variants include:

a. A one-time processing fee for water supply development and administration,

b. Annualized payments for water service, and

c. Specified program fees,

d. Individualized mitigation without program fees.

The objective of this module was to better understand the importance of program characteristics, including fee structure, on program participation decisions. A survey was delivered to individuals who chose to or declined to participate in the different target programs, obtained from Ecology's water right application database. The survey data acquired from an original sample of 800+ individual applicants was evaluated statistically to identify the most important determinants of program participation, and to estimate the price-responsiveness of potential participants.

The objective of this exploratory project was to better understand the importance of program characteristics, including fee structure, on program participation decisions. A survey was delivered to individuals who chose to or declined to participate in the different target programs, obtained from Ecology's water right application database. The survey data on 800+ individual applicants was evaluated statistically to identify the most important determinants of program participation, and to estimate the price-responsiveness of potential participants.

Key findings:

- To date, 128 of 859 initial survey requests have been completed, for a response rate of 17%. This is a relatively low response rate, though not uncommon in social science surveys such as this. Though additional reminders are on-going, the final response rate will likely remain relatively low.
- There are several factors that likely contributed to the low response rate, including:
    - Ecology does not have ready access to updated applicant contact information.
    - Some of the applications are over 20 years old, and may not represent the applicant's current needs. Some of the applicants are deceased, and a number of the applications are associated with property that has been sold.
- No analysis on the data has yet been done to date because data are still being collected.

This cost-effects analysis will help Ecology understand the large variation in water service program participation, and identify the factors that affect participation decisions among water rights applicants. Understanding program participation is critical for helping Ecology to address the backlog of water rights applications by providing information that may help in the design of these programs to be more attractive to water rights applicants while providing the cost recovery that Ecology needs to manage their water service programs. Improvements in this arena can help Ecology better address water management challenges expected given the long-term forecast of water supply and demand in eastern Washington.

WESTERN WASHINGTON SUPPLY AND DEMAND FORECASTING

Local watershed planning in Washington started in 1997, with varying success. In some watersheds, the plans resulted in stakeholder collaboration and agreement on both out-of-stream needs and adoption of instream flow rules. In other watersheds, the process was less successful in bringing together coalitions and achieving consensus-based supply and demand solutions.

In 2006, the Legislature required OCR to integrate water supply and demand forecasting for Eastern Washington and the entire Columbia River Basin, and harmonize it with local watershed planning efforts. The resulting forecasts provide coverage for watersheds without a plan, extend the momentum of successful plans, and inform water supply development. However, increasing demands on water are not limited to eastern Washington. The purpose of this module was to assemble information on available data, studies, and plans in western Washington, and evaluate the potential for a statewide Water Supply and Demand Forecast in 2021.

Key Findings:

- The primary datasets used as inputs to the integrated models used in eastern Washington extend to western Washington.
- The existing modeling framework developed for eastern Washington could be used to forecast water supply and agricultural demand across Washington State, and a process similar to that used in eastern Washington can be used to forecast municipal and hydropower demands.
- The existing modeling framework may not be ideal for all western Washington WRIAs, because of the existence of:
    - Smaller WRIAs than in eastern Washington,
    - Tidal effects in coastal WRIAs, not accounted for in this framework,
    - WRIA-specific groundwater–surface water interactions, as groundwater accounts for a higher proportion of water withdrawals,
    - Non-trivial small farm acreage missing in the WSDA land cover data, and
    - Livestock consumptive use, not accounted for in this framework, is a large fraction of agricultural water demands in certain WRIAs.
- Stakeholder input and local documents collected as part of this scoping effort should be used to evaluate the appropriateness of model results in western Washington WRIAs, and to identify WRIAs where additional modeling and data are needed.
- Western Washington has fewer interruptible water rights than Eastern Washington, primarily because Eastern Washington has several basins (e.g. Yakima, Walla Walla) where junior water rights are routinely called to curtail in favor of ensuring water needs of senior water rights are fully met. In comparison, Western Washington water right curtailment is instead focused on interruptible water users that are subject to instream flow provisions. Western Washington has a greater number of these kinds of interruptible users than Eastern Washington, 1373 and 909 interruptibles, respectively. This simplifies curtailment modeling for future Western Washington forecasting efforts if the modeling framework is able to provide realistic supply and demand estimates.
- For WRIAs with regulated supply, if the reservoir capacity is above a certain threshold, simple reservoir models that simulate the reservoir operation rules can be created.

In conclusion, it appears possible to extend the methods of the 2016 Forecast to provide a statewide long-term supply and demand forecast in 2021, though additional stakeholder input, modeling and data collection is likely to ensure results are accurate at the scale of Washington's watersheds.

MEETING EASTERN WASHINGTON'S WATER NEEDS

Aerial photo of Columbia River by William Durham.

The Columbia River Basin, the fourth largest watershed in North America in terms of average annual flow, is intensively managed to meet a range of competing demands. These include hydropower generation, irrigation, navigation, flood control, protection of salmonid species, municipal and industrial water needs, tribal treaty commitments, and recreation. Reliable access to water is essential for existing and future regional economic growth and environmental and cultural enhancement. Variations in water supply and demand across the Basin are increasingly leading to localized shortages as populations grow, the climate changes, and regulatory flow requirements increase. Managing these increasing and competing demands for fresh water resources requires understanding how future conditions will alter supply and demand, and strategically investing in projects that meet competing water management objectives.

Climate Change Impacts

Surface water flows in the Columbia River Basin are dominated by the temperature-sensitive cycle of snow accumulation and melting. During the winter, when the majority of precipitation occurs, snow accumulates in upper elevations of the Basin, forming a "natural reservoir" that stores water during times when demands are relatively low. Melting snow subsequently provides peak yearly flows in the spring and early summer, with nearly 60% of the unregulated surface water availability occurring during May, June, and July. This is generally followed by a low-flow period in the late summer and early fall, until late fall flows increase once again due to rainfall. Operations of major reservoirs have shifted a significant amount of water availability from the winter months to the drier summer months.

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The climate in the Pacific Northwest is already changing. Average temperatures are about 1.3° F higher than they were a century ago. Regional climate change projections suggest that these trends will intensify, with projected temperature changes in the range of 2 to 8.5° F by the middle of the 21st century, with more intense warming in the summer months1. Precipitation on the other hand is not projected to change much on average, though summers are projected to be drier and the other seasons somewhat wetter than historically[1] . These projected climate changes could fundamentally change the patterns of rain and snowfall in the Columbia River Basin, leading to reduced snowpack, earlier snowmelt and peak flows, with longer periods of lower flows during the summer, when out-of-stream demands are highest and instream demands for hydroelectricity generation and fish are important. Reservoir management can compensate for some timing changes in areas of the Basin with storage, though the overall level of storage in the Columbia River Basin is lower (as a percentage of annual runoff) than some other major river systems in the United States.

1 Dalton, M.M., Mote, P., Snover, A.K. (Editors) 2013. Climate Change in the Northwest: Implications for our Landscapes, Waters, and Communities. Island Press. Washington, DC

Simultaneously, higher summer temperatures under climate change could change out-of-stream demands for water in complex ways. Irrigated crops and natural vegetation are likely to have higher evaporation and plant transpiration rates, thus needing more water. Decreases in summer precipitation could also increase demand for irrigation to supplement rainfall. Some harvested crops may be planted and reach maturity earlier, which could change the seasonality of demand, as rainfall is also expected to increase early in the spring. Meanwhile, higher summer temperatures could also increase domestic water demands.

Trends in Agricultural Production

Irrigated agriculture accounts for a large portion of the demand for water in the Columbia River Basin. The mix of irrigated crops grown in Eastern Washington is constantly adjusting over time due to a number of factors including consumer tastes, export and import trends, and production technologies, to name a few. Water demand—both in hydrological and economic terms—depends on the mix of crops in the region, as different crops require differing amounts of water per acre. For example, expansion in acreage of wine grapes, that use relatively little water, would reduce the amount of water consumptively used (all other factors being equal).

Over the last twenty years, irrigated agricultural production trends in the Columbia River Basin show that hay crops (such as alfalfa and Timothy), tree fruit, herb crops (such as mint and hops) have remained relatively constant. Crops that have expanded include wine grapes and vegetables. Irrigated grains have seen the largest decline. Detailed analysis of these trends allows projections of crop mix in the future. While some of the crop groups have seen relatively large percentage changes, the relative acreage share for the region has remained stable, with hay crops covering by far the most acreage.

Fish Instream Needs

The waters of the Columbia River Basin support a variety of fish and other wildlife important to maintaining cultural, environmental, and recreational values, including several fish stocks listed as threatened and endangered under the Endangered Species Act (ESA) (see Figure 1 for the Washington portion of the Columbia River Basin, and Figure 10 for the entire Basin). All these species help support a vibrant tourism, recreation, and fishing industry in the Columbia River Basin, one that plays a vital role in maintaining the rural economy (Box 1). While Ecology recognizes the value of all fish and wildlife, Chapter 90.90 RCW directs OCR to focus on salmonids.

Columbia River Treaty and Tribal Water Rights

One important issue that could dramatically alter the surface water supplies entering Washington State is the re-negotiation of the Columbia River Treaty between the United States and Canada. The 1964 Treaty provided for the construction of four dams in the upper Columbia River Basin that more than doubled the amount of reservoir storage in the Basin: Libby in Montana, and Duncan, Keenleyside (also known as the High Arrow Dam), and Mica in Canada. These four dams are operated to benefit downstream hydropower generation and flood control. According to the U.S. Army Corps of Engineers, the dams provide billions of dollars of benefits to the two countries. The Treaty has an opt-out clause that allows either country to notify the other, as of 2014, that they intend to terminate the Treaty 10 years from the date of that notification.

Since the Treaty was originally ratified, the emergence of additional complex issues such as future needs for anadromous and resident fish, irrigation, recreation, municipal water supply, in addition to power and flood control, has both countries examining whether or not new operating rules would provide additional benefits. Though no notification to terminate has yet been given by either side, both sides are evaluating termination and re-negotiation alternatives. These could radically change the context in which OCR is working to meet water demands in the Columbia River Basin.

Tribal water rights may also have the potential to substantially alter how water supplies are allocated in the region, particularly those available for meeting instream demands. Tribes residing in eastern Washington reserve the right to fish, hunt, and gather their traditional foods across usual and accustomed and ceded areas beyond their reservations that encompass large stretches of the Columbia River and its tributaries. The water rights associated with these fishing rights have not yet been quantified. The implications of quantifying the tribal water rights are difficult to predict, and are outside the scope of this 2016 Forecast.

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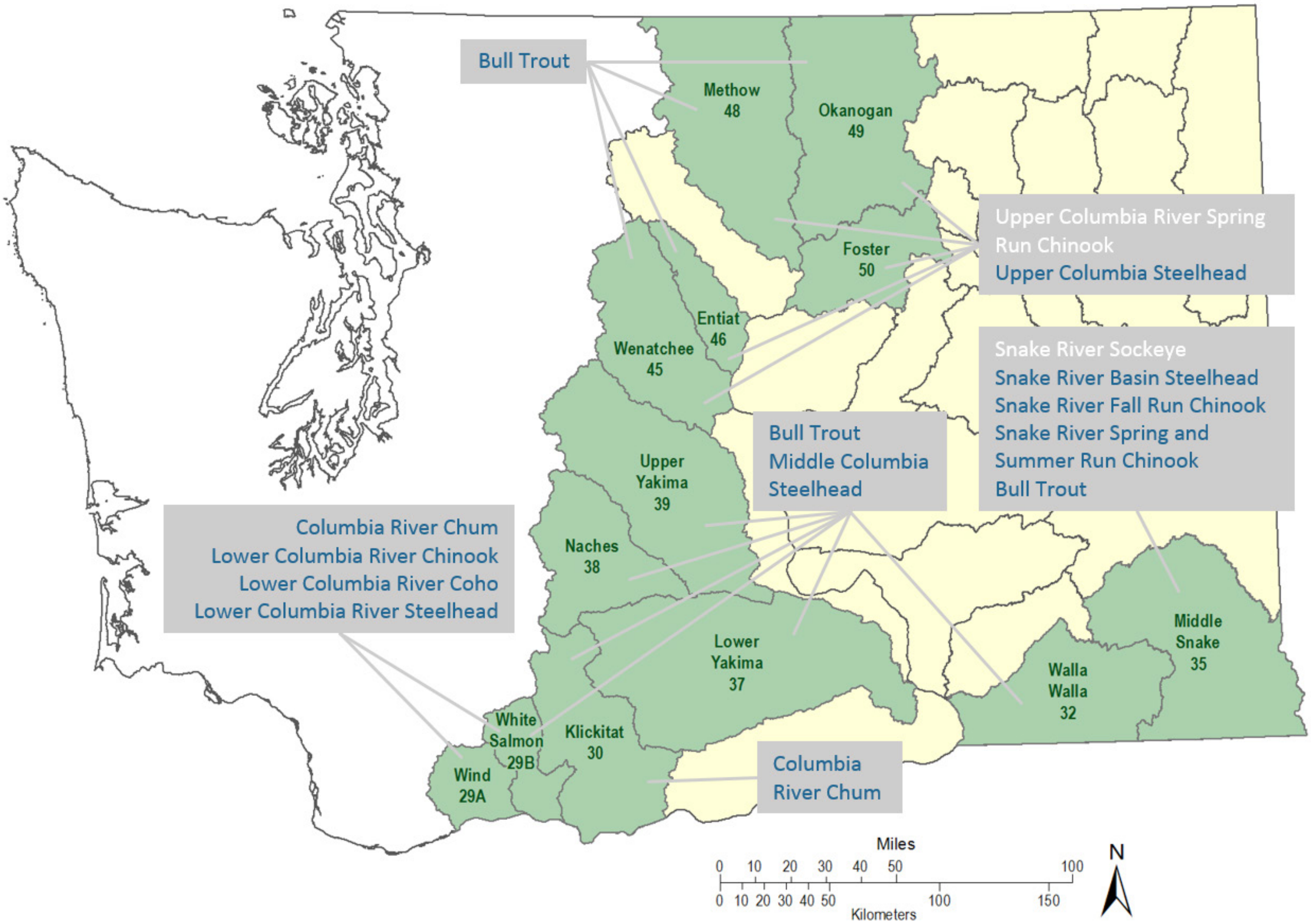


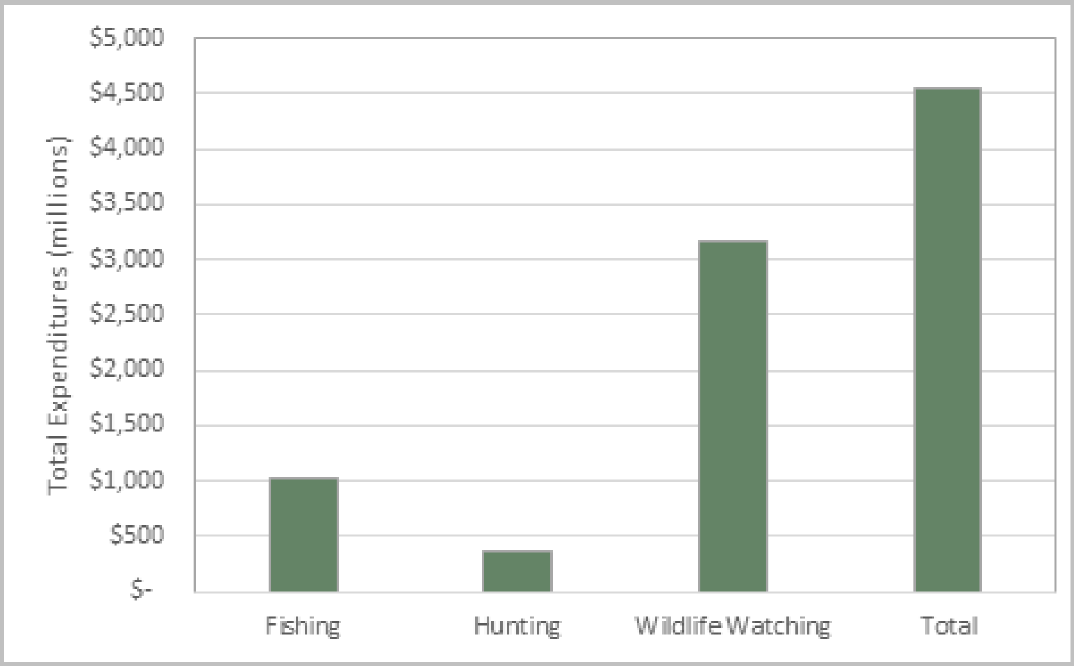
Figure 1. Endangered Species Act (ESA)-listed anadromous salmonid stocks known to occur—though not necessarily spawn—in specific subbasins within the 12 Water Resource Inventory Areas (WRIAs) evaluated in the 2016 Columbia River Instream Atlas (CRIA) update (see Box 9 for details). Threatened stocks in blue, and endangered stocks in white.

BOX 1

Economic value of fish- and wildlife-dependent activities in Washington State

Spending associated with recreational fishing, hunting and wildlife viewing across Washington State was estimated to be over $4.5 billion in 2011, a 67.6% increase from 2006 (USFWS and USCB, 2008, 2014). The Washington Department of Fish and Wildlife estimated that the 2006 activities supported some 46,250 jobs in the state (WDFW, 2010).

The census data used to develop these estimates is not available at a county or regional scale within the state, so numbers for eastern Washington are not available.



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Fish, wildlife and Washington's economy. 2010. Published by the Washington Department of Fish and Wildlife, Olympia, Washington. Available online at http://wdfw.wa.gov/publications/01145/wdfw_01145.pdf

BOX 2

The Office of Columbia River in Washington State

The Office of Columbia River (OCR) was formed in 2006 as a result of Chapter 90.90 RCW. The OCR has a mission to develop water supplies to:

- **Provide alternatives to groundwater for the Odessa Subarea.**
- **Provide water for pending water right applications.**
- **Secure water for drought relief and interruptible water users.**
- **Provide water for new municipal, domestic, industrial, and irrigation uses.**
- **Provide water for instream flows to benefit fish.**

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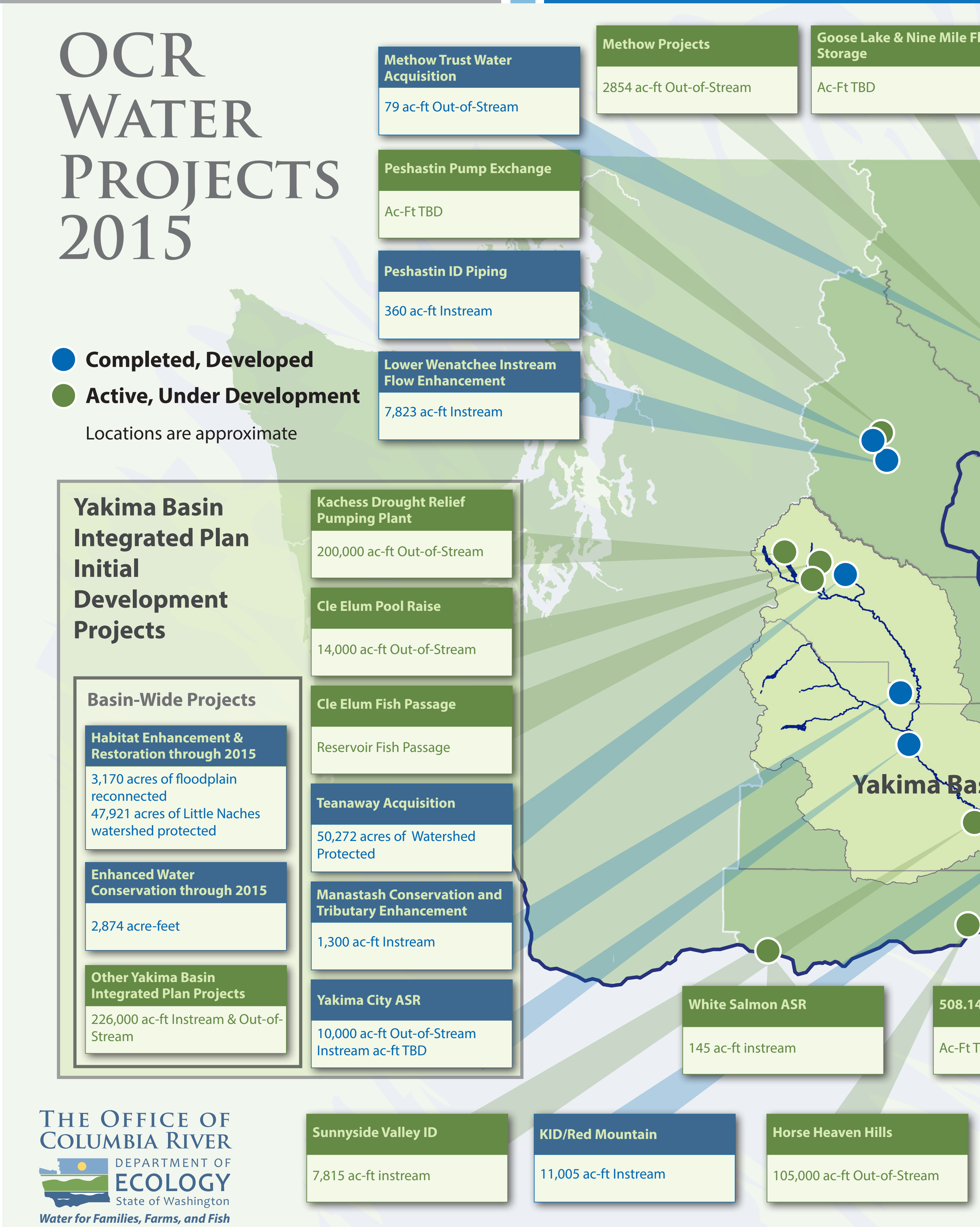
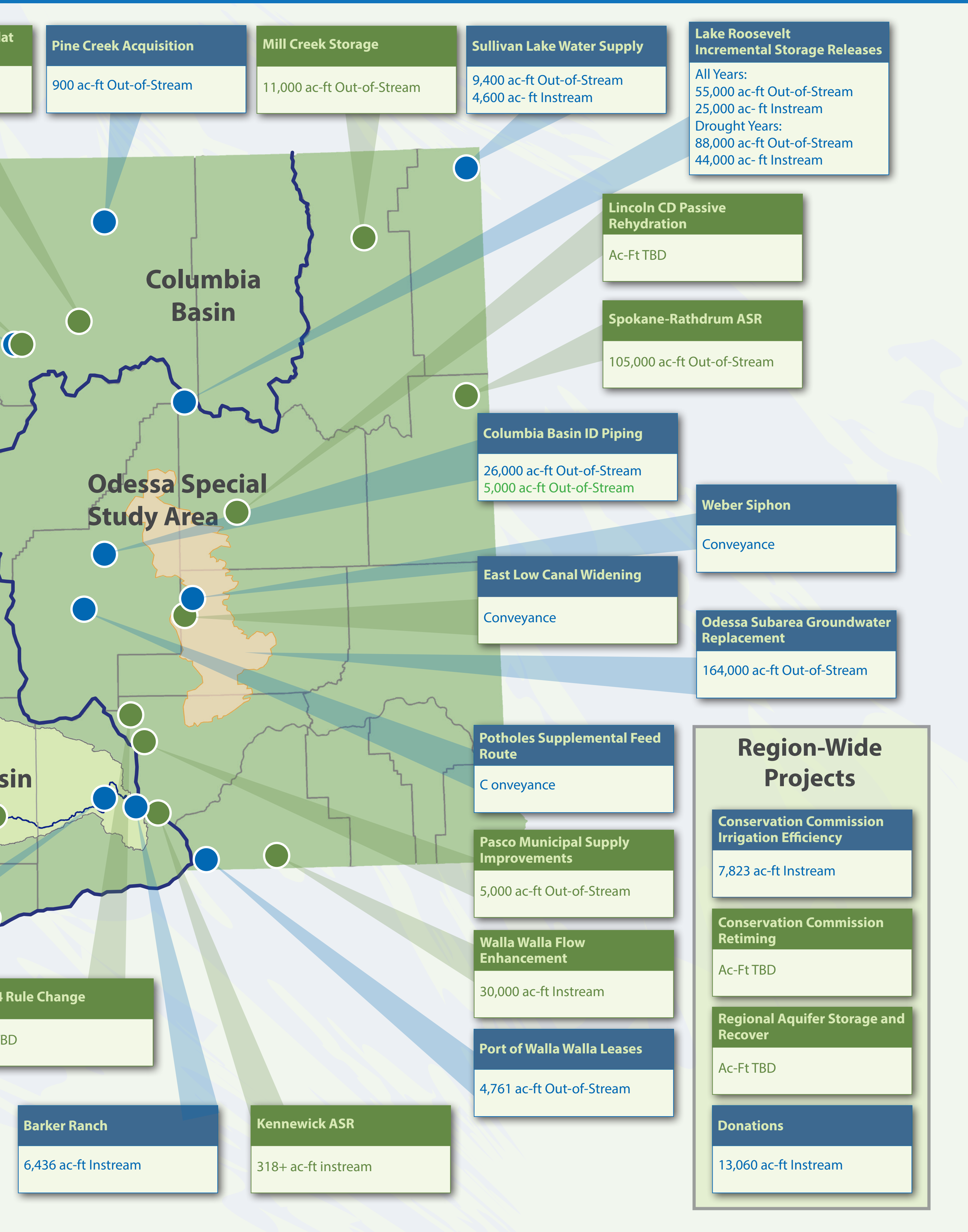


Figure 2. Projects funded by the Office of Columbia River.


Pine Creek Acquisition
900 ac-ft Out-of-Stream
Mill Creek Storage
11,000 ac-ft Out-of-Stream
Sullivan Lake Water Supply
9,400 ac-ft Out-of-Stream
4,600 ac- ft Instream
Lake Roosevelt Incremental Storage Releases
All Years:
55,000 ac-ft Out-of-Stream
25,000 ac- ft Instream
Drought Years:
88,000 ac-ft Out-of-Stream
44,000 ac- ft Instream
Columbia Basin
Lincoln CD Passive Rehydration
Ac-Ft TBD
Spokane-Rathdrum ASR
105,000 ac-ft Out-of-Stream
Columbia Basin ID Piping
26,000 ac-ft Out-of-Stream
5,000 ac-ft Out-of-Stream
Odessa Special Study Area
Weber Siphon
Conveyance
East Low Canal Widening
Conveyance
Odessa Subarea Groundwater Replacement
164,000 ac-ft Out-of-Stream
Potholes Supplemental Feed Route
C onveyance
Region-Wide Projects
Conservation Commission Irrigation Efficiency
7,823 ac-ft Instream
Pasco Municipal Supply Improvements
5,000 ac-ft Out-of-Stream
Conservation Commission Retiming
Ac-Ft TBD
Walla Walla Flow Enhancement
30,000 ac-ft Instream
Regional Aquifer Storage and Recover
Ac-Ft TBD
Rule Change
Port of Walla Walla Leases
4,761 ac-ft Out-of-Stream
Barker Ranch
6,436 ac-ft Instream
Kennewick ASR
318+ ac-ft instream
Donations
13,060 ac-ft Instream

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LONG TERM WATER SUPPLY AND DEMAND FORECASTING

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The water supply systems in the Columbia River Basin were built to reliably deliver water under historical conditions. Changes in water supply and demand due to population growth and climate change have the potential to stress the system. This Long-Term Water Supply and Demand Forecast provides information that will help legislators, water managers, and agency professionals plan for future conditions that will likely be quite different from those we have experienced in the past.

The Office of the Columbia River

The Washington State Legislature recognized the complexities in the water supplies and needs of people and fish across the Columbia River Basin in Washington, and identified the development of new water supplies as a water resource management priority. In 2006, it passed Chapter 90.90 RCW, directing the Department of Ecology (Ecology) to aggressively develop water supplies for instream (one-third of the supply developed through new storage projects) and out-of-stream uses (the remaining two-thirds of the developed supply). With approximately 395,000 acre-feet (ac-ft) of water supply already developed since 2006 and another 320,000 ac-ft under development (Figure 2), OCR has met the challenge of rapidly improving water supply for eastern Washington, consistent with its legislative directives (Box 2).

Since OCR's inception, the pursuit of developing new water supply has provided insight that now shapes the way OCR allocates funds and prioritizes water supply projects. The 2015 drought reminded everyone of the fragile nature of the state's water resources and the need to build and maintain innovative partnerships that focus on resilient and integrated water resource management. Understanding where additional water supply is most critically needed will continue to assist OCR in making smart investments that help improve water supplies for our growing communities, rural economies and instream flow needs throughout the Columbia River Basin.

Past Water Supply and Demand Forecasts

Every five years OCR develops a long-term water supply and demand forecast (Forecast) and submits it to the Legislature. The primary purposes of the Forecast are to provide a generalized, system-wide assessment of:

- How future environmental and economic conditions are likely to change water supply and demand.
- Where OCR can invest in water supply projects that have the greatest chance of meeting new demand and improving flows for fish.

The first Forecast, in 2006, used a variety of existing data and methods to estimate water use in eastern Washington in 2000, and to make projections of water use for 2025.

A different approach was taken in the 2011 Forecast when, for the first time, a computer-based model was employed to forecast water supply and demand, incorporating the impacts of climate change, future regional and global economic conditions, and state-level water management actions. This Forecast quantified water supply and agricultural, municipal, and hydropower demands for water in 2011, and projected supply and demand in 2030. This represented a major endeavor that laid the foundation for future forecasts.

Meanwhile, the Columbia River Instream Atlas, a part of the Forecast first completed in 2011, evaluated stream flows, the status of fish populations and their use of habitat, and the condition of that habitat along 189 stream reaches in eight fish-critical watersheds in the Columbia River Basin.

Changes Explored in the 2016 Forecast

There is inherently a great deal of uncertainty in predicting changes in water supply and demand 20 years ahead. Many factors that influence water supply and demand need to be projected, such as agricultural market conditions, input costs, production decisions, global trade conditions, temperature and precipitation patterns, water management policies, and water storage capacity. By exploring different scenarios that address three broad types of changes that may occur, it is possible to represent the likely range of water supply and demand in 2035. The following three types of changes were updated for the 2016 Forecast:

- ***Climatic factors:*** Increases in greenhouse gas concentrations in the atmosphere are leading to changes in precipitation and temperature, which in turn affect water availability and agricultural growing conditions. The Pacific Northwest is expected to experience increasing temperatures, shifts in precipitation leading to wetter winters and springs and drier summers, declining snowpack, earlier snowmelt and peak flows, and longer periods of low summer flows. In addition, increased concentrations in carbon dioxide also influence crop water requirement through increases in water- and energy-use efficiencies.
- ***Economic factors:*** Changes in domestic food demand and international trade that affect production decisions. Water demand depends on the mix of crops in the region, which in turn is responsive to consumer tastes, export and import trends, and production technologies, among other factors. While some crop groups have seen relatively large changes, the relative acreage share for the region is expected to remain stable, with hay crops covering the most acreage.
- ***Water management factors:*** Changes in water availability, storage capacity, and cost of water supply development passed along to users affect water use. Increases in water storage capacity from planned water storage projects can supply water to new uses, including the development of new irrigated acreage. Such water management changes were explored using scenarios that simulate expanded irrigated acreage.

Other types of changes were beyond the scope of this Forecast, because sufficient data were not available to develop feasible scenarios, given the complexity of factors that drive them. The quantification of tribal rights, for example, involves complex legal issues beyond the scope of the Forecast. Similarly, there is yet no guidance from the United States or Canada on what changes might be made—or not—to the Columbia River Treaty.

The 2016 Forecast used an expanded and updated modeling framework that was initially developed for the 2011 Forecast to make projections of water supply and demand in 2035, using integrated biophysical and human decision-making models (Figure 3) (see details of model improvements in the *Integrated Modeling of Supply and Out-Of-Stream Demands* section, below).

In addition to the improved Forecast, six exploratory projects (hereafter called Modules) were conducted, to inform the 2021 Forecast and OCRs activities:

1. *Integrating Declining Groundwater Areas into Supply and Demand Forecasting:* A survey of declining levels of groundwater and a review of existing groundwater models were carried out, exploring the eventual inclusion of groundwater supply modeling in future Forecasts.
2. *Pilot Application of METRIC Crop Demand Modeling in Washington State:* METRIC, a satellite-based method to calculate field evapotranspiration, was applied in Washington State, as a potential approach to predicting agricultural crop demands, irrigation return flows, and stream discharges at a watershed scale.
3. *Water Banking Trends in Washington and Western States:* An evaluation of methods for facilitating and increasing the efficiency of water banking in Washington State.
4. *Effects of User-Pay Requirements on Water Permitting:* An evaluation of the impacts of user-pay systems for water right permitting on demand for water.
5. *Western Washington Supply and Demand Forecasting:* An evaluation of data needs and availability for extending the water supply and demand forecast to western Washington as a foundation for a complete Washington State Water Plan.

Finally, the Columbia River Instream Atlas (CRIA) was also updated in 2016 as part of the Forecast effort. These updates included:

- Expansion of the CRIA to include four more WRIAs: Wind River/White Salmon (WRIAs 29a and 29b), Klickitat (30), Entiat (46), and Foster (50).
- Development of an interactive Webmap of the 12 flow-critical WRIAs within a GIS-based framework that is publicly accessible.

OVERVIEW OF THE 2016 FORECAST

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Forecast for Three Geographic Scopes

Supply and demand was forecasted for the entire Columbia River Basin, and results are provided for three different geographic areas of interest (Figure 4), fulfilling specific objectives:

Columbia River Basin: Estimate climate-induced changes in surface water supplies and demands upstream of Bonneville Dam in seven U.S. States and British Columbia, with a particular focus on eastern Washington.

Washington's Watersheds: Conduct an in-depth analysis of surface water supply and demand for each of eastern Washington's 34 Water Resource Inventory Areas (WRIAs), from the Canadian border to Bonneville Dam.

Washington's Columbia River Mainstem: Estimate changes in supplies with regard to the mainstem's legal, regulatory, and management schemes.

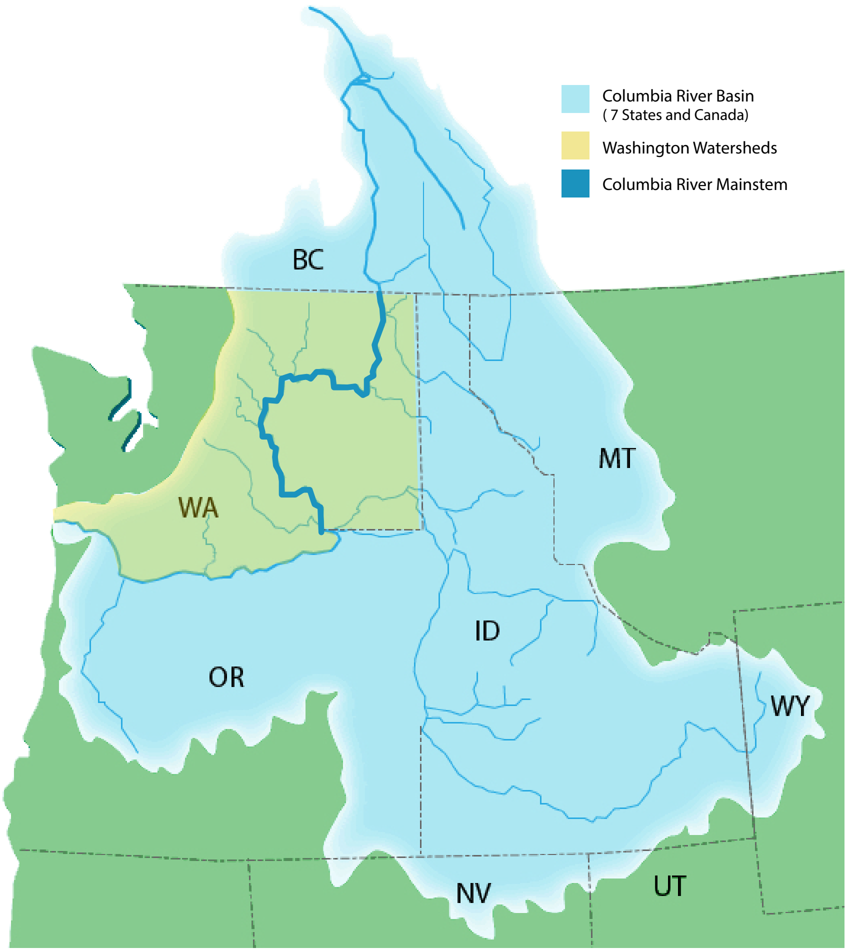

Figure 4. Long-term water supply and demand was forecasted for the entire Columbia River Basin, and results are provided for three different geographic scopes: Columbia River Basin, Washington's Watersheds, and the Columbia River Mainstem.

Instream and Out-of-Stream Elements of the Forecast

Four demand sectors were forecasted: agricultural, municipal, hydropower, and the needs of listed fish species. Washington State University (WSU) carried out integrated modeling of surface water supply and the dominant out-of-stream use (agricultural), estimated projections of municipal water use, and completed a review of hydropower planning projections and instream needs to meet flow regulations. The Washington Department of Fish and Wildlife (WDFW) and Ecology's OCR carried out the portion of the Forecast focused on instream flow requirements for endangered fish.

Integrated Modeling of Supply and Agricultural Demand

Water supply and demand impact each other. Out-of-stream diversions reduce supply downstream, while water that is diverted but not consumptively used—such as water that is lost through leaks in municipal systems—may return to the system and provide water supply downstream. Researchers at WSU thus simulated surface water supply and out-of-stream demands with an integrated computer model that simulated the relationships between climate, hydrology, water supply, irrigation water demand, crop productivity, economics, municipal water demand, and water management. Some of these elements, such as municipal water demand, were simulated in more depth or specificity within Washington State.

The 2016 Forecast's model integrates and builds upon three existing models—VIC, CropSyst, and ColSim (Figure 5)—that have been used independently in various studies to simulate conditions in the Columbia River Basin. What distinguishes this Forecast effort is that VIC and CropSyst exchange hydrologic and crop production information. What distinguishes this 2016 Forecast from the previous 2011 effort is that:

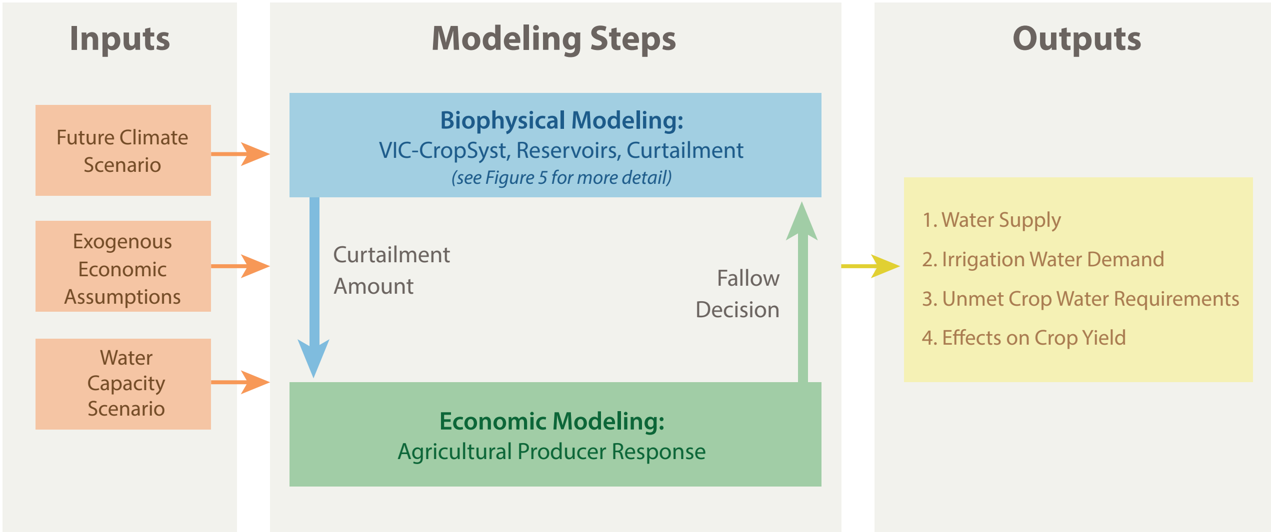

Figure 3. Integration of biophysical modeling (surface water supply, crop dynamics and climate) with economic and policy (human decision-making) modeling.

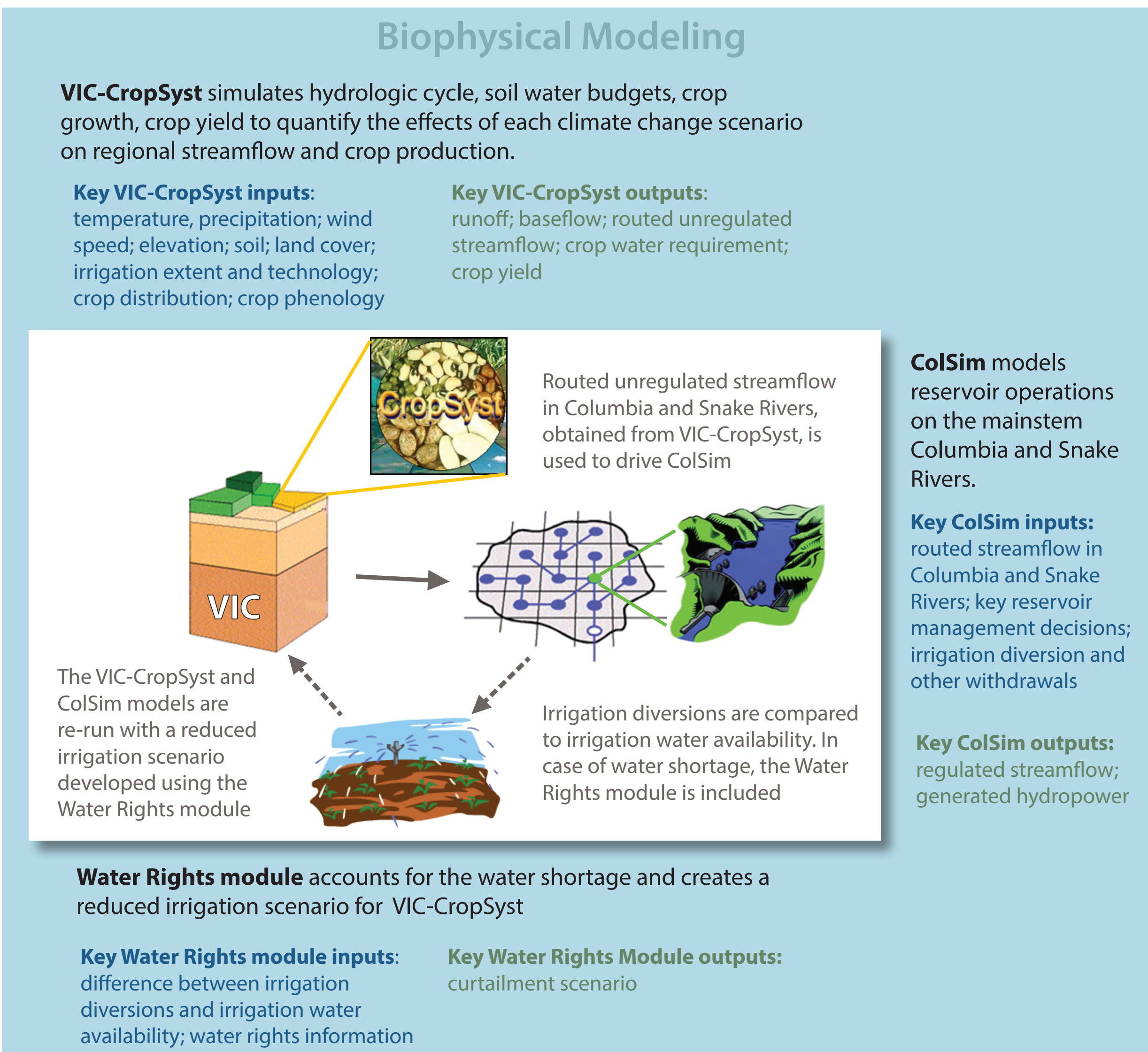

Figure 5. Biophysical modeling framework for forecasting surface water supply and agricultural water demand across the Columbia River Basin.

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- The hydrological (VIC) and crop production (CropSyst) models are more tightly integrated, so that the interactions between the hydrological cycle and crop growth processes are better captured. This improves the simulation of crop water requirements, particularly during drought conditions.
- Newer climate change projections (CMIP 5) and improved downscaling methods were used, so that future climate scenarios are more appropriate for the region, and are better able to capture changes in temperature and precipitation extremes, in addition to changes in average temperatures and precipitation.
- Improved historical climate and crop data were available, reducing the number of assumptions that were needed to model historical supply and demand across the region.
- Only one 2035 crop mix was projected, simplifying the assumptions made about future domestic economic growth and international trade. The 2011 Forecast demonstrated that scenarios based on varying these assumptions have relatively little effect on the future crop mix.
- Improved water rights curtailment modeling was performed using the results of surveys from and discussion with watershed water masters about water management in response to the 2015 drought. Modeling improvements included modeling curtailment at weekly (rather than monthly) time-steps, modeling curtailment of non-interruptible water rights, and using Yakima RiverWare to simulate prorationing in the Yakima River Basin.
- Two scenarios of responses to water shortages were captured, which provides upper-where all crops suffer curtailment-and lower-where farmers fallow lower value crops first-estimates of the negative impacts of reduced water availability on production and profitability

Forecasting Water Supply and Agricultural Demand – Framing Principles

VIC-CropSyst v2.0 used daily precipitation and temperature observations from across the Basin for 1981-2011 to generate baseline simulations of historical conditions for each location. To forecast future conditions, the model used daily weather information for the 2030s decade (referred to in this Forecast as 2035) from ten different climate change scenarios, representing a range of future greenhouse gas emissions, and adapted for our region by the University of Idaho.[2] Increased carbon dioxide concentrations are also used for the future scenarios.

To accurately simulate surface water supply and agricultural demand, the VIC-CropSyst model needs accurate land use information for the entire Columbia River Basin upstream of the Bonneville Dam, including upstream areas in other states and British Columbia. To simulate these variables for the 2030s decade, projections in land use—characterized by the mix of crops across the region—are needed. There are two options for forecasting a future crop mix. The first option is to directly model each factor that influences cropping decisions, such as economic growth and export trends. The second option is to simply statistically analyze the historical changes in crop mix and forecast those trends into the future, based on an understanding that changes in cropping patterns reflect changes in these many factors, so it is not necessary to model them directly. This approach would have limited utility if changes in the factors that influence crop mix in the future suddenly move in a different direction than in the recent past. However, there is a significant amount of research in economics demonstrating that this approach produces more accurate forecasts than trying to model all factors, so this was the approach taken in this 2016 Forecast.

Based on the weather, land use, and other inputs, VIC-CropSyst simulates the hydrologic cycle, soil water budgets, crop growth, and crop yield to quantify the effects of each climate change scenario on regional streamflow and crop production (Figure 5).

Key principles that guided the VIC-CropSyst simulations include:

- The Forecast focused on surface waters and shallow subsurface/surface hydrologic interactions. Though deep groundwater supplies play a significant role in many parts of eastern Washington, this Forecast does not analyze deep groundwater dynamics (but see *Integrating Declining Groundwater Areas into Supply and Demand Forecasting*).

2 Modeling used downscaled climate projections from the 4.5 (medium greenhouse gas emissions) and 8.5 (high greenhouse gas emissions) Representative Concentration Pathways (RCPs), as developed by the Intergovernmental Panel on Climate Change (IPCC).

- Reservoir modeling captured operations of 36 of the 400 dams in the Columbia River Basin, focusing on the major storage dams on the Columbia and Snake Rivers, and the five major reservoirs in the Yakima Basin (Figure 6). Dam management captured within ColSim included operations for power generation, flood control, instream flow targets, water storage, and stream flow regulation.
- The Forecast modeled supply using current water management and existing reservoirs. Reservoir and water rights curtailment models enabled evaluation of how a changing water supply might impact future reservoir storages and releases, irrigation application amounts, crop yields, and how frequently some groups of water users might see their use interrupted.
- Irrigation demands were modeled assuming that the land base for irrigated agriculture remained constant between the historical snapshot (1981-2011) and the future timeframe (2035). Movement of acreage into and out of agriculture were beyond the scope of this Forecast.
- The historical (1981-2011) simulations used recent crop mix information from the United States Department of Agriculture's (USDA) Cropland Data Layer (CDL; 2013 dataset) for areas outside of Washington, and used the Washington State Department of Agriculture's (WSDA; 2013 dataset) slightly more precise data for areas inside the state.
- Each crop within Washington was identified as irrigated or not based on irrigation information in the WSDA dataset. Since the USDA dataset does not include any irrigation information, irrigation methods outside of Washington were assigned based on the most dominant type of irrigation for that crop in the WSDA dataset. High value crops such as corn, fruit crops, potato were always irrigated.
- The future crop mix was projected based on recent changes in the relative acreage of various types of crops. The future crop mix scenario assumes that historical trends in the relative acreage of crop types—and the main driver of those changes: the relative profitability of each crop—will continue into the future.
- The Forecast focused on irrigation, which represents the majority of out-of-stream water use in the Columbia River Basin and supports irrigated agricultural production, a prominent driver of Washington's economy. While other agricultural uses—such as stock water—are important within some WRIAs, the magnitude of these uses Basin-wide is small relative to consumptive use for crops, so they were not estimated for this Forecast (Box 3).
- Nearly 40 groups of field and pasture crops, tree fruit, and other perennials were simulated (Box 4), capturing the diversity of eastern Washington's crop mixes.

BOX 3

Stock water use accounts for a small portion of the agricultural water uses in eastern Washington

Every five years, the U.S. Geological Survey (USGS) estimates the amount of water used in homes, businesses, industries, and farms across Washington State. In 2010, their most recently published estimate, the USGS found that stock water uses represented approximately 0.45% of out-of-stream water use, considering public- and self-supplied domestic use, irrigation, stock water, aquaculture, industrial, and mining.

Stock water use was estimated to increase 3% in eastern Washington, with greater increases coming from groundwater than from surface water.

Even given this slight increase in stock water use, the total amount of water this represents continues to be very small, on average, relative to other water uses in eastern Washington.

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- As in the 2011 Forecast, all irrigated agriculture in the Odessa Subarea that was served by groundwater to grow irrigated crops in the historical period was assumed to need surface water in 2035.
- The 2016 Forecast utilized only a medium, or "most likely" scenario for economic growth to project the 2035 crop mix. The 2011 Forecast demonstrated that scenarios based on varying assumptions about domestic economic growth and trade have relatively little effect on crop mix in general, likely because the U.S. population spends a relatively small portion of their household budget on food, and because export markets had an effect on only a few crops. Therefore, alternative scenarios are not considered in this 2016 Forecast.
- The 2016 forecast captures water shortage response of producers as two scenarios that provide an upper and lower estimate of the economic cost of drought:
    - The upper cost estimate is arrived at by assuming that all crops are curtailed in proportion to their water use,

BOX 4

Field, pasture, tree fruit, and other perennial crops simulated in the historical and future crop mixes

Field Crops		Vegetables and Fruits	Pasture Crops	Tree Fruit and Other Perennial Crops	Other Perennial Crops
Winter Wheat	Millet	Sweet Corn	Alfalfa	Apple	Silviculture
Spring Wheat	Sorghum	Green Peas	Pasture	Cherry	Christmas Trees
Durum Wheat	Soybeans	Mint	Pasture Grass	Pear	Poplar
Barley	Speltz	Onions	Grass Hay	Peach or Nectarine	Daffadil
Potato	Canola	Asparagus	Bluegrass Hay	Plum	Tulip
Corn	Chickpea	Carrots	Timothy	Apricots	Sod Grass
Lentils	Mustard	Squash	Rye Grass	Hops	Green Manure
Dry Peas	Camelina	Garlic	Clover Hay	Grapes	Yellow Mustard
Sugar Beet	Safflower	Spinach	Vetch	Grape – Juice	Clover, Wildflowers
Canola	Beet Seed	Green Beans	Barley Hay	Grape – Wine	Sudangrass
Oats	Corn Seed	Herbs	Alfalfa Seed	Caneberry	Nursery Silviculture
Rye	Pea Seed	Turnips	Bluegrass Seed	Blueberry	Nursery Orchard, Vineyard
Dry Beans	Flax Seed	Watermelon	Ryegrass Seed	Cranberry	Nursery Ornamental
Buckwheat	Sugar Beet Seed	Green Beans	Fescue Seed	Strawberries	Walnuts
Triticale	Sunflower Seed	Broccoli	Grass Seed	Other Orchards	Conifer Seed
Sunflower	Rape Seed	Cabbage	Other Hays		
Other Small Grains		Cauliflower			
		Cucumber			
		Lettuce			
		Peas			
		Peppers			
		Potatoes			
		Pumpkin			
		Radish			
		Greens			
		Dill			
		Carrot Seed			
		Spinach Seed			

which is consistent with the assumption that farms have very little crop diversity and there is little to no short-term leasing of water between farms.

- ◦ The lower cost estimate assumes that farmers are able to fallow lower value crops first. This is consistent with the assumption that at the farm level there is substantial crop diversity or that farms are able to lease water, such that farms with higher value crops pay those with lower value crops to fallow.

This provides upper and lower bounds on the negative impacts of reduced water availability on production and profitability.

- As part of this Forecast, additional modeling is ongoing, exploring different scenarios with additional water capacity allowing an expansion of irrigated acreage across the region.

Water supply under the different climatic, economic and water management scenarios was obtained from the unregulated streamflow outputs of VIC-CropSyst, and the regulated streamflow outputs of ColSim (Figure 5). Agricultural water demand under those same scenarios were obtained from the crop water requirements outputs (plus conveyance losses) of VIC-CropSyst (Figure 5). Evaluation of the VIC-CropSyst agricultural water demand simulations was primarily based on observed diversion data at Banks Lake, serving the Columbia Basin Project irrigated area in central Washington. Lack of high quality metered diversion data was an impediment to doing similar evaluations of modeling results at the scale of Washington's watersheds.

Other Demands for Water

Forecasting Municipal Water Demand – Framing Principles

Municipal use represents a much smaller portion of water use than agriculture in the Columbia River Basin, but one that is important for supporting the continued prosperity of the region.[3]

- Municipal demand was assessed only within Washington State.
- Values for self- and municipally-supplied domestic, industrial, and commercial water use were obtained from the 2010 USGS Estimated Use of Water in the U.S. report, and were forecasted and integrated with the modeling.
- Calculations of total WRIA water demand were estimated as the sum of municipal, industrial, and domestic demand for each block of County population (obtained from the U.S. Census Bureau) residing within a WRIA.
- It was assumed that growth in rural demand will likely be met by groundwater supplies, but domestic wells are expected to be shallow enough to directly impact surface water flows.
- Consumptive municipal use was estimated by subtracting wastewater returns (reported at County level) from public supply values for each WRIA. Some adjustments were needed to make these two datasets comparable, which were done by computing the mean per capita wastewater return in each WRIA over the historical periods of 1985, 1990 and 1995 (the most recently reported values). The potential exists for significant discrepancies due to municipal inflow and infiltration.
- Per capita consumptive use values were multiplied by the population estimates for 2015 and 2035 (estimated through a logistic curve model) to gain total consumptive use values for these two years.
- No attempt was made to account for seasonal variations in water use.

Municipal water demands were obtained by equating demand to consumptive municipal use.

Forecasting Hydropower Water Demand – Framing Principles

The Northwest Power and Conservation Council collects data on energy produced by the major hydroelectric dams in the

3 The U.S. Geological Survey estimated that domestic uses (including public and self-supplied) represented 11% of out-of-stream water use statewide, considering domestic, irrigation, stock water, aquaculture, industrial, mining, and thermoelectric uses. Within eastern Washington, domestic uses represented 13% of all uses except thermoelectric (which could not be separated regionally due to limitations in data presentation). Lane 2009, op. cit.

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Columbia River Basin (Box 5). Power entities in the Northwest regularly carry out extensive forecasting of electricity demand and power-generating capacity. For this Forecast, researchers reviewed existing projections across the Columbia River Basin with two specific objectives in mind:

- Find out whether regional and state level power entities felt that they would be able to meet anticipated growth in demand over the next 20 years.
- Determine the likelihood of any additional hydroelectric storage capacity being built within the Columbia River Basin over the next 20 years.

Available reports that were reviewed included those carried out by the Bonneville Power Administration (BPA), Northwest Power and Conservation Council (NWPCC), Avista, Idaho Power, Portland General Electric (PGE), Grant County Public Utility District (PUD), Chelan County PUD, and Douglas County PUD. British Columbia (BC) Hydro documentation was also reviewed, though long-term planning documents were general in nature. In addition, newspaper articles and websites were examined for relevant content. It is important to recognize that some information was difficult to evaluate and market conditions and corporate announcements can quickly render some assumptions obsolete. Nevertheless, attempts were made to insure the most recent information was included. Reviews were supported with conversations with staff at public utility districts in Washington State and Avista Utilities.

Forecasting Instream Water Demand

Instream demands were not determined during the integrated modeling described above, but were represented through the adopted state and federal instream flows in the Washington portion of the Columbia River Basin, upstream of the Bonneville Dam:

- Adopted flows were assumed to be the same in the historical and future periods.

BOX 5

Hydroelectric power in the Columbia River Basin

Hydroelectric power is extremely important to economic development in the Pacific Northwest, including Washington State. The first hydropower turbines were installed on Columbia River tributaries in late 1800s, and water power from dams in the Columbia River Basin provided most of the electricity in the Pacific Northwest into the 1960s. As the population became larger and regional economy grew, demand for electricity surpassed the output of the dams, which gave rise to other types of power plants, including thermal plants fueled by coal, nuclear fission and natural gas. However, electricity in the Northwest is still dominated by hydropower, accounting for about two-thirds of the region's supply with most of the region's hydropower generated on the Columbia River and its tributaries.

The Northwest Power and Conservation Council (NWPCC) collects data on energy produced by the major hydroelectric dams in the Columbia River Basin. According to the NWPCC (2016a), more than 75 major federal and nonfederal hydroelectric dams in the Columbia River Basin produce upwards of 15,000 annual average megawatts (MWa) of energy, which accounts for approximately 55% of the power generating capacity in the Pacific Northwest (about three quarters of the region's electricity). Power entities in the Northwest regularly carry out extensive forecasting of electricity demand and power-generating capacity (NWPCC 2016b).

References:
Northwest Power and Conservation Council, 2016a. Seventh Power Plan, February 25, 2016. http://www.nwcouncil.org/energy/powerplan/7/plan/
Northwest Power and Conservation Council, 2016b. Demand Forecast, February 25, 2016. http://www.nwcouncil.org/media/7149913/7thplanfinal_appdixe_dforecast.pdf

- Within WRIAs, the highest adopted state and federal instream flows for each month were used to express current minimum flows for fish in both the historical and the 2035 forecast.
- Along the Columbia River mainstem, Washington state instream flows (WA ISF), and the Federal Columbia River Power System Biological Opinion instream flows (FCRPS BiOp) were compared to modeled historical and forecasted surface water supplies at Priest Rapids, McNary, and Bonneville Dams, to evaluate if and when water availability—quantified by the supply values—was likely insufficient to meet flow requirements, once water demands were accounted for. These two regulatory schemes were chosen because of their role in regulating interruptible water rights holders (in the case of the WA ISF) and managing federal dams and the Quad Cities[4] water permit (in the case of the FCRPS BiOp).

Additional detail on instream water demands was generated through two related efforts. Across the Washington portion of the Columbia River Basin, OCR developed a comprehensive database of available historical flow data for each major tributary to the Columbia River. Using these data, OCR compared historical low, average, and high flow water years to state and federal minimum instream flow targets. This work was intended to improve understanding of:

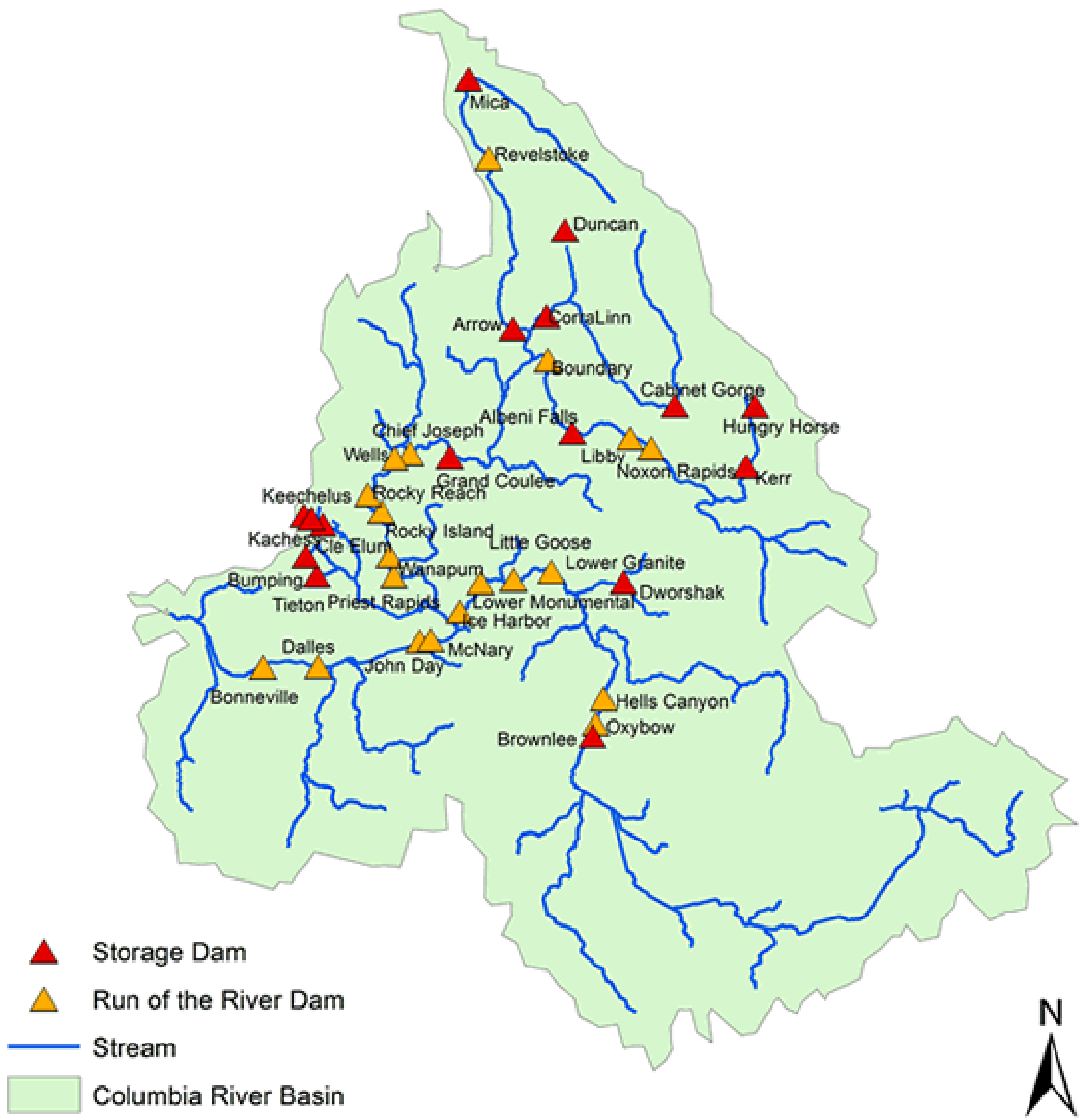

Figure 6. Dams incorporated in modeling of reservoir operations.

4 Kennewick, Pasco, Richland, West Richland

- How often minimum flow targets in fish critical basins are being met.
- How often water users subject to minimum flow targets see their water use curtailed.
- Whether trends exist in the historical data relative to water availability, the shape of the hydrograph, or drought severity.
- Where opportunities exist to improve stream conditions by re-timing or re-locating water.

In addition to the comparative work that covered the Washington portion of the Columbia River Basin, OCR contracted with the WDFW to update and expand information on instream water demands for 13 low flow critical subbasins (12 WRIAs) that provide habitat for ESA-listed anadromous salmonids in eastern and central Washington (Box 6). The resulting Columbia River Instream Atlas (CRIA; Ecology Publication in preparation):

- Presents the WDFW's updated data, quantitative analyses, and best professional knowledge for 316 stream reaches in 12 WRIAs (Box 6) at a finer geographic scale than WSU's modeling analysis.
- Scores each reach on three critical components: (a) fish stock status and habitat utilization, (b) fish habitat condition, and (c) stream flow.
- Allows for comparisons of fish habitat conditions in stream reaches within each of the WRIAs, and thus provides a consistent means for evaluating flow use constraints and opportunities for fish habitat enhancement.

The CRIA empirical data, statistical analyses, and scores based on expert judgment will be incorporated into a spatially explicit, interactive, GIS-based Webmap tool with links to more detailed information. OCR will use the results summarized in the CRIA Webmap, as well as consultations with WDFW staff, to identify and prioritize projects that benefit stream flows while considering fish use and habitat condition.

Stakeholder Input

Feedback received during the 2011 Forecast process was essential for planning for the 2016 Forecast. So too were responses to the many presentations WSU researchers have given on the Columbia River Long-Term Forecast to diverse groups in the intervening years. WSU researchers have continued to obtain feedback from the Columbia River Policy Advisory Group (PAG), a group that provided input on the original modeling methods. This group represents a range of stakeholder interests, and helps OCR identify and evaluate policy issues. In addition, WSU carried out targeted outreach to agricultural, municipal, tribal, and federal professionals to identify any relevant datasets not yet incorporated into the modeling and model evaluation.

Columbia River near Wenatchee

BOX 6

Low flow critical subbasins included in Washington Department of Fish and Wildlife's Columbia River Instream Atlas

Subbasin	WRIA	Stream Miles	Number of Reaches
Wind River	29A	74.6	25
White Salmon	29B	84.9	20
Klickitat	30	360.3	46
Walla Walla	32	337.2	36
Middle Snake	35	430.2	32
Lower Yakima	37	233.3	11
Naches	38	119.5	9
Upper Yakima	39	309.1	36
Wenatchee	45	172.6	30
Entiat	46	36.1	7
Methow	48	173.7	35
Okanogan	49	293.6	25
Foster	50	59.4	4
Total		**2,684.5**	**316**

Endangered Species Act (ESA)-listed anadromous salmonid species1 that occur—though do not necessarily spawn—in the 12 Water Resource Inventory Areas (WRIAs) evaluated in the Columbia River Instream Atlas (CRIA) Project are illustrated in Figure 1. All of the WRIAs under study in the CRIA Project are within the geographic area designated by National Oceanic and Atmospheric Agency (NOAA) Fisheries as the "Interior Columbia Domain" for ESA-listed stocks, with the exception of the salmon evolutionarily significant units (ESUs) in WRIA 29, that are within NOAA's Lower Columbia/Willamette Domain. Bull trout are designated by U.S. Fish and Wildlife Service as "threatened" throughout the Columbia Basin and the contiguous United States. For information about salmonids that spawn within each eastern Washington WRIA, please refer to the appropriate WRIA in the Forecast Results for Individual WRIAs section.

[1] The technical terms for "ESA species" are Evolutionarily Significant Unit (ESU) for salmon under the jurisdiction of NOAA Fisheries, or Distinct Population Segment (DPS) for steelhead (under NOAA) and other fishes, e.g., bull trout and sea run cutthroat trout under the jurisdiction of US Fish & Wildlife Service (USFWS and NMFS 1996). These ESA-listed populations are generally geographically and reproductively isolated units of a biological species – that may also be referred to as subspecies or stocks in conventional fisheries nomenclature.

References:

Waples, R. S. (1991). "Pacific salmon, Oncorhynchus spp., and the definition of "species" under the Endangered Species Act". Mar. Fish. Rev. 53 (3): 11–22.

United States Fish and Wildlife Service, and National Marine Fisheries Service. 1996. Policy regarding the recognition of distinct vertebrate population segments under the Endangered Species Act. Federal Register (7 February 1996)61(26):4722-4725.

FORECAST FOR THE COLUMBIA BASIN

To accurately forecast Washington's water supply and demand, it is necessary to understand water supply and demand throughout the entire Columbia River Basin. This Columbia River Basin Forecast therefore provides a broad assessment of the Basin as a whole and an in-depth analysis of its Washington portion. The results at this scale estimate the changes in surface water supplies and demands that can be expected by 2035, including under different climatic scenarios. Ongoing modeling will also provide results from different water management scenarios in the near future.

Figure 7. Columbia River Basin

Columbia River Basin Surface Water Supply

Modeled Surface Water Supplies across the Whole Basin

The amount and timing of water entering Washington State within the Columbia River Basin is highly impacted by existing infrastructure and management in British Columbia, Idaho, Montana, and Oregon, the major water contributors—with Washington—to Columbia River flows (Figure 7).

The comparison of the modeled results for surface water supply for the Columbia River Basin in 2035 versus the historical supply (1981-2011) highlighted the following changes:

- An increase of around 11.7% (±6.5%) in annual supplies across the Columbia River Basin, on average[5], by 2035 (Table 1).
- The timing of supply will shift water away from the times when demands are highest by 2035. An average increase in unregulated surface water supply of 28.6% (±7.4%) is expected between November and May, followed by a 10.6% (±5.8%) decrease, on average, between June and October (Figure 8).

The increase in supplies projected for 2035 is mainly due to the fact that the climate is projected to get somewhat wetter. The shift in timing, on the other hand, is in response to warming temperatures. Warming results in a smaller snowpack (as the ratio of precipitation falling as snow versus rain is smaller) and an earlier snowmelt peak. It is noteworthy that, even with an overall increase in annual water supplies, this shift in supply away from the season of highest water demand has the potential to cause increased water stress throughout the Columbia River Basin.

Table 1: Modeled water supply in the historical (1981-2011) and forecast (2035) periods for the entire Columbia River Basin. Estimates are presented for average years (50th percentile), with the range in parentheses representing low supply (20th percentile) and high supply (80th percentile) years.

	Historical (million ac-ft per year)	2035 Forecast (million ac-ft per year)	% Change
Entire Columbia River Basin	132 (113-151)	136 (122-161)	3.03%[5]

5 When discussing modeled supply and irrigation demand results, "average" by itself (as opposed to "average flow conditions") refers to the average value over all climate scenarios and flow conditions, and a 90% confidence interval around that average, usually shown in parentheses. Note that this value of 11.7% is an average over all climate scenarios whereas the value of 3.03% is for 50th percentile of the middle climate scenario, only.

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Modeled Surface Water Supplies Entering Washington

The direction and reason for changes in surface water supply entering Washington projected for 2035 are similar to those estimated for the entire Columbia River Basin:

- Annual water supplies entering Washington will increase by approximately 14.1% (±2.0%) by 2035, on average. This includes inflows into Washington from the Similkameen, Kettle, Columbia, Pend Oreille, Spokane, Clearwater, Snake, John Day and Deschutes Rivers. While most of the rivers show all increases in supply for each of the climate scenarios, the direction of change was unclear for the Kettle River which, on average, showed a decrease in supply (-0.2±3.8%) (Figure 9).
- Surface water supplies entering Washington will generally decrease in the summer and early fall and increase in the late fall, winter and spring, consistent with the patterns observed across the entire Columbia River Basin (Figure 9, inset panels). The exact timing of these shifts vary by watershed (see *Forecast Results for Individual WRIAs*).

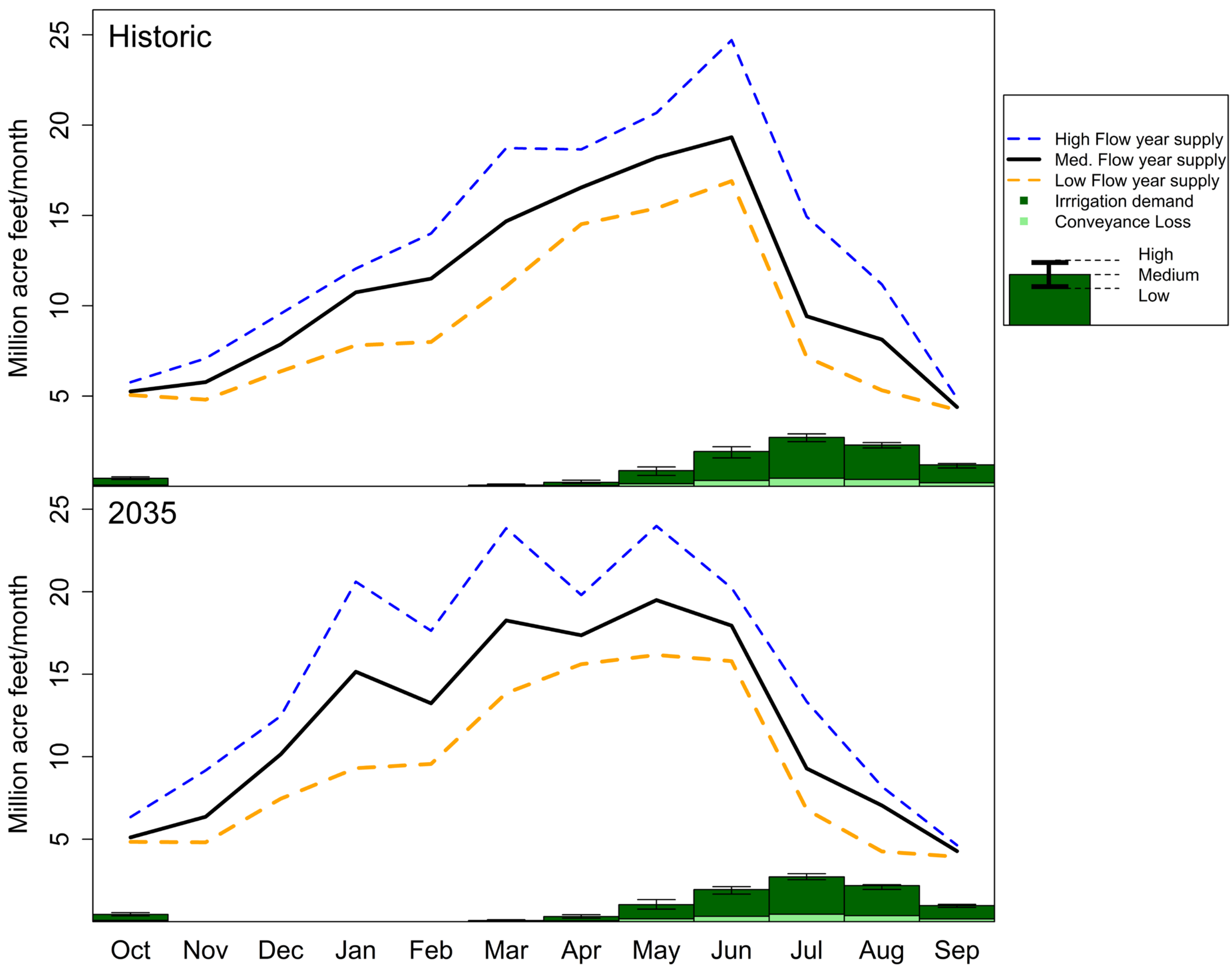

Figure 8. Comparison of regulated surface water supply and agricultural water demands for the historical (1981-2011; top panel) and forecast (2035; bottom panel) periods across the entire Columbia River Basin, including portions of the basin outside of Washington State. A range of values is for both supply (dotted lines) and demand (error bars). This range represents low (20th percentile), median (50th percentile), and high (80th percentile) supply and demand conditions.

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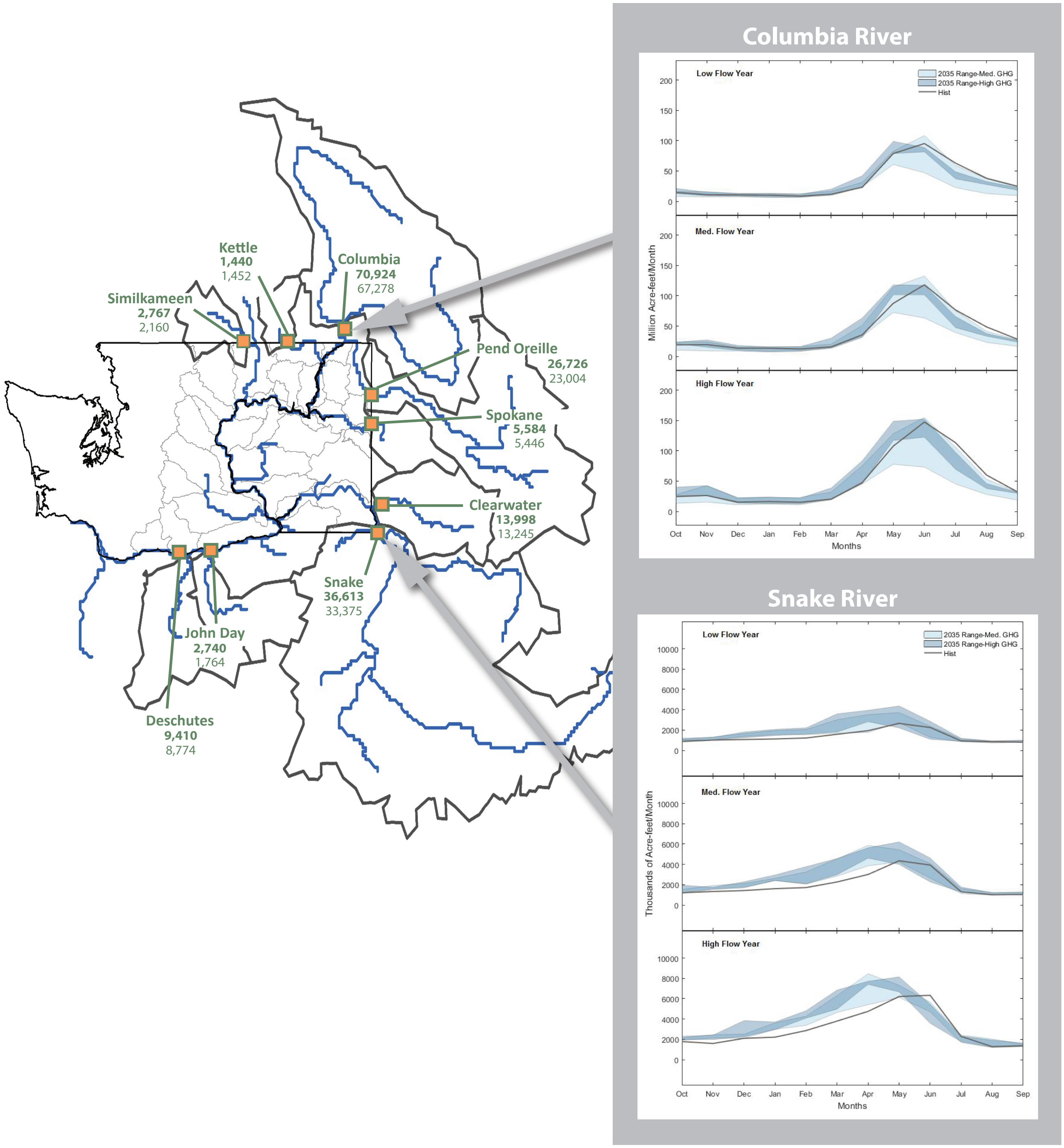

Figure 9. Surface water supplies for major Columbia River tributaries, upstream of the point where the rivers enter Washington State. The top number for each tributary (in bold) refers to forecasted (2035) water supplies for median (50th percentile) flow conditions and the RCP 4.5 scenario, while the bottom number (in italics) refers to historical (1981-2011) water supplies. All values are in cubic feet per second. Inset panels show the historical (1981-2011) and forecasted (2035) regulated surface water supplies on the Snake and Columbia Rivers upstream of the point where they enter Washington State for low (20th percentile; top graph in each panel), median (50th percentile; middle graph in each panel), and high (80th percentile; bottom graph in each panel) supply conditions. The spread of forecast (2035) flow conditions is due to the range of climate change scenarios considered.

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Columbia River Basin Agricultural Water Demand

Modeled Agricultural Demand across the Whole Basin

Agricultural demand is the largest out-of-stream water demand in the Columbia River Basin. Results from modeling projected changes in climate and in the planted crop mix by 2035 suggest that:

- "Top of crop" demand for agricultural irrigation water across the entire Columbia River Basin is estimated to decrease approximately 0.5 million ac-ft (4.9%) by 2035, relative to estimated demands for the historical period (1981-2011), during average (50th percentile) flow conditions[6] (Table 2).

Approximately 0.3 million ac-ft out of the 0.5 million ac-ft decrease is due to projected changes in climate and in crops' response to those changes (Table 2). The Basin is expected to be wetter by 2035, and the higher concentrations of carbon dioxide expected by 2035 would allow most crops to use water more efficiently (they can absorb the carbon dioxide more easily, thereby loosing less water in the process). The remaining 0.2 million ac-ft are attributable to how the crop mix is projected to change by 2035 (Table 2), where crops that use less water are expected to replace others with greater demand for water per acre.

These values of projected agricultural water demand provide an upper bound of "top of crop" water demand, assuming no change in the land base for irrigated agriculture. Ongoing modeling is exploring the effect of additional water storage capacity, that would allow additional arable land to be irrigated.

Table 2: Modeled agricultural water demands, excluding conveyance losses (known as "top of crop"), in the historical (1981-2011) and forecast (2035) periods. Two different future scenarios were explored, first only including climate change projections, and the second including both climate change projections and projections of future crop mix. Extent of agricultural acreage was kept constant in all cases. Estimates are presented for median years, with the range in parentheses representing low demand (20th percentile) and high demand (80th percentile) years. Note that these demands could be met with surface or groundwater.

	Historical (1981-2011)	2035 Forecast			
	Historical climate, historical crop (million ac-ft per year)	Future climate, historical crop mix		Future climate, future crop mix	
		(million ac-ft per year)	% Change	(million ac-ft per year)	% Change
Entire Columbia River Basin	10.1 (9.2-10.9)	9.8 (9.3-10.3)	**-2.97%**	9.6(9.1-10.1)	-4.90%
Washington Portion of the Columbia River Basin	4.2 (3.9-4.4)	4.0 (3.8-4.2)	**-4.76%**	3.9(3.7-4.0)	-7.10%

Columbia River Basin Hydropower Water Demand

Review of Projections by Power Planning Entities

The Northwest Power and Conservation Council[7] forecasts regional electricity demand will grow from 19,400 average megawatts in 2013 to somewhere between 20,600 to 23,600 average megawatts by 2035. In other words, regional demand is expected to increase by anywhere from 1,200 to 3,200 average megawatts over the 2013-2035 timeframe (Table 3), with the possibilities of these numbers reaching 2,200 to 4,800 average megawatts considering distribution and transmission system losses. This represents a relatively modest growth rate of 0.5 to 1.0% per year.

6 When discussing modeled supply and agricultural demand results, "average flow conditions" (as opposed to simply "average" values) refers to the 50th percentile (middle) value under the moderate climate change scenario (RCP 4.5).

7 (1) Northwest Power and Conservation Council, 2016a. Seventh Power Plan, February 25, 2016. *http://www.nwcouncil.org/energy/powerplan/7/plan/* and (2) Northwest Power and Conservation Council, 2016b. Demand Forecast, February 25, 2016. *http://www.nwcouncil.org/media/7149913/7thplanfinal_appdixe_dforecast.pdf*

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A preliminary effort was made to translate the increased regional demand for electricity into flows needed to generate said electricity using hydropower. Net power generation and water right data for Grand Coulee, Rocky Reach, Rock Island and Lake Chelan were averaged to develop an approximate power-to-water conversion factor of approximately 16 ac-ft/MW. Applying this conversion factor to the 2,200 to 4,800 MW that electricity demand is expected to grow by 2035 led to estimated increases in hydropower water demand of approximately 35,000 to 75,000 ac-ft (Table 5). Because this projection is based on existing dams as opposed to new projects, and because these average numbers do not account for peak power needs, actual demand may be higher. Alternatively, if this demand is met via conservation, efficiency improvements, or non-hydro sources, the demand projections could be lower.

Peak demand is perhaps more important than average demand. The regional peak demand for power, which typically occurs in winter, is forecast to grow from 30,000 to 31,000 megawatts in 2015 to 31,600 to 35,600 megawatts by 2035. Summer-peak demand is forecast to grow faster than winter peak, however[7].

In the Canadian portion of the Columbia River Basin, BC Hydro expects that demands may grow as much as 40% across British Columbia. Conservation and transmission improvements will be essential in meeting this anticipated new demand. Power entities in the Columbia River Basin feel that new storage reservoir projects may be needed to help meet growing future surface water supply demands, which will probably require off-channel storage due to concerns about fish passage. Several power entities also mentioned concerns about the potential for climate variability and possible renegotiation of the international Columbia River Treaty to disrupt or reduce hydropower generation capacity.

Columbia River Basin Water Demand for Fish

The Columbia River is home to multiple species of salmonids listed under the Endangered Species Act (ESA) (Figure 10). A comparison of the flow targets defined in the federal Biological Opinion (BiOp) for these species with the historical (1981-2011) and forecast (2035) surface water supplies at Bonneville Dam (Figure 10, inset panels) suggests that:

- From November through May, average forecast supplies are as likely to meet the BiOp targets in 2035 as they have been historically. It is important to note, however, that (a) climate change impacts on water temperatures and on fish directly may lead to changes in requirements not considered in this Forecast, and (b) these results are average across years, so do not detail changes in frequency of droughts, which could also impact fish.
- From June through October, when supplies across the entire Columbia River Basin are forecast to decrease by approximately 11%, ensuring flows are sufficient to meet the needs of fish are likely to become more challenging. As the BiOp flow targets depend on emergence of the different species, this Forecast was unable to compare flow targets to projected water supplies in detail for these months.

Table 3: Projected increase in energy demands from hydropower across the entire Columbia River Basin by 2035.

	Historical - 2013 (MW)	2035 Forecast (MW)	% Change
Entire Columbia River Basin	19,400	20,600 to 23,600	6.19 to 21.65%

Table 4: Historical (2015) and forecast (2035) municipal diversion demands for the Washington State portion of the Columbia River Basin

	Historical - 2015 (million ac-ft per year)	**2035 Forecast** (million ac-ft per year)	**% Change**
Washington Portion of the Columbia River Basin	433,418	513,141	18.39%

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Summary of Water Supply and Demand in Washington State

Projected Out-Of-Stream Demands in Washington

Historical (1981-2011) out-of-stream diversion demands within the Washington State portion of the Columbia River Basin for municipal and agricultural irrigation water (excluding irrigation conveyance losses) were estimated to be on average 4.6 million ac-ft (Tables 2 and 4). Forecasted water demand for combined agricultural irrigation and municipal uses in 2035, including both surface water and groundwater demands, were estimated to reach 4.4 million ac-ft by 2035 (Tables 2 and 4; see Box 7). These demand values do not include potential improvements due to water conservation measures, nor do they address areas of unmet water requirements suggested by other studies (Table 5), with the exception of the demand currently supplied by Odessa groundwater, which was assumed would need to be supplied by surface water in the future.

The projected changes in agricultural water demand by 2035 within Washington State are expected to be similar to those for the entire Columbia River Basin:

- "Top of crop" agricultural water demand within Washington State is estimated to decrease by approximately 272,100 (±29,200) ac-ft by 2035, relative to historical values (Tables 2 and 5). This decrease includes both ground and surface agricultural irrigation water demand, plus the additional water needed due to irrigation application inefficiencies. This estimate assumes no change in irrigated acreage, and no additional water supply development. Ongoing modeling is exploring the impact of further water supply development on agricultural demand.
- It is important to highlight that, though a decrease in overall agricultural demand is projected, 56,800 (±24,200) ac-ft of additional surface water will be needed annually by 2035, to replace demand currently being met by groundwater in the Odessa Subarea. This number does not change the overall agricultural demand, but does change the amount of future water surface supplies will need to fulfill.

As with the results for the entire Columbia River Basin, the overall decrease in agricultural water demand by 2035 is due to a combination of two factors: climate change—which leads to a 4.7% decrease in demand—and forecasted changes in crop mix, which further reduces the demand by 2.4% (Table 2). The climatically driven portion of this decrease is due to projected wetter overall climate by 2035, as well as most of the crops grown regionally being able to more efficiently use their water when atmospheric carbon dioxide concentrations are higher. The additional decrease attributable to changes in crop mix are due to the projected increase in acreage under crops with lower water demands.

The Forecast anticipates the following changes in water use or need, by the municipal sector:

- Per capita municipal water demands varied considerably throughout eastern Washington, with an average (including system losses) of approximately 242 gpcd[8]. These results are in line with a 2005 U.S. Geological Survey study of domestic water use, which estimated 285 gpcd[9]. These per capita values add up to 80,000 ac-ft in additional total diversion demands for municipal and domestic water annually by 2035 (Table 4), which represents an 18% increase over 2015. This increase in municipal and domestic demand is due to a 17% increase in population expected between 2015 and 2035. Although some new municipal demands will likely be met by deep groundwater supplies, others will likely come from shallow groundwater or surface water.
- Total municipal consumptive demands for eastern Washington were estimated to be 210,000 ac-ft per year in 2035, compared to 177,000 ac-ft per year in 2015. This represents approximately 41% of the total municipal diversion quantity.

It is important to note that these estimates do not address seasonality in municipal use. Municipal use increases in the drier summer months (for example, due to lawn irrigation within city limits). This is one limitation of these estimates.

Impacts of Modeled Changes in Supply and Demand on Meeting Instream Flows across Eastern Washington

Forecast changes in surface water supply timing and the shift in peak season for demands within and outside of Washington by 2035 are likely to increase the challenge of meeting instream demands. Lower flows, particularly in the

8 gpcd stands for gallons per capita daily

9 Lane 2009, op. cit.

summer and early fall, could negatively impact threatened and endangered fish, as well as other fish important to the culture and economy of eastern Washington.

The possibility for re-negotiation of the international Columbia River Treaty and unquantified tribal water rights could change the amounts and timing of water available to meet instream needs in the Columbia River mainstem within Washington State (and beyond). These factors have the potential to impact future water supplies in ways that are difficult to predict, and thus were not feasible to capture in this analysis.

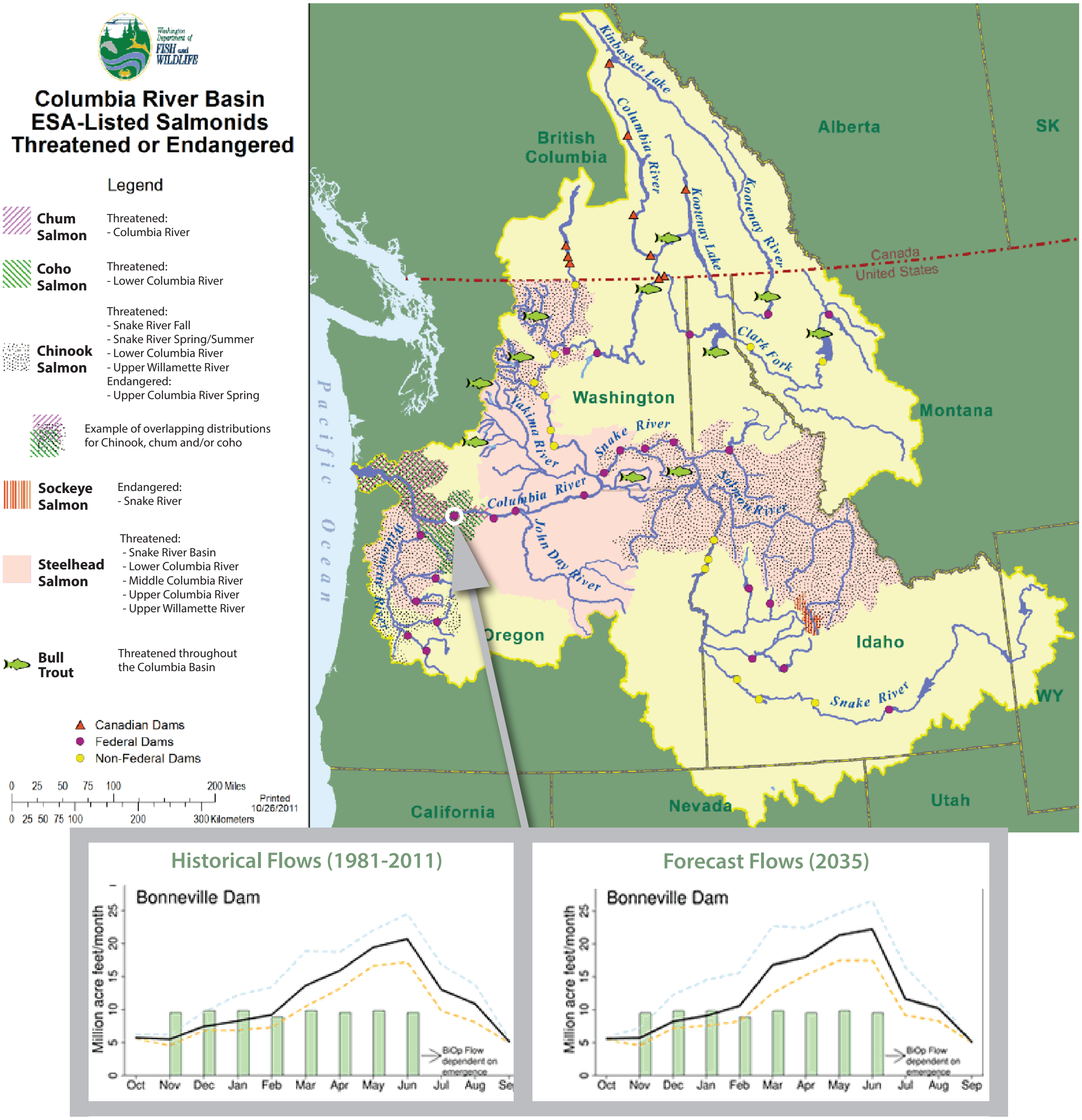

Figure 10. Distribution of fish listed under the Endangered Species Act in the Columbia River Basin. Inset panels show historical (1981-2011; left panel) and forecast (2035; right panel) surface water supplies at Bonneville Dam for low (20th percentile), median (50th percentile), and high (80th percentile) supply conditions. Also shown are the federal Biological Opinion (BiOp) flow targets (bars in both inset panels).

Table 5: Forecast changes in demands in eastern Washington, by sector.

Water Use or Need	Estimated Volume (acre-feet)	Source
Projected changes in Agricultural Demand by 2035[a]	-301,300 to -242,200	WSU Integrated Model
Projected changes in Municipal and Domestic Demand (including municipally-supplied commercial) by 2035	80,000	Municipal Demand Projections
Projected changes in Hydropower Demand by 2035[b]	35,000 to 75,000	Review of Projections by Power Planning Entities
Water Use or Need to be Met with Surface Supplies		
Unmet Columbia River Instream Flows[c]	13,400,000	Ecology data, McNary Dam, 2001 drought year
Unmet Tributary Instream Flows[d]	659,918	Ecology data, tributaries with adopted instream flows, generally for the 2001 drought year
Unmet Columbia River Interruptibles	40,000 to 310,000	Ecology Water Right Database (depending on drought year conditions)
Yakima Basin Water Supply (pro-ratables, municipal/domestic and fish)[e]	450,000	Yakima Integrated Water Resource Management Plan (April 2011)
Alternate Supply for Odessa[f]	155,000	Odessa Draft Environmental Impact Statement (October 2010), adjusted based on consultations with the East Columbia Basin Irrigation District
Declining Groundwater Supplies (other than in the Odessa Subarea)[g]	750,000	*See Integrating Declining Groundwater Areas into Supply and Demand Forecasting* posters

a Additional agricultural demands were modeled assuming the land base for irrigated agriculture remains constant, and climate change is moderate (RCP 4.5 scenario). Projected changes in irrigation demand were estimated as a decrease of 272,100 ac-ft, with a confidence interval of ±29,200 ac-ft. The confidence interval reflects that, though we cannot be sure the projected change is exactly-272,100 ac-ft, we are 90% certain that the value will lie between-301,300 (-272,100 minus 29,200) and-242,200 (-292,100 plus 29,200). These decreases in demand were due to the combined impacts of climate change (wetter in the early growing season) and crop mix (projected shift to crops that use less water).

b Hydropower projections are based on an average need of 2,200 to 4,800 MW by 2035. This demand is historically expressed as a nonconsumptive water use. Net power generation and water right data for Grand Coulee, Rocky Reach, Rock Island and Lake Chelan were averaged to develop an approximate power-to-water conversion factor of approximately 16 ac-ft/MW. Because this projection is based on existing dams as opposed to new projects, and because these average numbers do not account for peak power needs, actual demand may be higher. Alternatively, if this demand is met via conservation, efficiency improvements, or non-hydro sources, the demand projections could be lower.

c Unmet Columbia River instream flows are the calculated deficit between instream flows specified in Washington Administrative Code (WAC) and actual flows at McNary Dam in 2001 under drought conditions. 2001 is the only year when Columbia River flows were not met and interruptible water users were curtailed.

d Unmet tributary instream flows are the combined deficits between current instream flows specified in WAC and actual flows for the driest year on record at the following locations: Walla Walla River at East Detour Road, Wenatchee River at Monitor, Entiat River near Entiat, Methow River near Pateros, Okanogan River at Malott, Little Spokane River at Dartford, Spokane River at Spokane, Colville River at Kettle Falls. All deficits are for drought year 2001, with the exception of the Little Spokane and Colville Rivers, where the greatest unmet flows were in 1992, and the Walla Walla River, where data collection started in 2007. Data on the 2015 drought year are being evaluated, to determine whether 2015 should be used to adjust this estimate for the final report.

e Multiple water projects planned in the Yakima River Basin, as part of the Yakima Integrated Water Resource Management Plan, are expected to lead to decreases in the estimated volume needed by the 2021 Forecast. Examples include: Yakima Aquifer Storage and Recovery (ASR), Cle Elum Reservoir, and the Kachess Drought Relief Pumping Plant.

f Reports of Examination state that 164,000 ac-ft are needed to serve 70,000 acres. The East Columbia Basin Irrigation District is currently serving 3,000 acres of groudwater replacement via the Columbia Basin Project. Assuming these acres are served with an average 3 ac-ft/ac, the volume still needed was estimated. Two additional sources are expected to contribute to this alternate supply, the Odessa Subarea Special Study and the Lake Roosevelt Incremental Storage Releases Program. As the contributions of these two additional sources were not quantified at the time of this report, the volume estimated here should be considered a conservative estimate.

g This estimated need was calculated on the following basis: approximately 230,000 acres of irrigated under water rights within areas affected by unreliable and/or declining groundwater supplies, an assumed average irrigation rate of 3 ac-ft/ac, and an approximate affected population of 200,000 with an average use of 200 gpcd. This estimate does not include the Odessa Subarea. Significant uncertainty exists in this estimate related to the geographic extent of the affected areas and other factors.

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Hydropower Demand in Washington

The approach taken to estimate increases in water needed to provide the additional electricity that planning agencies project will be needed via new hydropower has limitations, and is a very coarse first effort at estimating this value. Neither the data nor the range of factors that control the relationship between flows and energy produced are well captured in this first estimate. Trying to allocate some portion of the estimated additional 35,000-75,000 ac-ft needed to meet increases in hydropower demand by 2035 (Table 5) to Washington State or finer scales would simply provide a false sense of accuracy. Researchers therefore focused this estimate solely for the whole Columbia River Basin.

Summary of Water Demands in Washington State, Estimated in the 2011 and 2016 Forecasts

The estimated changes in demand for different sectors obtained in this 2016 Forecast are somewhat different to those estimated in the 2011 Forecast (Table 6). The most notable change is in the decreased agricultural water demand. There are multiple reasons why demand may change from one effort to the next (Box 7), including:

BOX 7

Water Demand – What it is and why it might change

What Is demand for water? Demand for water in this 2016 Forecast represents water needed for use by humans, crops, fish, and for hydropower generation.

How is demand characterized? Demand consists of uses that are met by current reliable water supplies, uses that are at risk to changing reliability of supplies (e.g. due to declining groundwater or to climate change), and uses that are unmet (e.g. no supply currently available, or supplies that will not be available in the future either temporarily during drought, or as a result of depletion).

What Affects Demand Numbers? Demand for different uses is affected by many factors. Agricultural water demand, for example, is affected by how warm it is and how much it rains, what crops are grown, whether it is an average or a drought year, the available acreage that can be developed, and the price of irrigation water (which is highly variable throughout Washington). The effects of many of these factors were explored in the 2016 Forecast through calculating agricultural water demand for several different scenarios. For example, historical agricultural water demand represents water needs of existing irrigated cropland, under the existing crop mix, and under the climate of the beginning of the 21st century. Projected agricultural water demand represents water needs of existing cropland under a projected crop mix and under projected climate for 2035. An additional scenario looking at expanded cropland served by future water storage projects is also being explored.

What does it mean when forecasted agricultural (met) demand changes as the Forecast is updated? Crop water demand may increase or decrease on existing irrigated acreage due to changes in cropping patterns or climate change. Projected crop water use may also change as modeling efforts more accurately predict demand relative to previous forecasts.

What are unmet crop water demands? Unmet crop water demand (also called unmet irrigation requirements) occur when there is not enough water supply to meet all crops' irrigation needs on existing or potentially irrigated acres. The difference between the agricultural water needed for crops planted in a typical year to achieve optimal yield, and the water supply available for agricultural irrigation is the unmet requirement. Unmet demand also includes demand for water on cropland that could support irrigated production but is currently not under irrigation.

What does it mean when forecasted unmet crop water demands go down? Crop water demands may go down if additional water supplies allow for additional irrigated acres, or if they increase the reliability of water for existing uses (e.g. reduce the risk of curtailment to junior water rights). Such additional water supplies are being explored through additional modeling scenarios.

What does it mean when projected unmet crop water demands go up? Again, this may be due to more accurate modeling, or if projected uses outpace water supply development, or if previously reliable supplies are now projected to be at risk

- Changes in climate change projections. The data used to characterize the climate in 2035 (CMIP5 climate change projections) are newer and more appropriate for this region, compared to those used in the 2011 Forecast (CMIP3 climate change projections). The CMIP5 projections estimate the region will be wetter than previously estimated using CMIP3 projections , which helps explain why crops may need less irrigation.
- Improved crop data, especially for irrigated pasture. In 2011, the WSDA data used to determine crop mix and extent did not provide accurate information on irrigated pasture extent, a crop that has a high demand for water. By 2016, the WSDA's characterization of irrigated pasture in their dataset is much improved, allowing a more accurate—and much lower—estimate of irrigated pasture, also contributing to explain the reduction in irrigation demand.

Another notable change was the increase in the estimate of unmet tributaries instream flows, from 500,000 in the 2011 Forecast to almost 660,000 in this 2016 Forecast (Table 6). The main reason for the increase in unmet tributary instream flows between the 2011 and 2016 estimates is the addition of a new watershed. The Spokane River adopted instream flows between these two estimates, explaining the increase in unmet flows.

Table 6: Changes in demand projected for 2030 in eastern Washington in the 2011 Forecast, compared to changes in demand projected for 2035 in this 2016 Forecast. For details on each value, see the 2011 Forecast (Ecology Publication 11-12-011) and the Water Supply and Demand Forecast for the Columbia Basin section of this report. Please see the caption and footnotes in Table 5 (2016 Forecast) and Table 7 (2011 Forecast; Ecology Publication 11-12-011) for details on how each value was estimated.

Water Use or Need	2011 Forecast Estimated Volume (acre-feet)	2016 Forecast Estimated Volume (acre-feet)
Projected changes in Irrigation Demand[a]	170,000	-301,300 to -242,200
Projected changes in Municipal and Domestic Demand (including municipally-supplied commercial)	117,500	80,000
Projected changes in Hydropower Demand[b]	0	35,000 to 75,000
Water Use or Need to be Met wtih Surface Supplies		
Unmet Columbia River Instream Flows	13,400,000	13,400,000
Unmet Tributary Instream Flows[c]	500,000	659,918
Unmet Columbia River Interruptibles	40,000 to 310,000	40,000 to 310,000
Yakima Basin Water Supply (pro-ratables, municipal/domestic and fish)	450,000	450,000
Alternate Supply for Odessa	164,000	155,000
Declining Groundwater Supplies (other than in the Odessa Subarea)[d]	**N/A**	**750,000**

a As described in this report, the overall decrease in agricultural water demand by 2035 is due to a combination of two factors: climate change and forecasted changes in crop mix. The climatically driven portion of this decrease is due to projected wetter overall climate by 2035, as well as most of the crops grown regionally being able to more efficiently use their water when atmospheric carbon dioxide concentrations are higher. The additional decrease attributable to changes in crop mix are due to the projected increase in acreage under crops with lower water demands.

b Estimates of hydropower demand are based on a very coarse conversion of energy projections to ac-ft of water needed to produce it. In addition, this value is for the entire Columbia River Basin. Due to the coarse nature of the estimate, allocating some portion of this volume to Washington State could not be achieved at this time.

c The main reason for the increase in unmet tributart instream flows between the 2011 and 2016 estimates is the addition of a new watershed. The Spokane River adopted instream flows between these two estimates, explaining the increase in unmet flows.

d The evaluation of areas experiencing groundwater decline was not part of the 2011 Forecast.

Water Supply and Demand Forecast for Washington's Watersheds

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Within Washington State numerous management decisions are made at the scale of individual watersheds (Figure 11). As much of eastern Washington's water demands come from areas that cannot be hydrated by the Columbia River, the analysis of water supplies at the watershed level focused on those supplies generated within the watershed, excluding (a) supplies from upstream areas that are outside Washington, and (b) supplies from the mainstem Columbia and Snake Rivers (for insights on the contributions of these two exclusions see Water Supply and Demand Forecast for the Columbia River Basin and for Washington's Columbia River Mainstem, respectively). In addition, municipal demand and instream flow (ISF) requirements (for those watersheds that have adopted ISFs) were estimated and forecast in detail for Washington's watersheds.

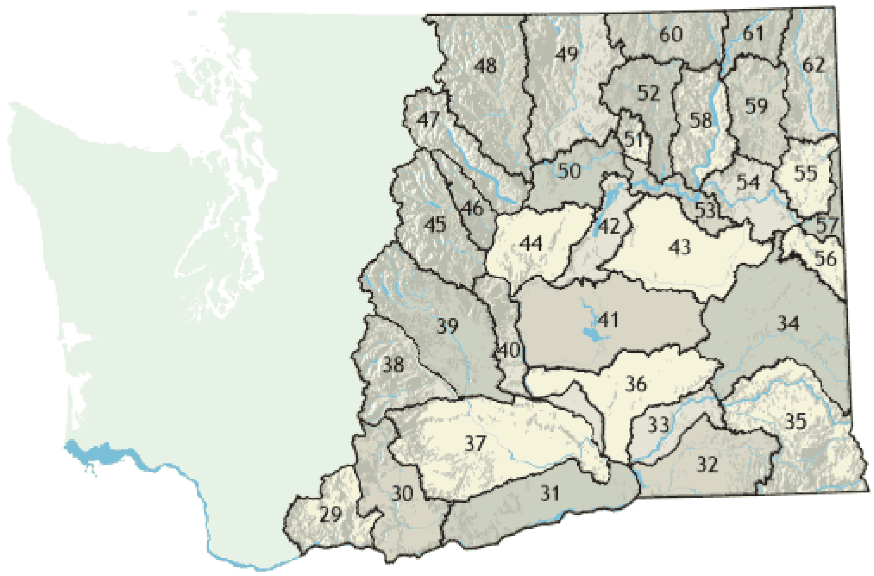

Figure 11: Water Resource Inventory Areas (WRIAs) in eastern Washington

Washington Watersheds' Surface Water Supplies

Major tributary areas make sizeable water supply contributions to the Columbia River as it makes its way from the Canadian border to Bonneville Dam (Figure 12). Annual surface water supplies generated within the Washington portion these watersheds are expected to increase by approximately 22.2% (±3.5%) by 2035, on average. This includes increases in water supplies expected in the Walla Walla (16.9±3.0%), Palouse (41.5±4.0%), Colville (28.2±5.0%), Yakima (12.8±3.6%), Wenatchee (11.8±2.0%), Chelan (9.5±2.0%), Methow (50.7±2.7%), Spokane (7.1±2.7%), and Okanogan (21.3±6.9%) watersheds (Figure 12). While most of these rivers show primarily increases in supply regardless of the climate scenario used, three rivers showed mixed results, ranging from increasing to decreasing supplies as the climate scenarios varied: the Colville, Chelan, and Okanagan watersheds.

At the watershed scale, shifts in timing of water supply towards the winter and spring months by 2035 are similar to those observed for the entire Columbia River Basin. The details vary by watershed; however, the rivers experiencing the greatest shift in timing of supply are those for which streamflow was predominantly derived from snowmelt during the historical period, such as the Methow River (see *Washington Watersheds' Supply and Demand – Detailed Results,* below).

Washington Watersheds' Water Demands

Washington Watersheds' Out-of-Stream Water Demands

Forecasted water demand for combined agricultural irrigation and municipal uses in 2035, including both surface water and groundwater demands, was concentrated within the southern and central Columbia Basin, including Lower Yakima (37), Lower Crab (41), and Esquatzel Coulee (36), as well as Rock-Glade (WRIA 31), Walla Walla (32), and Upper Yakima (39) (Figure 13).

The change in agricultural water demand between historical (1981-2011) and forecast (2035) periods varied geographically and in magnitude. Individual WRIAs are projected to see changes that range from a 79,727 ac-ft decrease, on average, in the Lower Yakima (37) to a 37,095 ac-ft increase, on average, in the Upper Crab-Wilson (43) watershed (Table 7).

With the exception of the Upper Crab-Wilson (43) watershed, all WRIAs are projected to have increased municipal water demands by 2035, both in the estimated water diverted for municipal use, and in the amount of that water that is consumptively used. Maximum increases at the WRIA level were projected for Esquatzel Coulee (36), reaching 20,325 ac-ft and 8,127 ac-ft more by 2035, for diversions and consumptive use, respectively (Table 8).

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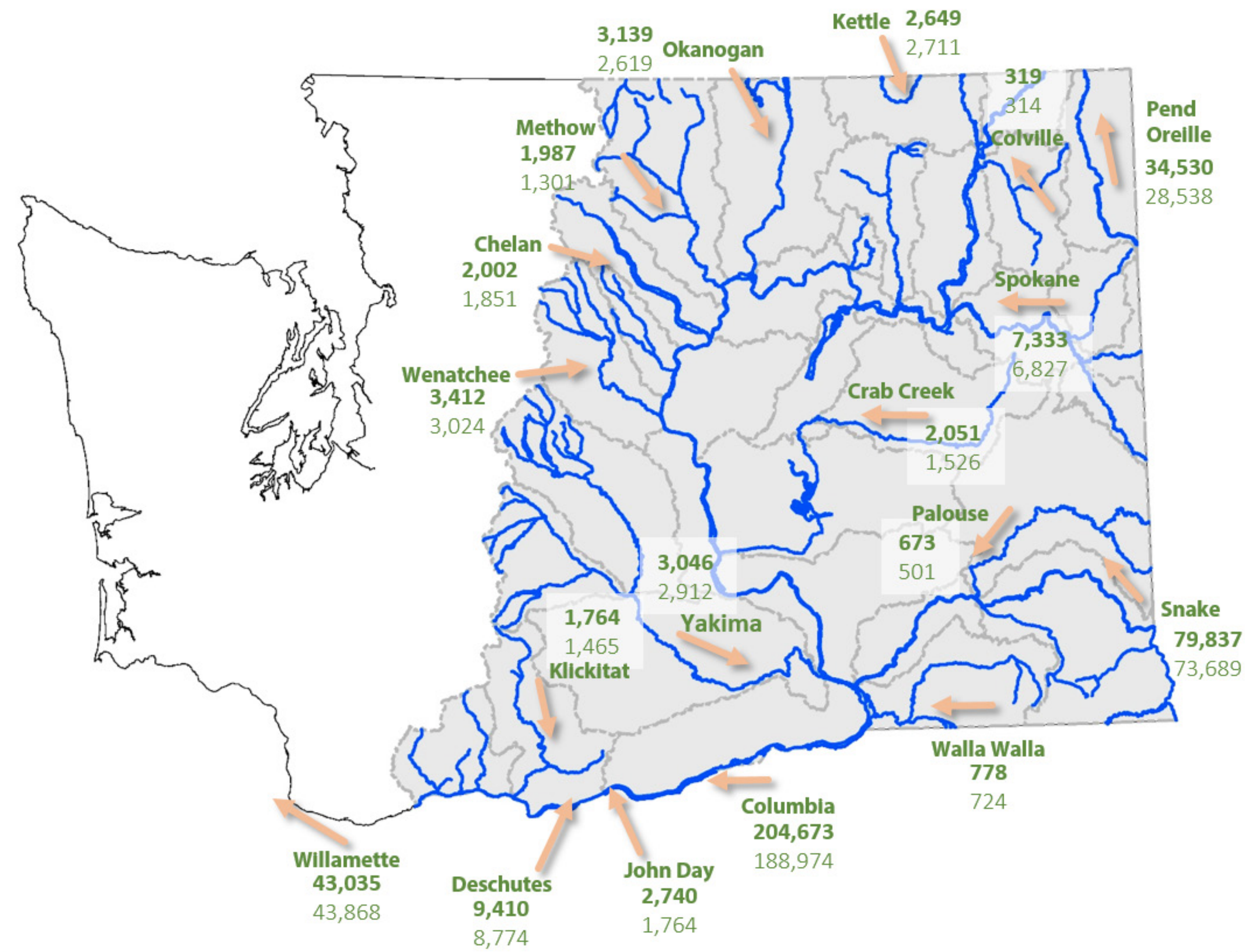

Figure 12: Water supplies (prior to accounting for demands) from tributaries to the mainstem Columbia River, including all areas of tributary basins that extend outside of Washington State. Top number (in bold) refers to forecast (2035) surface water supplies for median (50th percentile) supply conditions. Bottom number (in italics) refers to the historical (1981-2011) water supplies. All values are in cubic feet per second, and represent annual median values (50th precentile).

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Table 7: Modeled agricultural water demands, excluding conveyance losses (known as "top of crop") for each Washington Water Resource Inventory Area (WRIA) in eastern Washington. Estimates for each WRIA include the demand during average historical (1981-2011) and forecast (2035) periods, as well as the proportion of said demand occurring within one mile of the Columbia River mainstem.

WRIA	WRIA Name	Total modeled WRIA-level irrigation demand		Modeled WRIA-level irrigation demand within one mile of the Columbia River mainstem			
		ac-ft/year		ac-ft/year		As a percentage of WRIA-level demand	
		Hist	2035	Hist	2035	Hist	2035
29	Wind-White Salmon	5,677	4,210	0	0	0%	0%
30	Klickitat	14,341	9,465	0	0	0%	0%
31	Rock-Glade	240,161	227,827	50,159	47,557	21%	21%
32	Walla Walla	109,900	119,346	5,647	5,303	5%	4%
33	Lower Snake	95,270	87,202	0	0	0%	0%
34	Palouse	12,888	18,348	0	0	0%	0%
35	Middle Snake	1,051	1,039	0	0	0%	0%
36	Esquatzel Coulee	611,744	619,864	113,296	106,134	19%	17%
37	Lower Yakima	825,822	746,095	2,340	2,193	0%	0%
38	Naches	43,107	38,026	0	0	0%	0%
39	Upper Yakima	193,317	189,039	0	0	0%	0%
40	Alkali-Squilchuck	15,405	13,908	14,740	13,389	96%	96%
41	Lower Crab	960,381	993,822	44,816	43,677	5%	4%
42	Grand Coulee	46,512	47,902	0	0	0%	0%
43	Upper Crab-Wilson	13,529	50,624	0	0	0%	0%
44	Moses Coulee	19,004	16,801	14,570	12,495	77%	74%
45	Wenatchee	15,065	12,790	1,161	920	8%	7%
46	Entiat	1,252	1,247	486	557	39%	45%
47	Chelan	13,370	11,308	5,643	5,161	42%	46%
48	Methow	6,763	6,124	2,068	1,741	31%	28%
49	Okanogan	58,290	49,694	8,220	7,070	14%	14%
50	Foster	15,903	13,307	15,658	13,074	98%	98%
51	Nespelem	0	0	0	0	0%	0%
52	Sanpoil	131	119	0	0	0%	0%
53	Lower Lake Roosevelt	1,692	1,522	1,120	949	66%	62%
54	Lower Spokane	6,029	5,679	0	0	0%	0%
55	Little Spokane	2,112	2,136	0	0	0%	0%
56	Hangman	273	264	0	0	0%	0%
57	Middle Spokane	1,094	1,229	0	0	0%	0%
58	Middle Lake Roosevelt	1,332	1,320	745	681	56%	52%
59	Colville	7,430	8,485	0	0	0%	0%
60	Kettle	1,813	1,675	0	0	0%	0%
61	Upper Lake Roosevelt	261	233	151	151	58%	65%
62	Pend Oreille	116	145	0	0	0%	0%
	TOTAL	**3,341,034**	**3,300,798**	**280,819**	**263,089**	**8%**	**8%**

Table 8: Estimated municipal water demands for each Washington Water Resource Inventory Area (WRIA) in eastern Washington. Estimates for each WRIA include the demand in the historical (2015) and forecast (2035) periods, for the Washington State portion of the Columbia River Basin. These values reflect water diversions, which include consumptive and non-consumptive water use.

WRIA	WRIA Name	2015 Population Estimate	2035 Population Estimate	Population Increase 2015-2035	Change in Diversion 2015-2035	Change in Consumptive Use 2015-2035
				%	(ac-ft/year)	(ac-ft/year)
29	Wind-White Salmon	15,294	17,384	14	480	278
30	Klickitat	11,456	11,668	2	55	31
31	Rock-Glade	83,196	94,540	14	2,723	911
32	Walla Walla	62,113	67,968	9	1,580	387
33	Lower Snake	3,463	3,761	9	88	23
34	Palouse	53,860	66,567	24	2,529	924
35	Middle Snake	25,232	26,668	6	365	119
36	Esquatzel Coulee	107,913	165,229	53	20,325	8,127
37	Lower Yakima	299,350	350,944	17	10,390	4,668
38	Naches	15,627	16,976	9	252	127
39	Upper Yakima	61,687	68,077	10	1,672	820
40	Alkali-Squilchuck	26,930	27,917	4	227	70
41	Lower Crab	80,563	108,726	35	11,810	7,132
42	Grand Coulee	10,403	11,908	14	606	356
43	Upper Crab-Wilson	7,199	7,151	-1	-17	-9
44	Moses Coulee	35,181	38,997	11	600	188
45	Wenatchee	57,125	63,197	11	1,116	193
46	Entiat	2,327	2,476	6	27	5
47	Chelan	11,281	13,511	20	417	83
48	Methow	6,968	8,267	19	365	243
49	Okanogan	30,461	32,101	5	476	331
50	Foster	4,731	5,708	21	161	57
51	Nespelem	1,301	1,341	3	11	8
52	Sanpoil	3,150	3,642	16	121	103
53	Lower Lake Roosevelt	5,118	5,711	12	199	127
54	Lower Spokane	101,217	115,141	14	4,501	1,696
55	Little Spokane	115,235	135,681	18	6,554	2,247
56	Hangman	60,859	76,658	26	5,061	1,639
57	Middle Spokane	223,066	241,763	8	6,029	1,952
58	Middle Lake Roosevelt	3,735	4,046	8	89	72
59	Colville	24,573	26,133	6	505	382
60	Kettle	4,426	4,803	9	95	81
61	Upper Lake Roosevelt	3,916	4,241	8	105	79
62	Pend Oreille	7,889	8,615	9	205	91
	TOTAL	**1,566,845**	**1,837,515**	**17.3%**	**79,723**	**33,543**

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Washington Watersheds' Instream Water Demands for Fish

The CRIA Project led by WDFW scored each reach in 12 WRIAs (Figure 1) based on fish stock status, fish habitat utilization, and instream flow. Combined scores and ranks varied across stream reaches (in preparation; see future Ecology Publication). Interpretation of these variations led WDFW to conclude that flow augmentation is generally helpful in salmonid restoration efforts, especially in smaller systems that have limited flow, in over-appropriated basins, or in combination with other recovery measures. Opportunity to improve salmonid production exists by pursuing water acquisition in smaller, lower elevation streams with good to excellent habitat. In addition, streams with good or better habitat in higher elevations or less populous areas are likely to benefit from flow augmentation (orange in Table 9). Most anadromous stocks migrate through the low elevation mainstem reaches that benefit from the cumulative effects of upstream flow augmentation. However, these mainstem reaches are generally not targets for augmentation because large flow inputs would be needed for a measurable effect in these relatively high flow reaches.

The drought conditions during 2015 provided WDFW biologists with substantial insight on the effects of low flow conditions on fish stocks in the area under evaluation by the CRIA Project. Drought conditions result in critically low flow conditions in many streams, including small streams with water over-allocation, but also larger streams with moderate to low water diversions. A greater range of stream types would benefit from flow augmentation under such drought conditions (red in Table 9).

The OCR's database of historical flow information provides site-specific information on historical flow levels, drought occurrences and how often instream flow rules are or are not met for tributaries to the Columbia River in Washington. Summaries of this information are provided in the Management Context table for each eastern Washington WRIA (see the *Forecast Results for Individual WRIAs* section).

Banks Lake Reservoir below Grand Coulee Dam

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Table 9: Conditions under which flow augmentation could provide benefits to stream reaches where anadromous fish populations exist and physical habitat conditions are good or better. Certain stream types would benefit from flow augmentation in normal precipitation years (orange), while others would benefit particularly under drought conditions (red).

Flow Conditions and Stream Types	**Flow Appropriation/Instream Restrictions**		
Elevation/ Stream Size	Low	Medium	High
Low/Larger Streams			
Medium/ Medium			
High/ Small Stream			

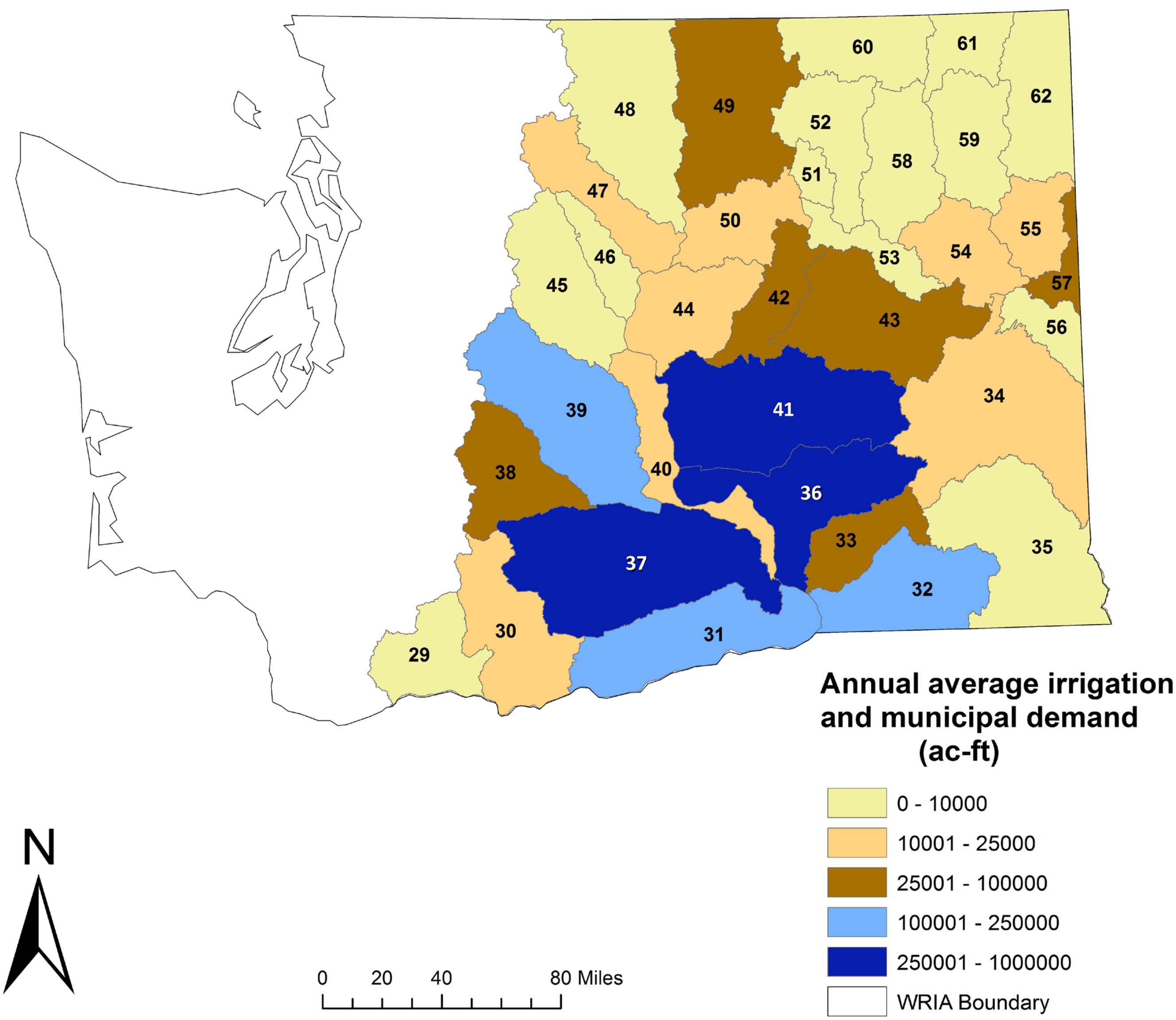

Figure 13: Total forecast (2035) median (50th percentile) annual surface (excluding conveyance losses) and groundwater demands for agricultural and municipal uses (including self-supplied domestic use) by WRIA. All values are in ac-ft per year.

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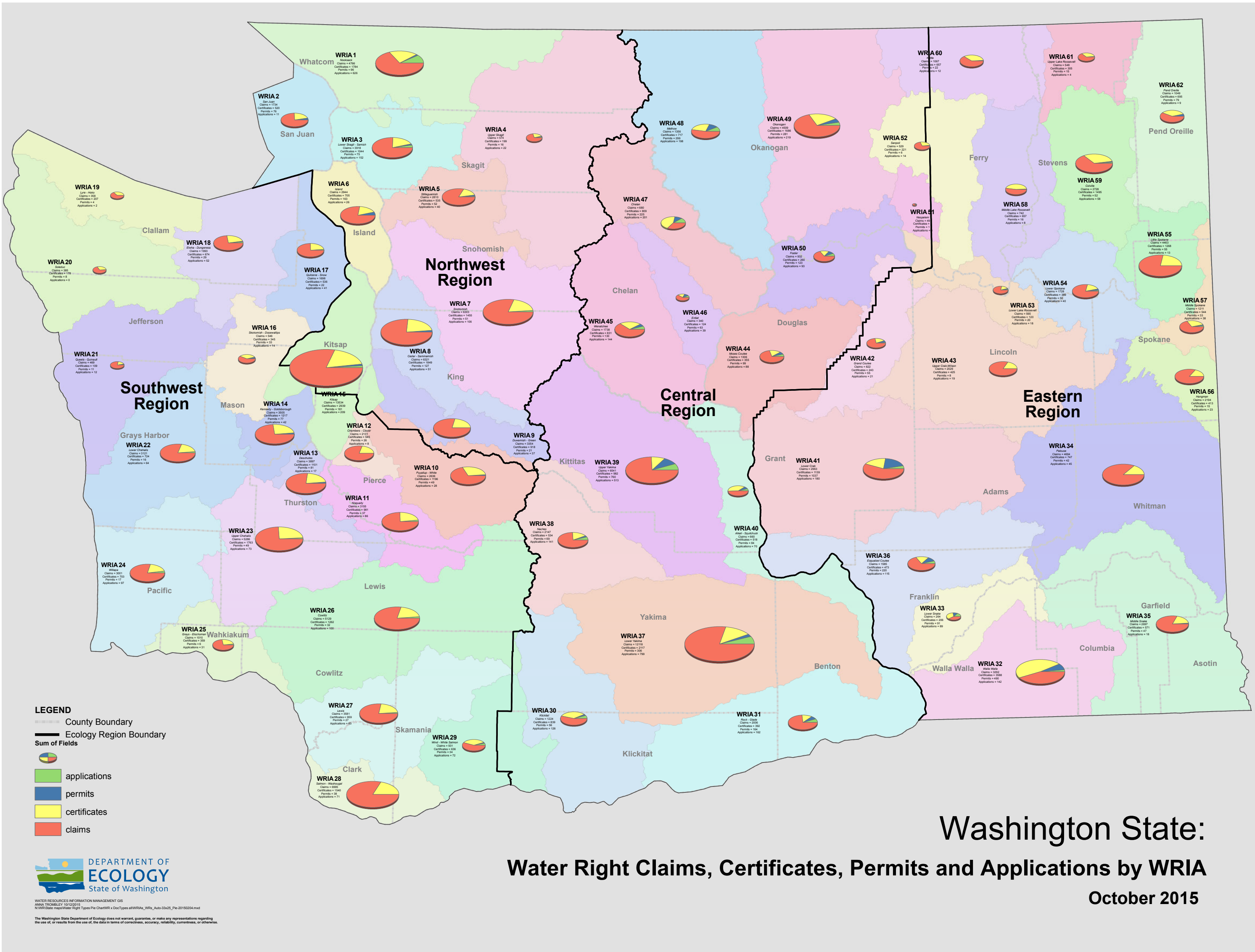

Figure 14. Water right claims, certificates, permits and applications in Washington Department of Ecology's Water Rights Tracking System (WRTS), by WRIA. The WRTS data do not include tribal or federal quantified or unquantified water rights. The size of the pie chart in each WRIA reflects the total number of water right documents in that WRIA.

Washington Watersheds' Unmet Crop Water Demands

Ongoing modeling is exploring the impact of curtailment of interruptible and pro-ratable water rights on unmet agricultural demand at the watershed scale.

Washington Watersheds' Supply and Demand – Detailed Results

Water supply and demand—and changes in supply and demand forecasted for 2035—vary in magnitude and in some cases direction of change, from WRIA to WRIA. Similarly, the water right claims, certificates, permits and applications vary by WRIA (Figure 14). Detailed results for individual WRIAs, including modeled historical and forecast water supply, and modeled historical and forecast water demand by sector, are provided in the Forecast Results for Individual WRIAs section. Additional information on the management context—the watershed's water management, water allocation, and (for fish-critical WRIAs) fish populations—is also provided. This section also includes guidance on how to read and interpret these WRIA-specific results (see the How to Read the WRIA's Results guide on page 40).

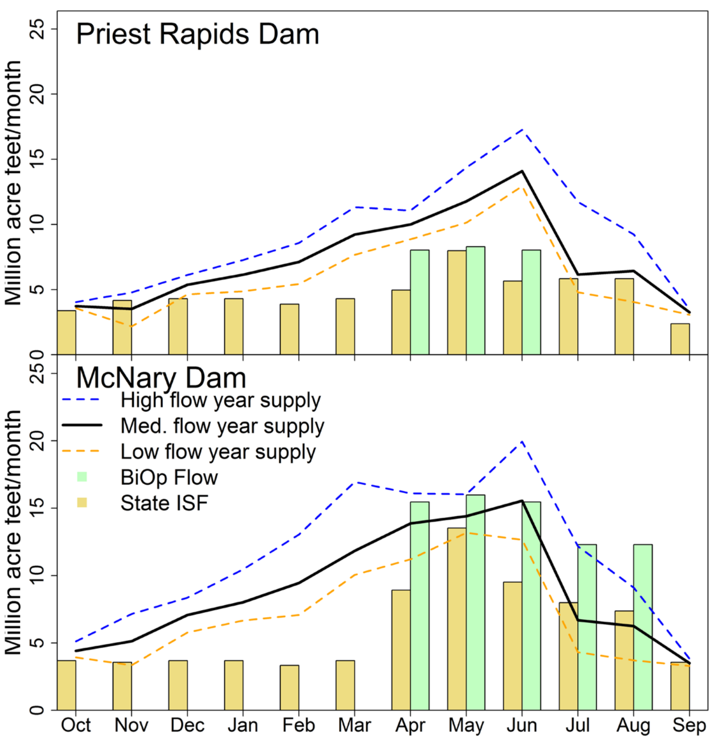

Figure 15. Historical (1981-2011) regulated surface water supply at McNary and Priest Rapids dams for low (20th percentile), median (50th percentile), and high (80th percentile) supply conditions. Also shown are the Washington State instream flow (ISF) and federal Biological Opinion (BiOp) flow targets (bars).

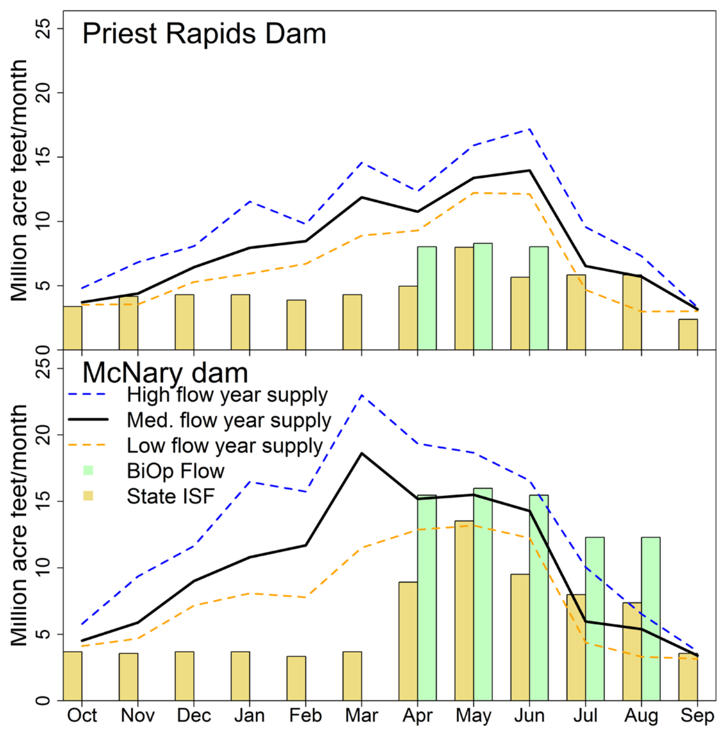

Figure 16. Forecast (2035) regulated surface water supply at McNary and Priest Rapids dams for low (20th percentile), median (50th percentile), and high (80th percentile) supply conditions. Also shown are the Washington State instream flow (ISF) and federal Biological Opinion (BiOp) flow targets (bars).

Water Supply and Demand
Forecast for Washington's Columbia River Mainstem

Flows on the Columbia River mainstem are a reflection of water supplies and demands in upstream areas of the Basin, including areas outside of Washington and tributary areas within Washington. Mainstem water supplies provide instream flows for migrating salmonids and other fish species, hydroelectricity as part of the federal Columbia River Power System, and water to those in proximity to the river.


Columbia River near Chelan, WA

Comparison of Modeled Surface Water Supplies and Regulatory and Management Schemes

Regulation of mainstem water users is not triggered unless the total water supply forecasted on March 1 at The Dalles is less than 60 million ac-ft. On a month-to-month basis, modeled historical and forecasted (regulated) surface water supplies prior to meeting demands under average flow conditions were considered sufficient to meet Washington State instream flow targets (WA ISF) in most months at most points along the mainstem (Figures 15 and 16). However:

- Under median flow conditions forecast for 2035, modeled November and August water supplies at Priest Rapids Dam would not meet WA ISF targets.
- Under low flow conditions, both historically (1981-2011) and in the future (2035), modeled July and August surface water supplies would fail to meet WA ISF targets at Priest Rapids and McNary.

Water supplies prior to meeting demands were considered insufficient to meet BiOp flow targets in more months, in both the historical (1981-2011) and forecast (2035) conditions (Figures 15 and 16, also Figure 9):

- Under average flow conditions, modeled historical and forecasted water supplies were below BiOp flow targets from April to August at McNary Dam.
- Under average flow conditions, both modeled historical and forecasted water supplies were below BiOp flow targets at Bonneville in November. Imbalances were generally smaller in the future (2035) than the historical case for the summer months.
- Under dry flow conditions at Bonneville, the period during which modeled water supplies were insufficient to meet BiOp flow targets historically extended through February, but is expected to end in January under the forecasted (2035) conditions.
- Under dry flow conditions, there are even more months when modeled surface water supplies failed to meet BiOp flow targets: water supplies were below BiOp flow targets at McNary Dam in May and from July through September.

These two regulatory schemes are important because of their role in regulating interruptible water rights holders and managing federal dams and the Quad Cities water permit.

Proportion of WRIA-Level Demand along the Columbia River Mainstem

The Columbia River provides an important source of water supply to meet agricultural water demand for many WRIA water users within close proximity to the river. To give a sense of what portion of WRIA-level surface water "top of the crop" irrigation demand (excluding conveyance losses) was close enough to the Columbia River mainstem to possibly be supplied by the mainstem, a one-mile corridor on each side of the Columbia River was defined, based on OCR's guidance.

- Both historically and in the future (2035), more than half of the surface water agricultural demand was within one mile of the Columbia River mainstem for five WRIAs: Alkali-Squilchuck (WRIA 40), Moses Coulee (44), Foster (50), Lower Lake Roosevelt (53), and Upper Lake Roosevelt (61) (Table 7).
- Three additional WRIAs— Rock Glade (31), Esquatzel Coulee (36), and Lower Crab (41)—each have more than 40,000 ac-ft per year of surface water agricultural demand within one mile of the Columbia River mainstem, although this does not represent a large proportion of their irrigation demand, as there are large numbers of irrigated acres in all of these WRIAs.
- The percent of a WRIA's agricultural water demand provided by the mainstem in no case changed by more than 7 percentage points (increase or decrease) from historical to future.

It is possible that demands outside this corridor could be met by Columbia River supplies under some circumstances; however, evaluating all possible supply options was beyond the scope of the Forecast, and existing water rights data do not provide sufficient accuracy to confidently estimate what proportion of this amount is already being met by Columbia River mainstem supplies, or whether it is feasible to serve specific areas with water diverted from the Columbia River.

Curtailment along the Columbia River Mainstem

As described in the Washington Watersheds' Unmet Crop Water Demands section above, ongoing modeling is exploring the impact of curtailment of interruptible and pro-ratable water rights on unmet agricultural demand along the Columbia River mainstem from the Canadian border to Bonneville Dam.

Conclusion

The results of the 2016 Forecast suggest that overall seasonal shifts in timing of water supply and demand will be a dominant issue, and will likely require area-specific management and adaptation strategies in the future. However, irrigation demand was forecast to decrease on average, due to wetter springs and a shifting of the growing season into the spring, when rain is projected to be more plentiful. Under warming temperatures, some crops will also reach maturity faster, thus decreasing irrigation demand later during the irrigation season. This decrease in demand will help to alleviate a reduction in summer water supply, at least in non-drought years.

Two important considerations that highlight the complexity of water management in the region are:

- Producers with existing water rights will likely respond to the decreased demand of crops, and anecdotal references already suggest increases in double-cropping and cover cropping are occurring. Actual irrigation demand in 2035 may therefore not decrease to the extent projected in this Forecast. The Washington Department of Agriculture data do not distinguish these double-cropping patterns, so estimating this trend is not currently straighforward.
- Vulnerability of agricultural production to future changes in climate will be most apparent in drought years, which are expected to occur more frequently as the climate changes, with droughts also becoming more severe. Ongoing curtailment modeling may provide additional information on the extent of this vulnerability.

This Forecast improves our understanding of future surface water supplies and instream and out-of-stream demands. Unfortunately, it cannot answer all questions related to water supply and demand in the Columbia River Basin. However, it does provide projections 20 years into the future and highlights the main changes that can be expected in water supply and demand. It can therefore serve as a capital investment planning tool to help OCR and others make decisions that contribute to maintaining and enhancing the region's and eastern Washington's economic, environmental, and cultural prosperity.

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Forecast Results for Individual WRIAs

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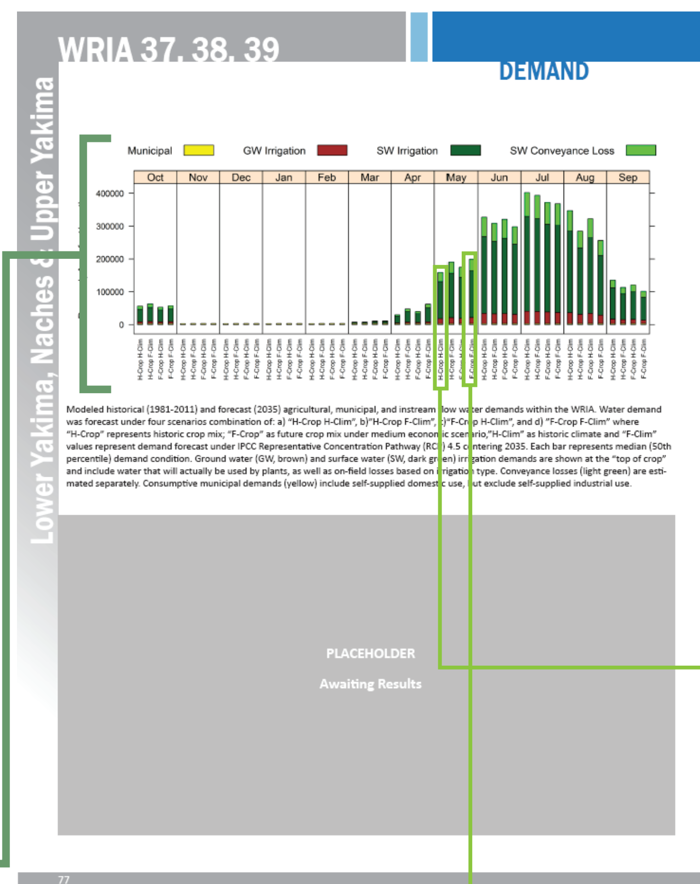
How to Read the WRIA's Results

WRIA Highlights note key, WRIA-specific results. Particular focus is given to aspects where this WRIA might differ from other Washington WRIAs.

Management Context describes the regulatory and planning context of the specific WRIA.

Use By Fish Species on the Endangered Species List provides information on the months of the year when flows are most critical to threatened and endangered fish species in the WRIA. Only available for some WRIAs.

Historical Flows Data provide information on how flows have varied historically at the stream gauge located furthest downstream in this WRIA.

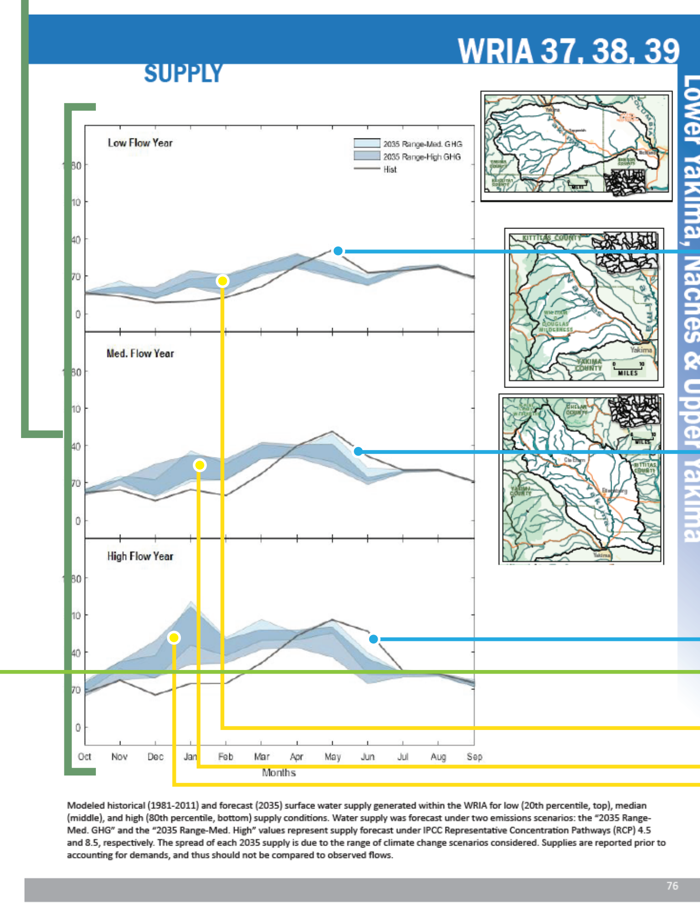


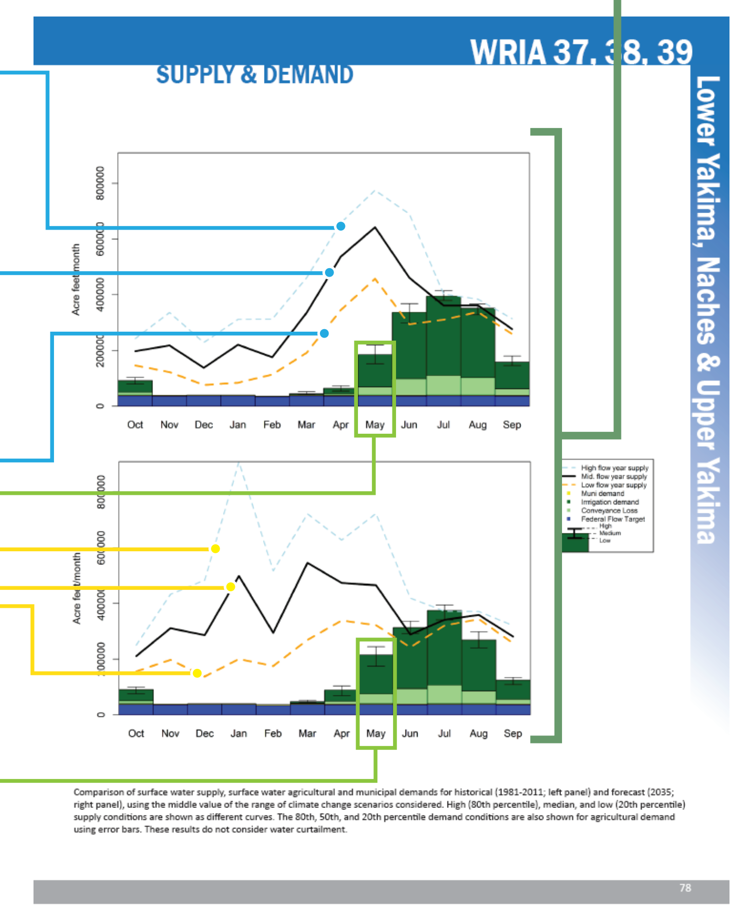
Modeled Historical and Forecast Water Demand shows how much water is needed in the WRIA each month for different uses (shown in different colors) under average flow conditions. The four bars for each month show:

(1) Historical demand, modeled and calibrated with 1981-2011 climate data and 2013 crop mix data; (4) Projected demand in 2035 under a moderate climate change scenario, and the crop mix expected in 2035 based on existing trends. The other two bars help distinguish the effects on water demand of only a changing climate (2) versus only a change in the crop mix (3).

Modeled Historical and Forecast Surface Water Supply shows how much water is available in the WRIA each month, prior to accounting for demands. The three panels show the expected supply in years with low, median, and high flow conditions, respectively. The three lines in each panel show:
(1) Historical supply, modeled and calibrate with 1981-2011 climate data (black line); (2) Projected water supply in 2035 under a moderate climate change scenario (light blue polygon); and (3) Projected water supply in 2035 under a more severe climate change scenario (dark blue polygon). The range shown by the polygons reflects how results for 2035 depend on the climate model used.

Comparison of Water Supply and Demand overlays water supply and water demand on the same graph, for the historical (1981-2011) period (top panel), and for the forecast (2035, including moderate changes in climate and changes in crop mix) period (bottom panel).





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MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Wind-White Salmon is characterized mostly by increases from late fall through early spring, with smaller decreases in the late spring and summer.
- Irrigation is the dominant source of demand, although it is smaller than irrigation demands in many other WRIAs of eastern Washington. Municipal demands are very small in comparison.
- Assuming no change in irrigated acreage, irrigation demands are projected to increase in May, June, and August, and decrease in July, September, and October.
- Municipal demands are expected to grow 14% by 2035, though the total municipal demand will still be quite small in comparison to other watersheds.
- This WRIA is included in the Columbia River Instream Atlas (Ecology Publication in preparation), which contains information on instream water demands for 12 WRIAs that provide habitat for ESA-listed anadromous salmonids.

PLACEHOLDER

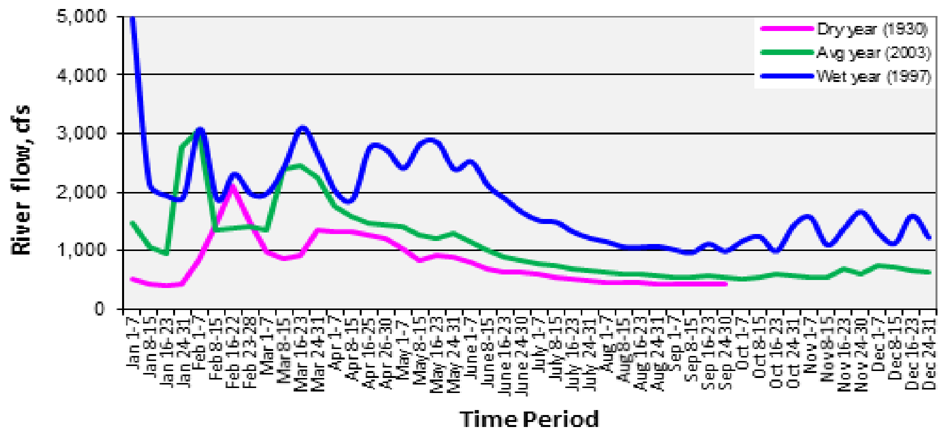
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	NO
Watershed Planning	WRIA 29a: Phase 4 (Implementation), WRIA 29b: NO (planning terminated)
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	Bull Trout, Lower Columbia River Chinook, Lower Columbia River Steelhead Middle Columbia Steelhead, Lower Columbia River Coho, Columbia River Chum Salmon [Columbia mainstem migratory corridor]
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

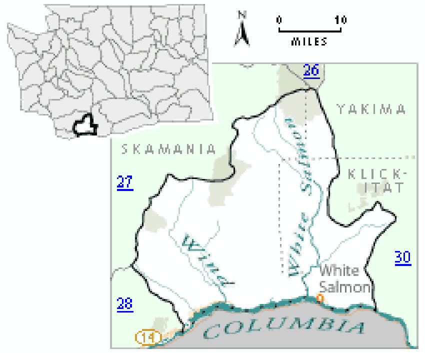
White Salmon River Dry, Average and Wet Years Flow

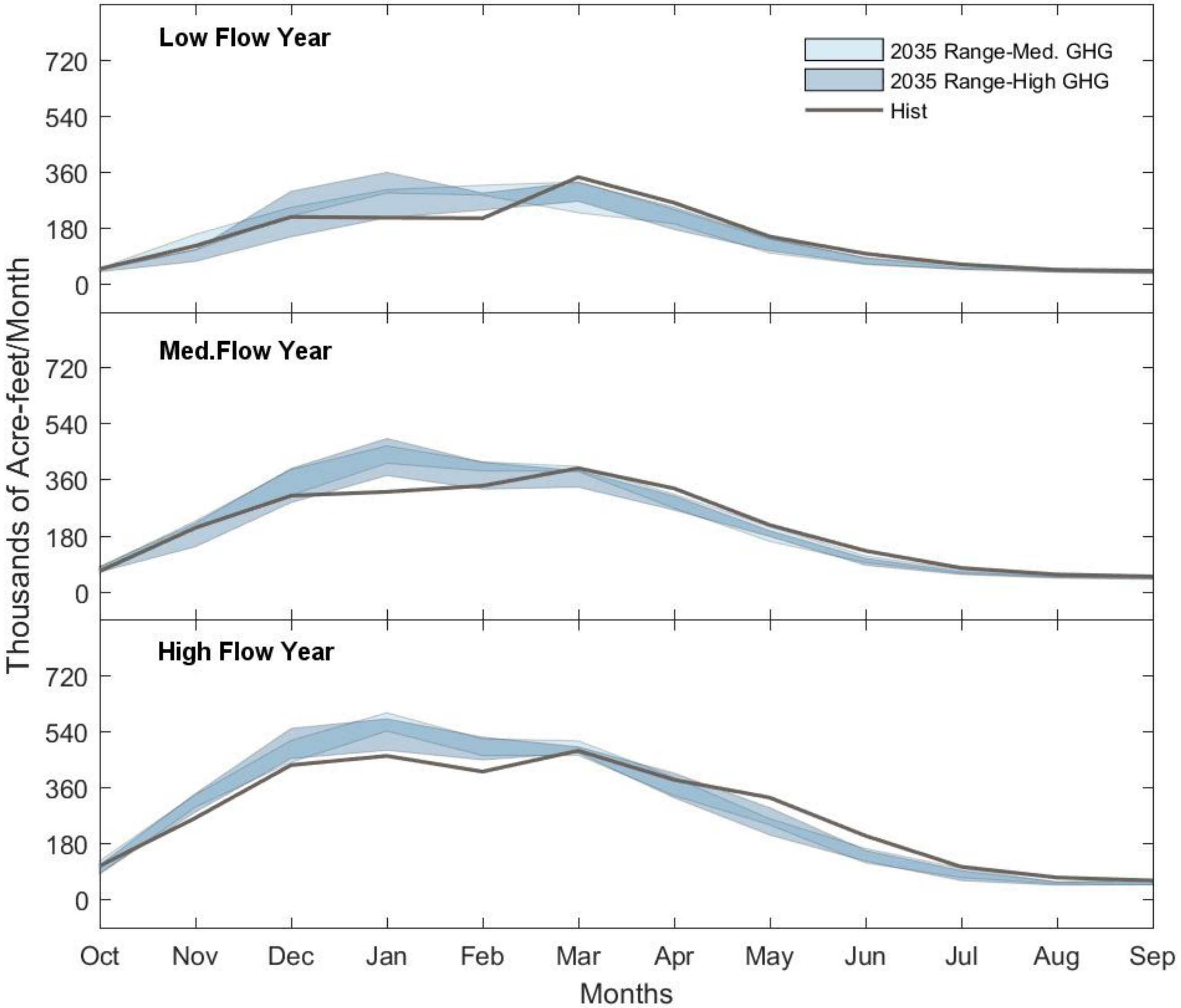
(White Salmon River near Underwood, WA) 1915-2015



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

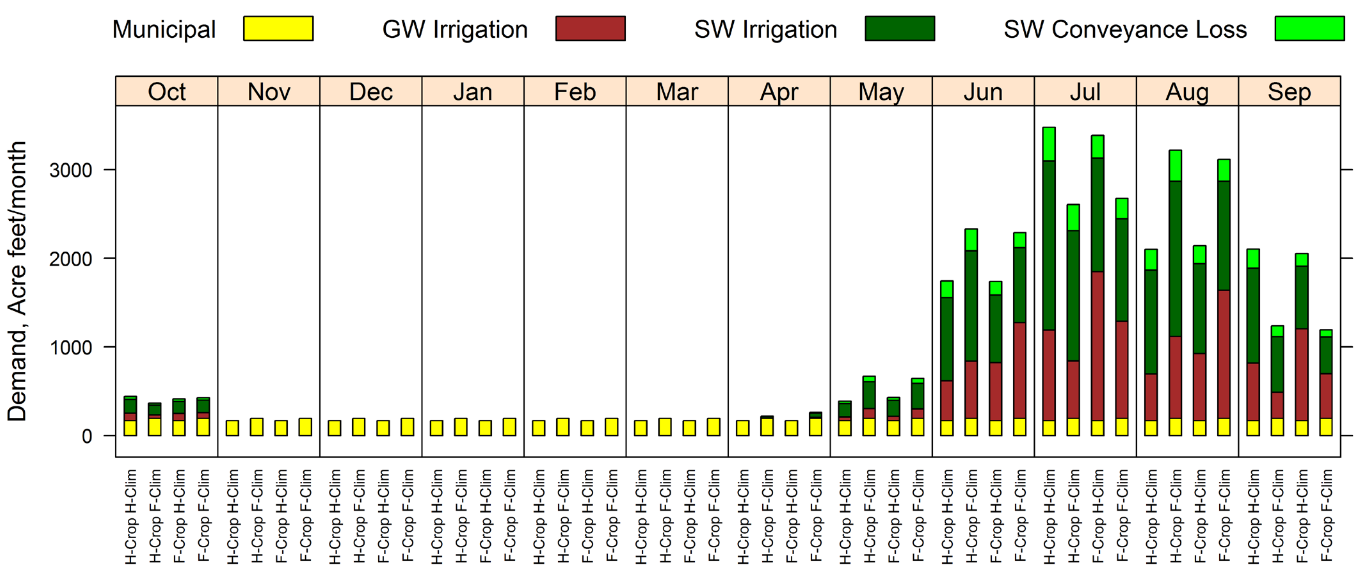
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

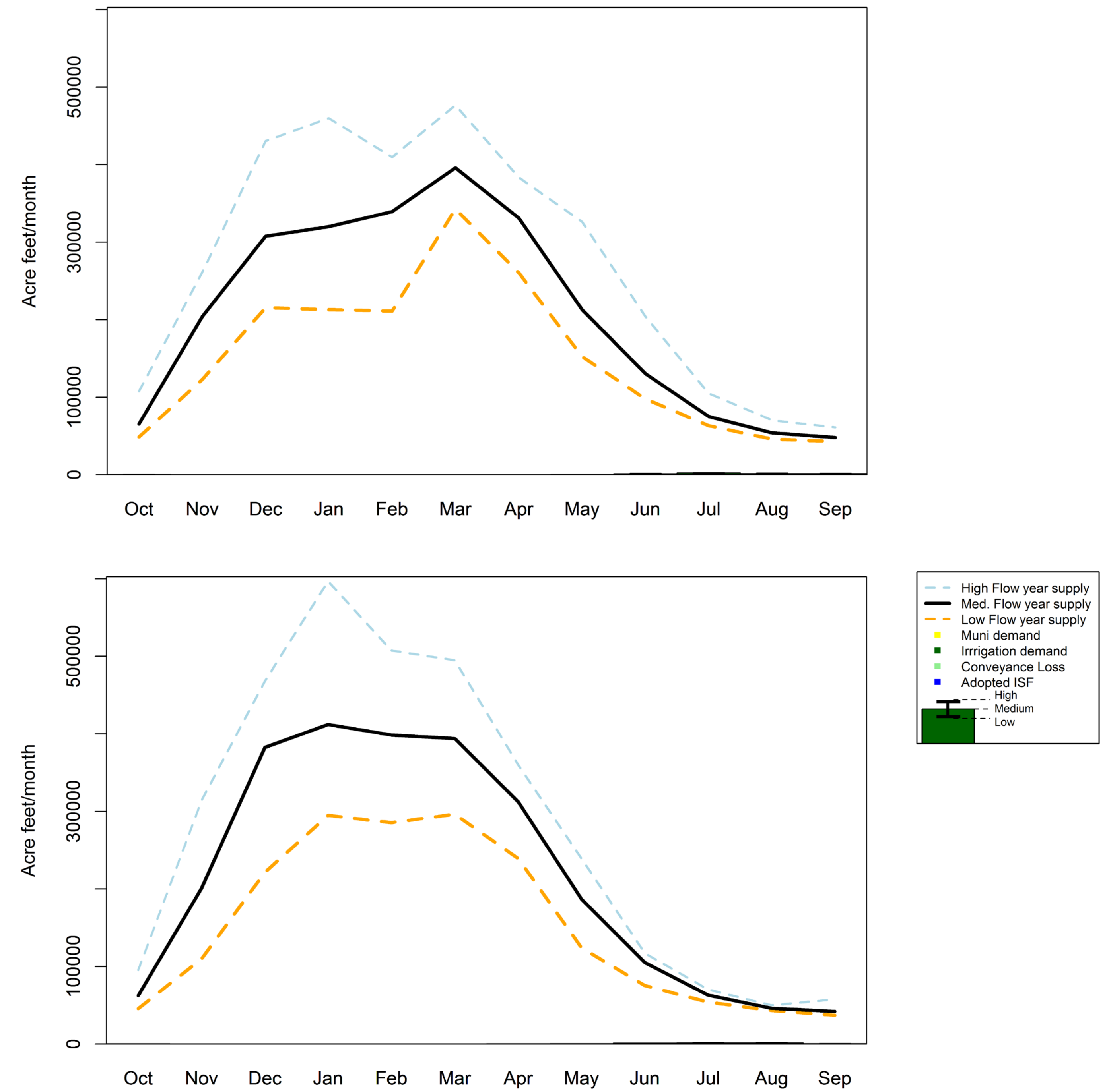


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

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MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Klickitat is uncertain with a combination of increases and decreases (depending on climate scenario) between January and August. The 80th supply, however, has more certainty with climate scenarios projecting mostly increases from December through March and decreases for May.
- Irrigation is the dominant source of demand, with municipal demands that are much smaller.
- Assuming no change in irrigated acreage, irrigation demand is forecasted to decrease in response to climate change and crop mix changes for most months of the irrigation season in the future. Irrigation demand increases in June and August.
- Municipal demands are expected to grow 2% by 2035.
- This WRIA is included in the Columbia River Instream Atlas (Ecology Publication in preparation), which contains information on instream water demands for 12 WRIAs that provide habitat for ESA-listed anadromous salmonids.

PLACEHOLDER

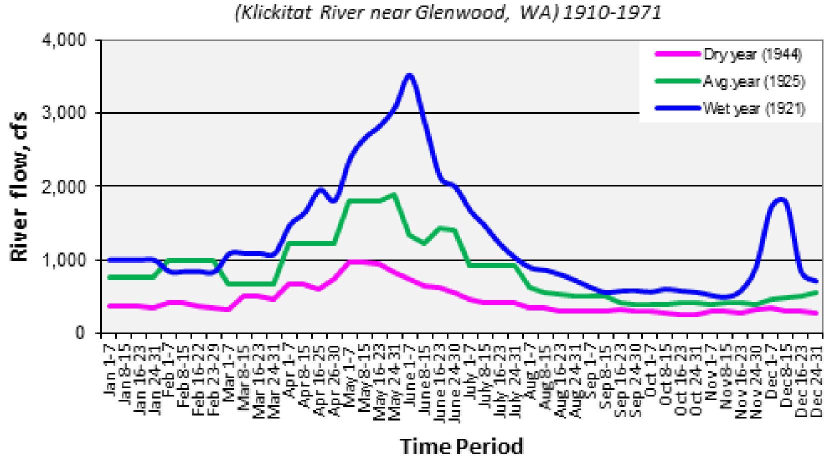
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Bird-Frazier Creeks, Bacon Creek, Little Klickitat River, Mill Creek, Blockhouse Creek
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	Bull Trout, Middle Columbia Steelhead [Columbia mainstem migratory corridor]
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

Klickitat River Dry, Average, Wet Years Flow

(Klickitat River near Glenwood, WA) 1910-1971



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

Klickitat

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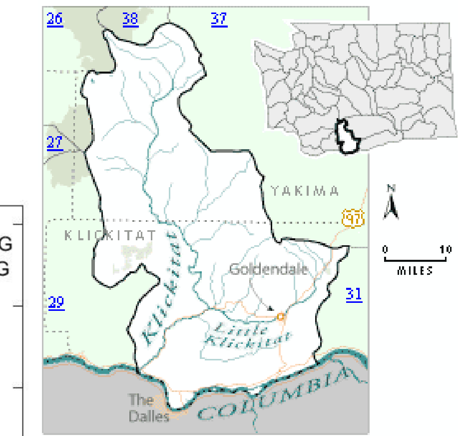
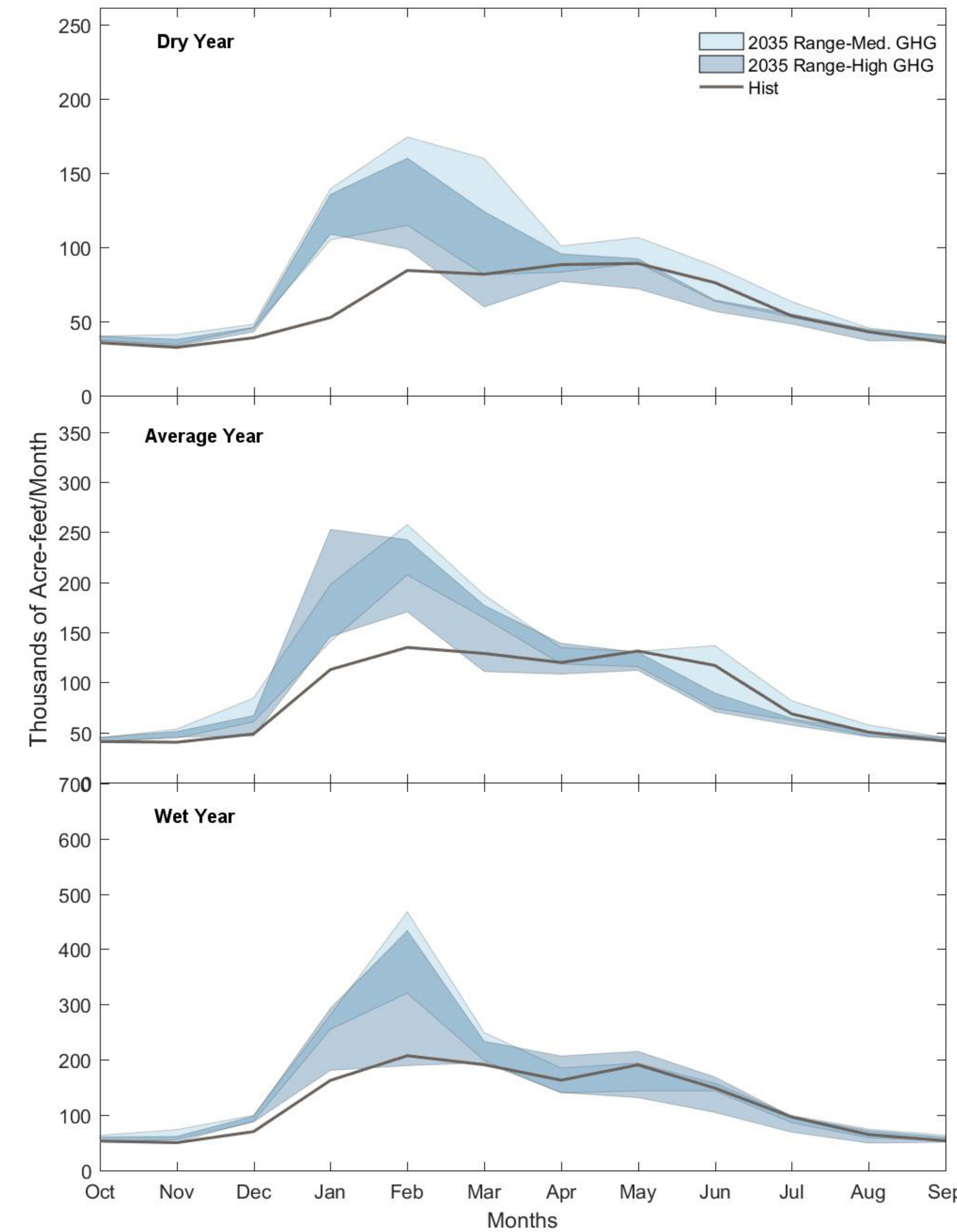
WRIA 30

SUPPLY

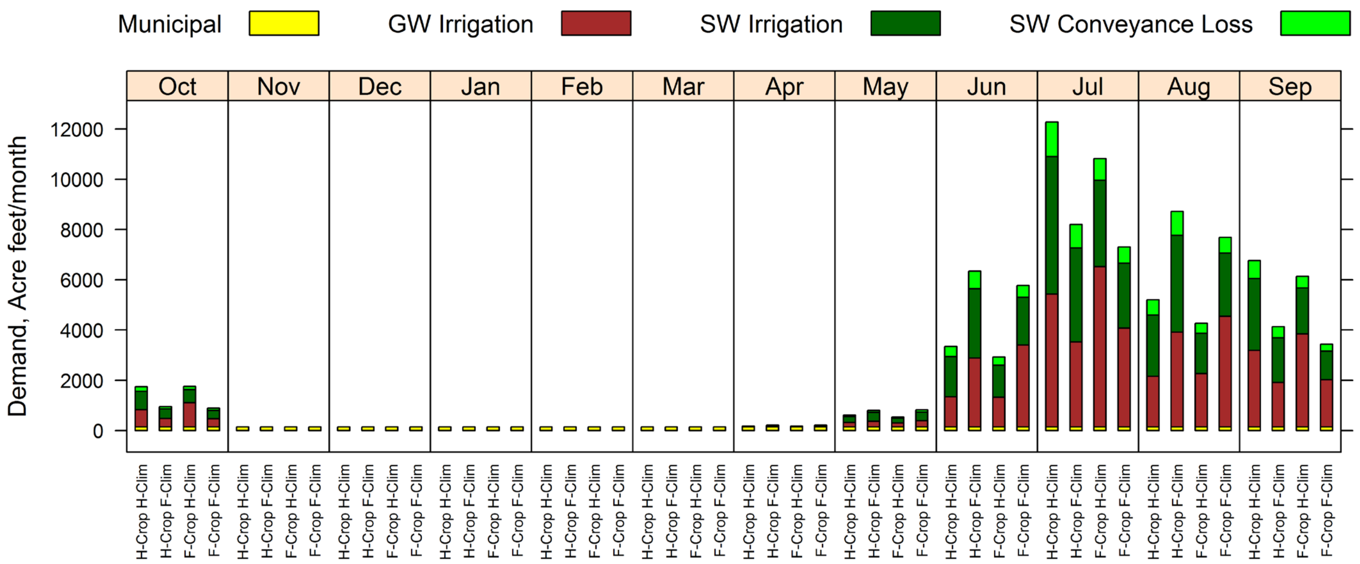




Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

Klickitat

DEMAND

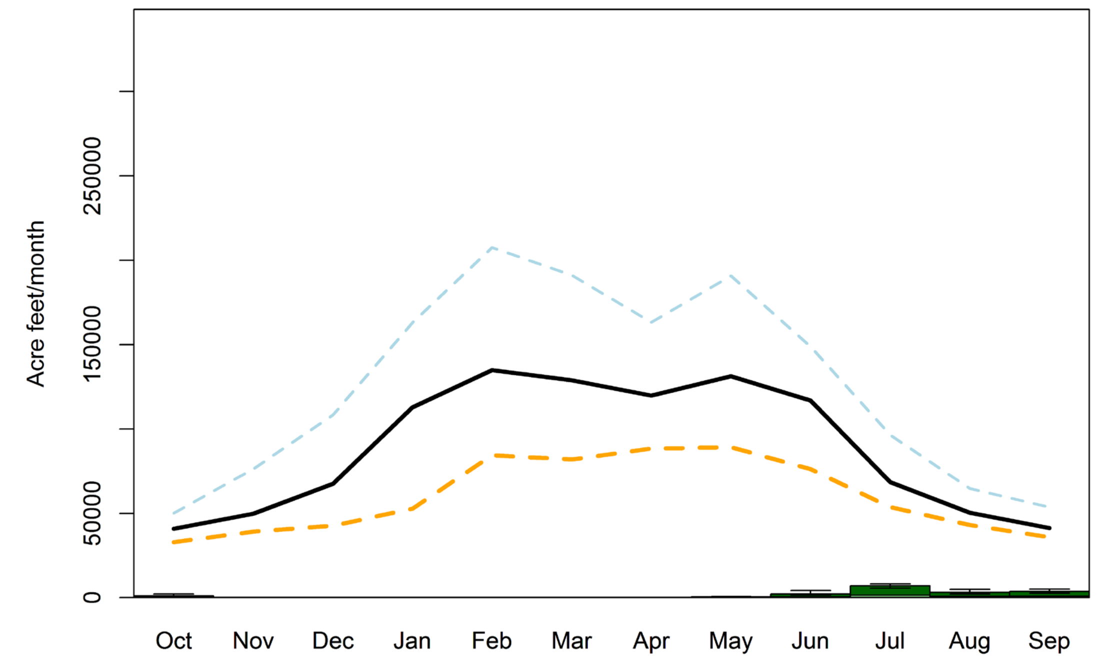


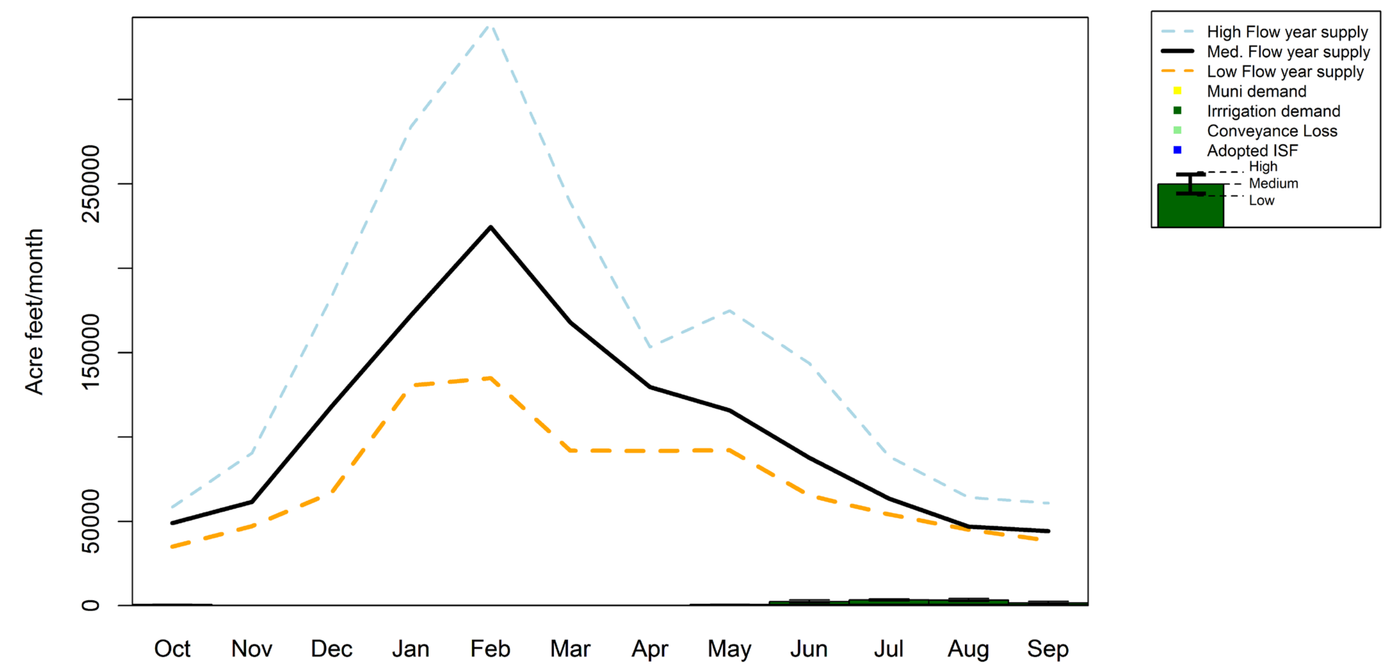
Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND





Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Rock Glade is characterized mostly by slight increases during the winter.
- Irrigation is the primary source of demand, with much smaller municipal demands.
- Assuming no change in irrigated acreage, irrigation demand is projected to increase slightly during April, May and October, and decrease slightly during July through September. These changes are primarily in response to climate change rather than crop mix changes.
- Municipal demands are expected to grow 14% by 2035.

PLACEHOLDER

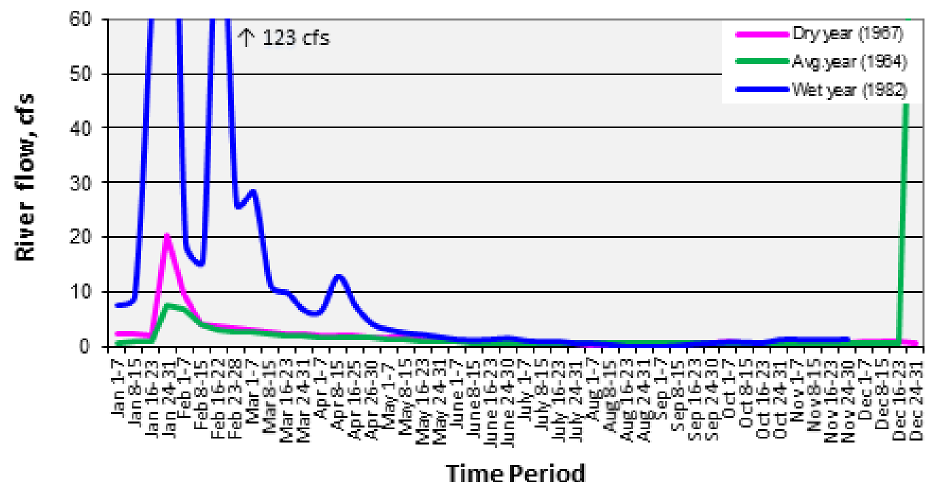
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	NO
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	Middle Columbia Steelhead [Columbia mainstem migratory corridor]
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

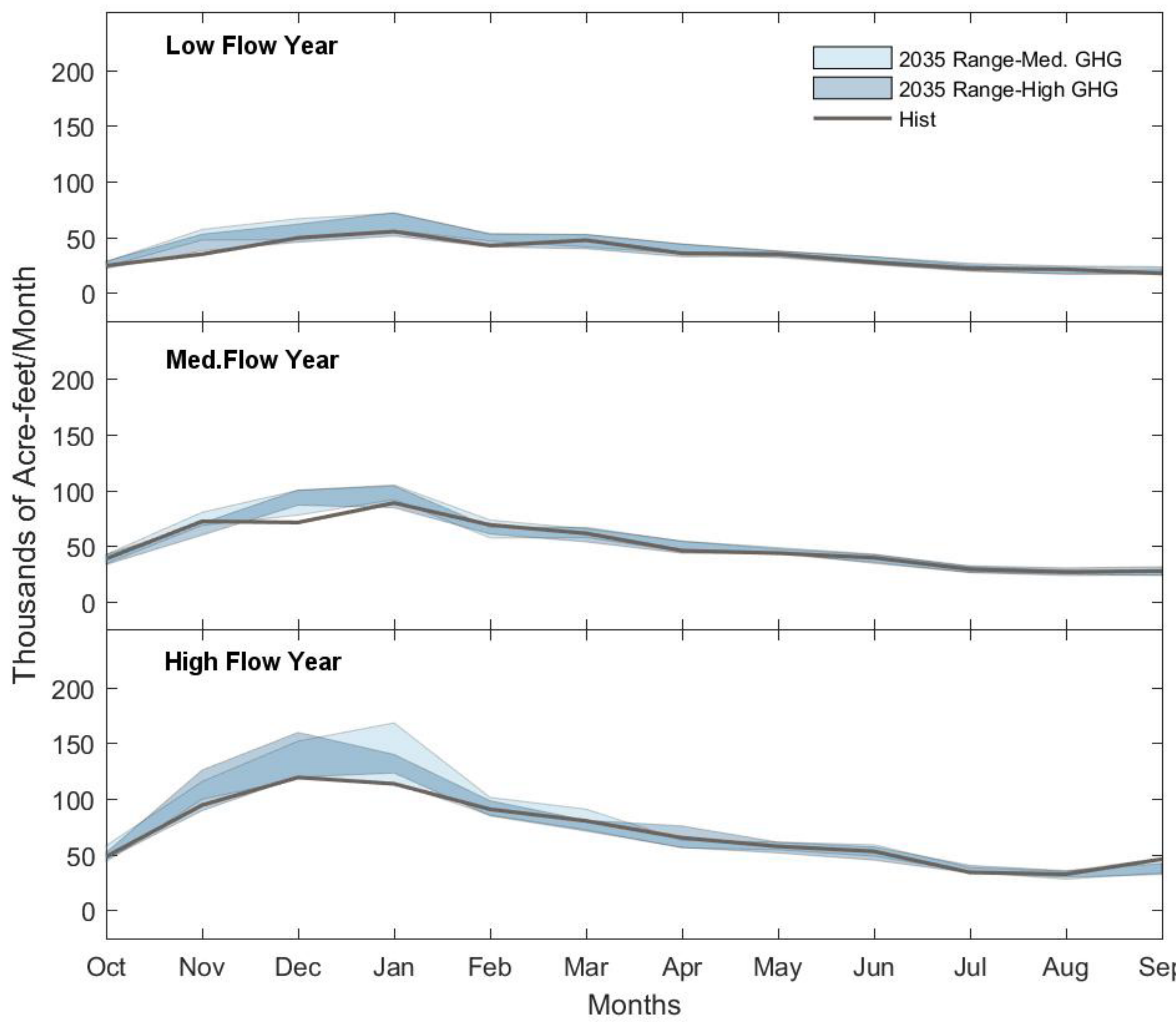
Alder Creek Dry, Average and Wet Years Flow

(Alder Creek at Alderdale, WA) 1963-1982



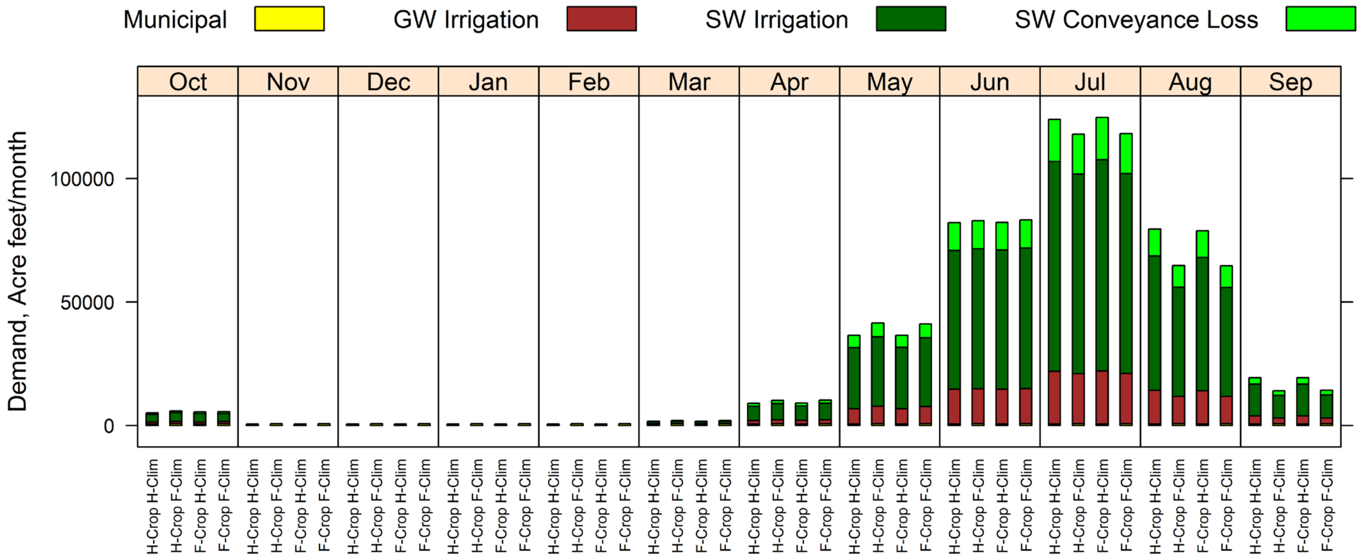
Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

SUPPLY



Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

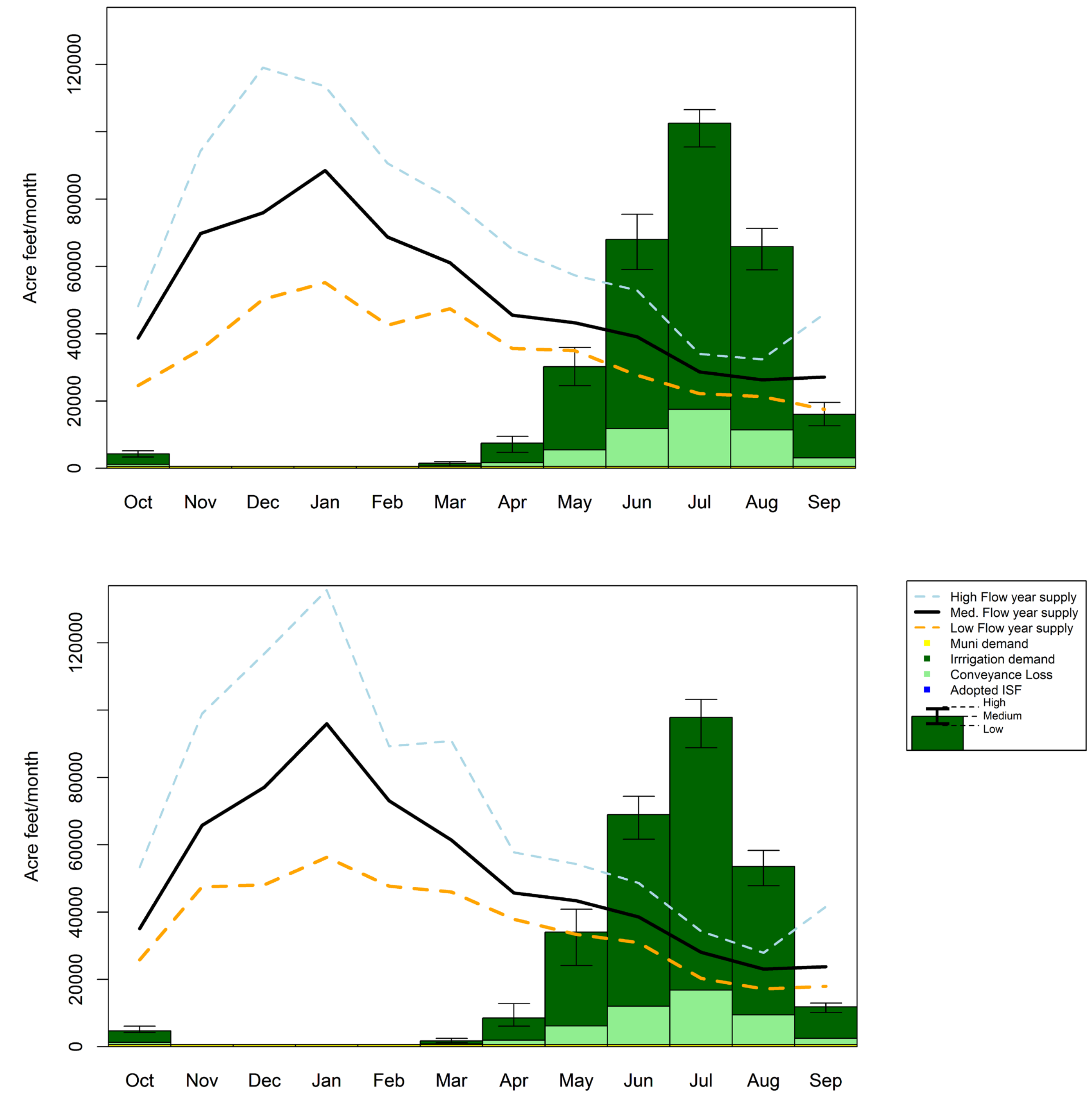


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

Walla Walla

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Walla Walla is uncertain with climate scenarios showing a combination of increases and decreases from January through June.
- Primary demands are irrigation and instream flow requirements, with much smaller municipal demands.
- Assuming no change in irrigated acreage, irrigation demands are forecasted to increase during the irrigation season between April and October. This increase is primarily due to crop mix changes (particularly during the months of May through September) with climate changes resulting (in isolation) in decreases in demand for Jun through September.
- Municipal demands are projected to grow 9% by 2035.
- This WRIA is included in the Columbia River Instream Atlas (Ecology Publication in preparation), which contains information on instream water demands for 12 WRIAs that provide habitat for ESA-listed anadromous salmonids.

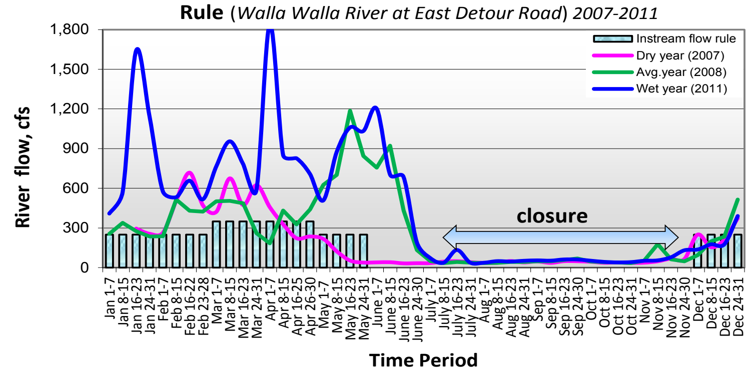
PLACEHOLDER

Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Upper Stone Creek, Doan Creek, Bigelow Gulch Creek, Touchet River, Dry Creek
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	Yes (Chapter 173-532 WAC). 65 interruptible water rights curtailed periodically. Weekly frequency of interruption from 1984-2014 averaged 4 to 5 years from December to June (85% reliable), and 8 years from July to October (75% reliable).
Fish Listed Under the Endangered Species Act[1]	Bull Trout, Middle Columbia Steelhead [Columbia mainstem migratory corridor]
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

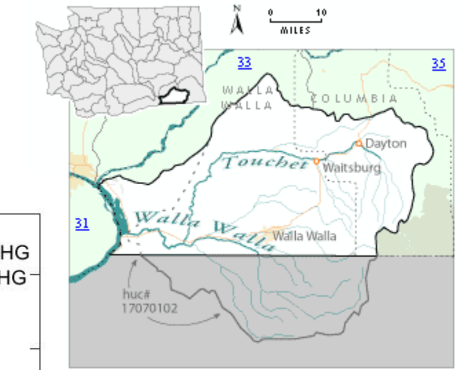
Comparison of Dry, Average and Wet Year Flows to Instream Flow Rule (*Walla Walla River at East Detour Road*) 2007-2011

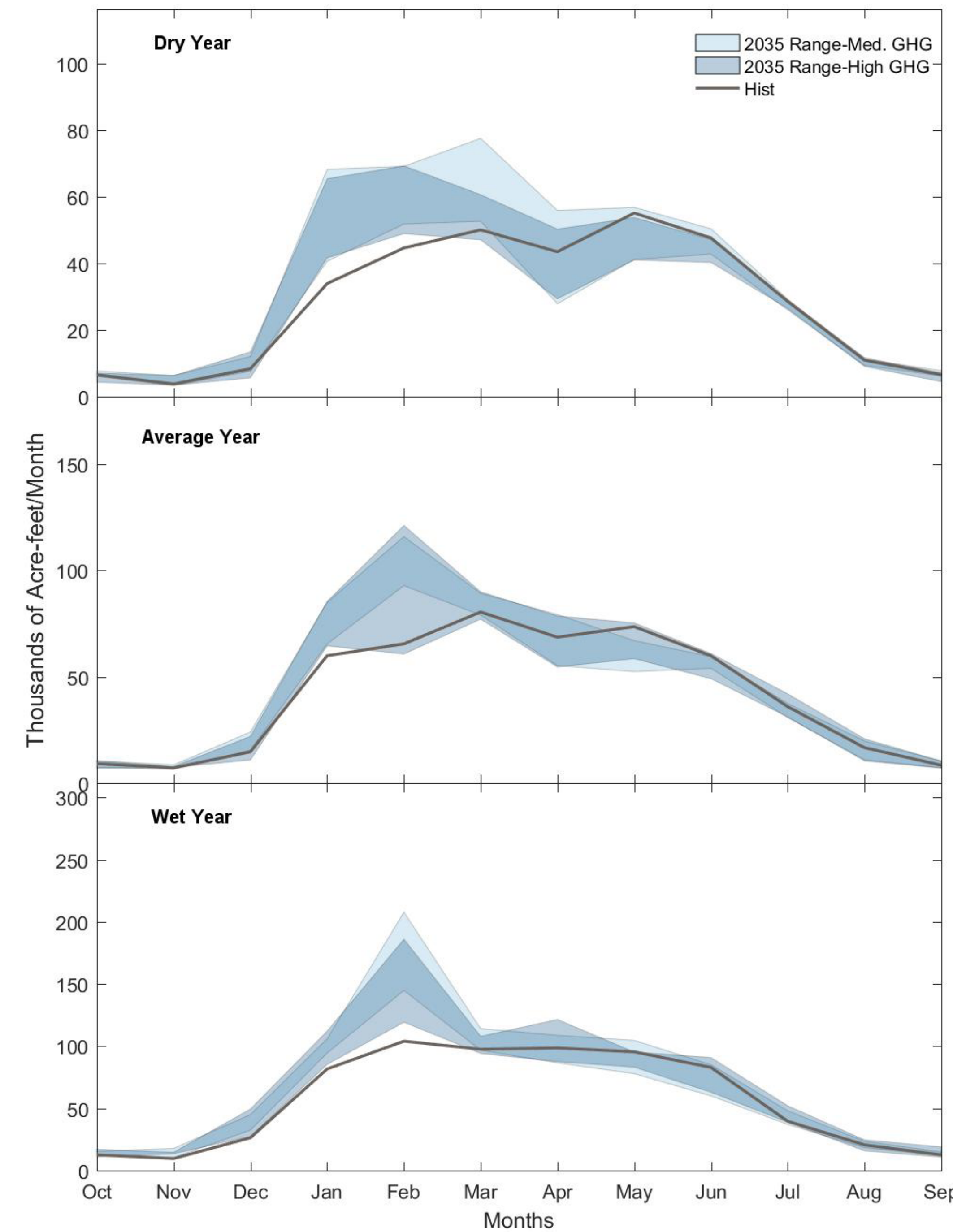


A table showing salmon, steelhead, and bull trout use of WRIA waters (provided by the Washington Department of Fish and Wildlife (WDFW)) is available on page 167. Summaries are also available online at http://wdfw.wa.gov/salmonscape/.

Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes. Because there are no adopted instream flows in Walla Walla at the mouth of the watershed, instream flows are shown as the highest quantified flow at any point for a given month, as specified in Chapter 173-532 WAC. For December through May, flows are shown at Walla Walla River at Detour road. For other months, when the Walla Walla River is closed to new uses, flows from other control points are shown.

SUPPLY

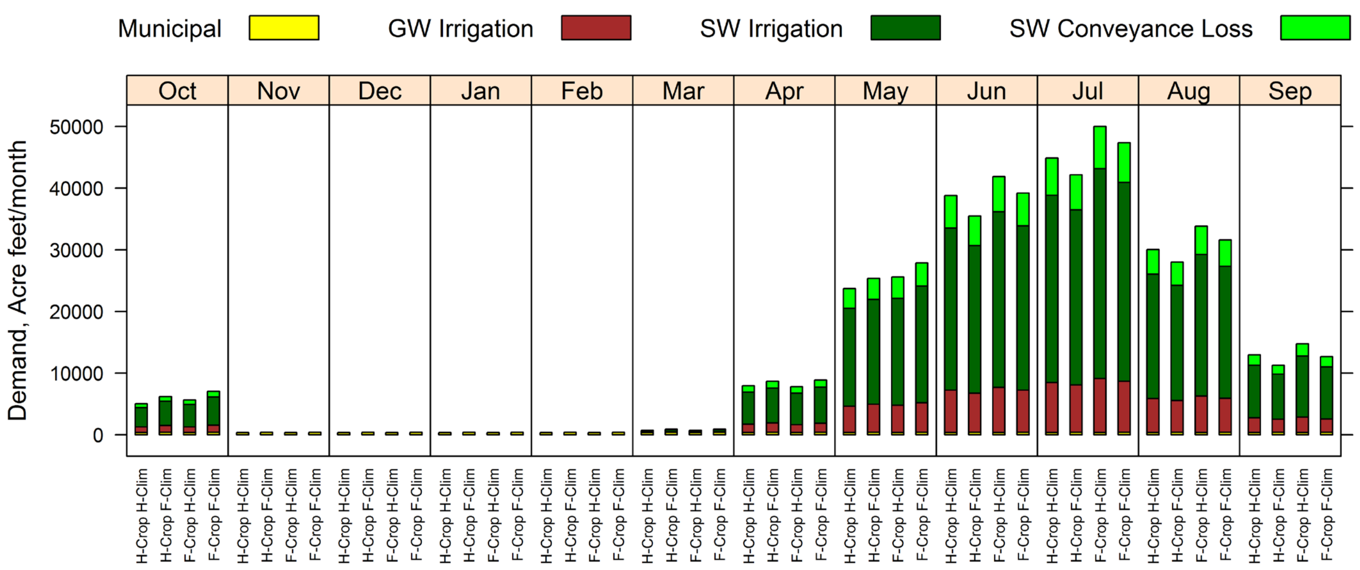




Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

Walla Walla

DEMAND

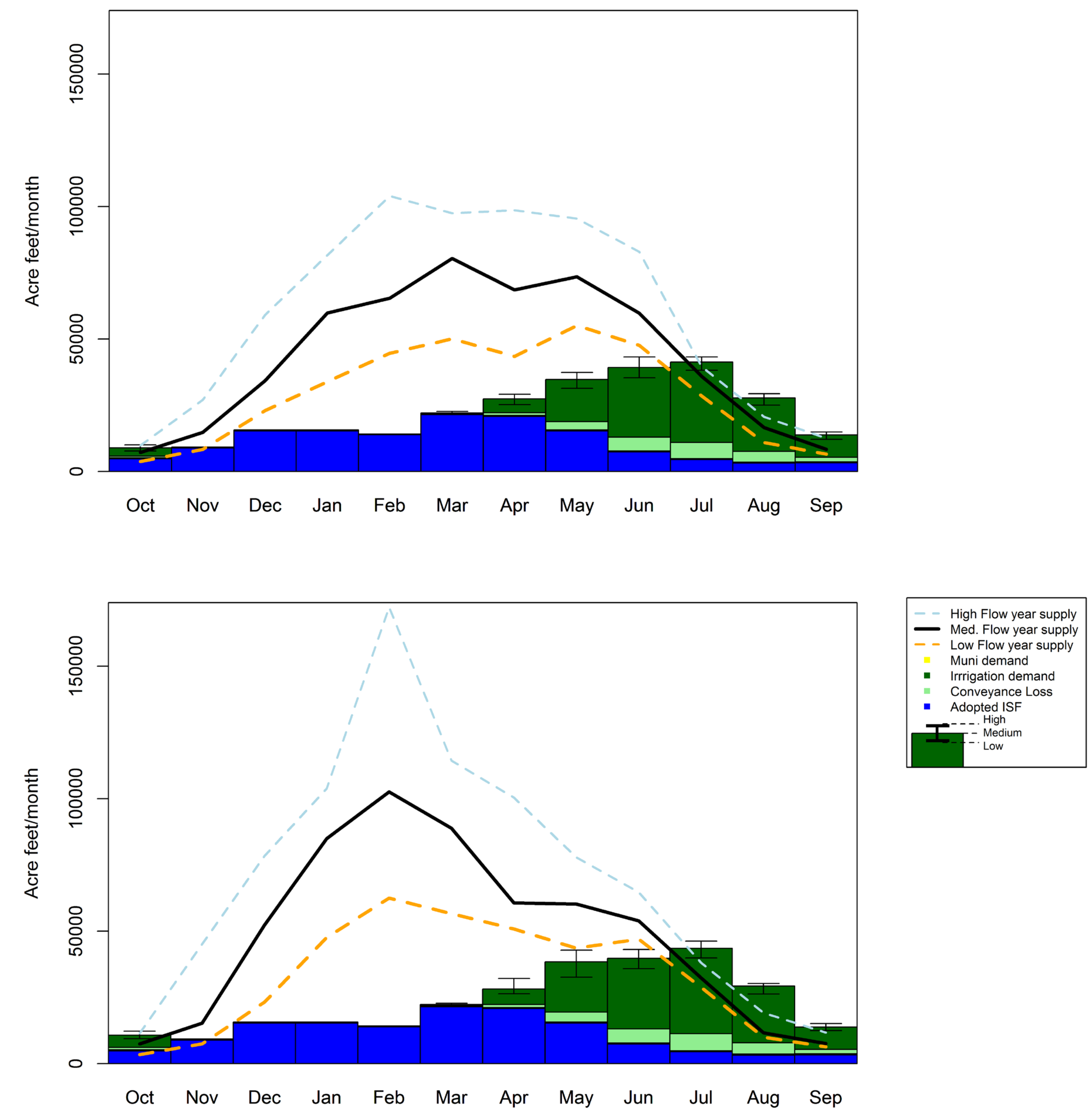


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

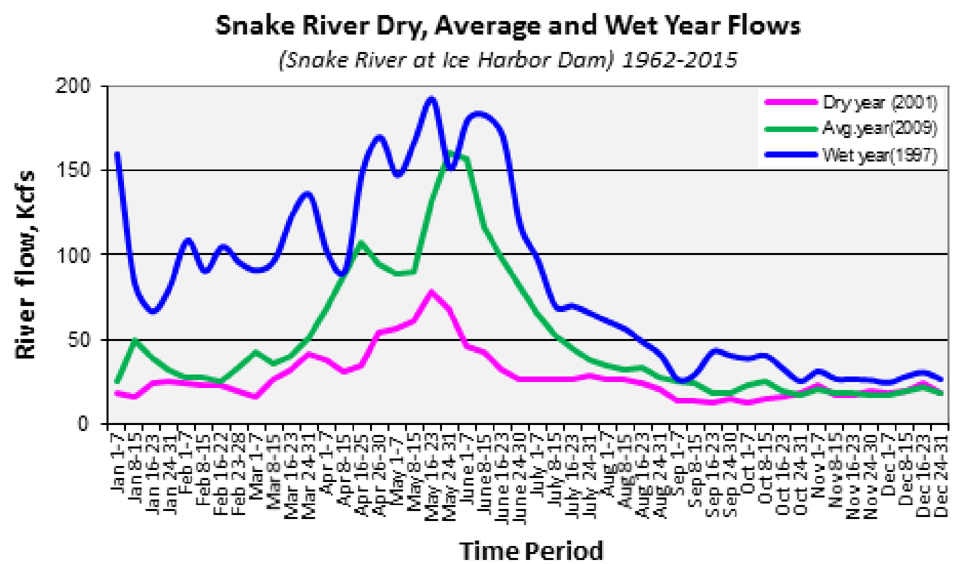
- The tributary surface water supply forecast for Lower Snake is characterized mostly by small increases in some years from October through February, and lower but uncertain changes from March through September.
- As in many other WRIAs in eastern Washington, irrigation demands dominate, and municipal demands are much smaller.
- Assuming no change in irrigated acreage, irrigation demands are projected to decrease somewhat for June through September and increase somewhat for October, April, and May. The changes are primarily in response to a crop mix change.
- Municipal demands are expected to grow 9% by 2035.

PLACEHOLDER

Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

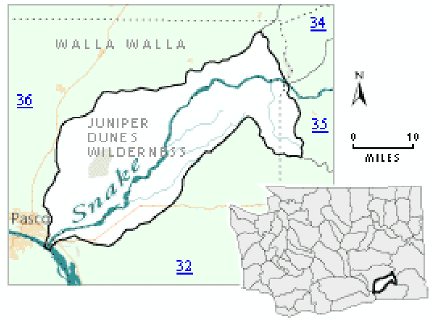
MANAGEMENT CONTEXT	
Adjudicated Areas	NO
Watershed Planning	NO
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	Snake River Basin Steelhead, Snake River Fall Run Chinook, Snake River Spring and Summer Run, Chinook, [Snake mainstem migratory corridor for Snake River sockeye]
Groundwater Management Area	YES (Franklin Co. portions are part of Columbia Basin GWMA)

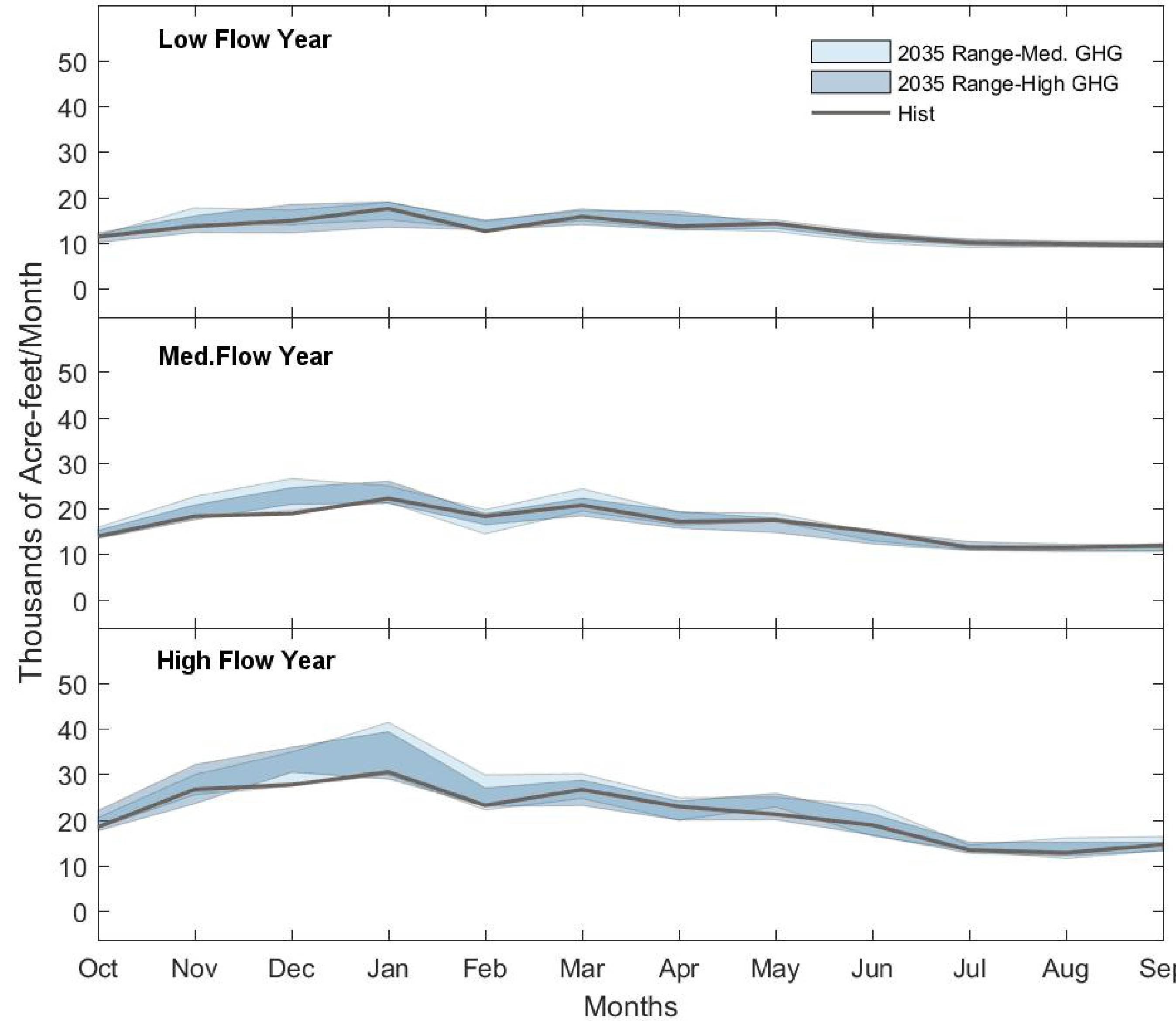
[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

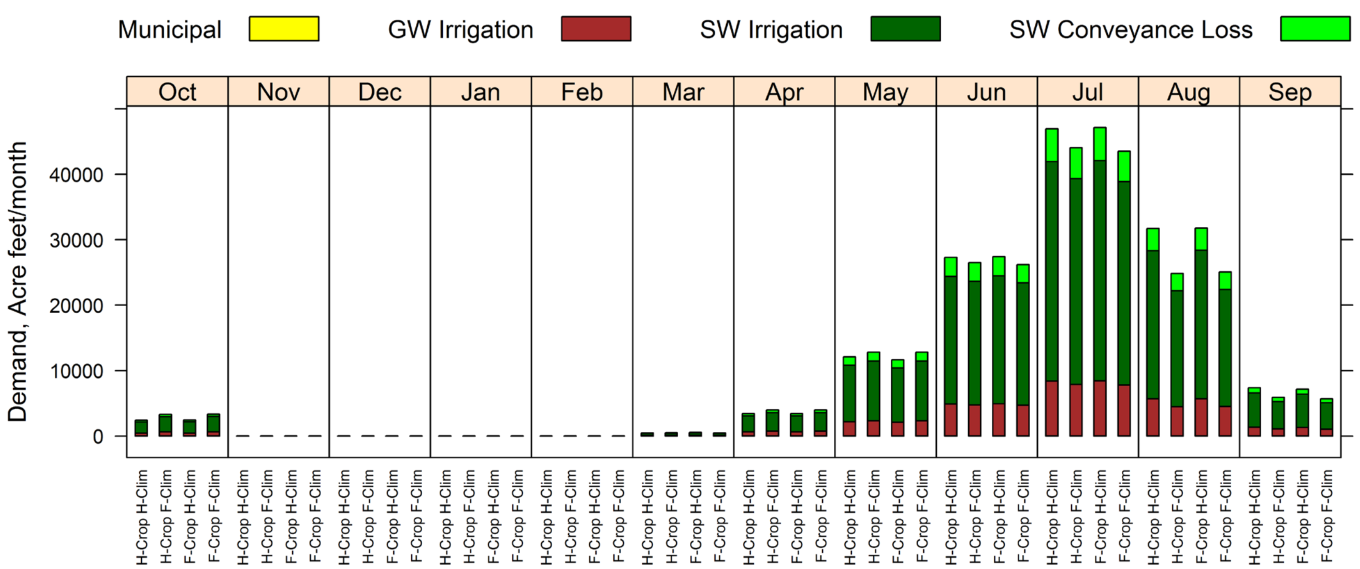
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND



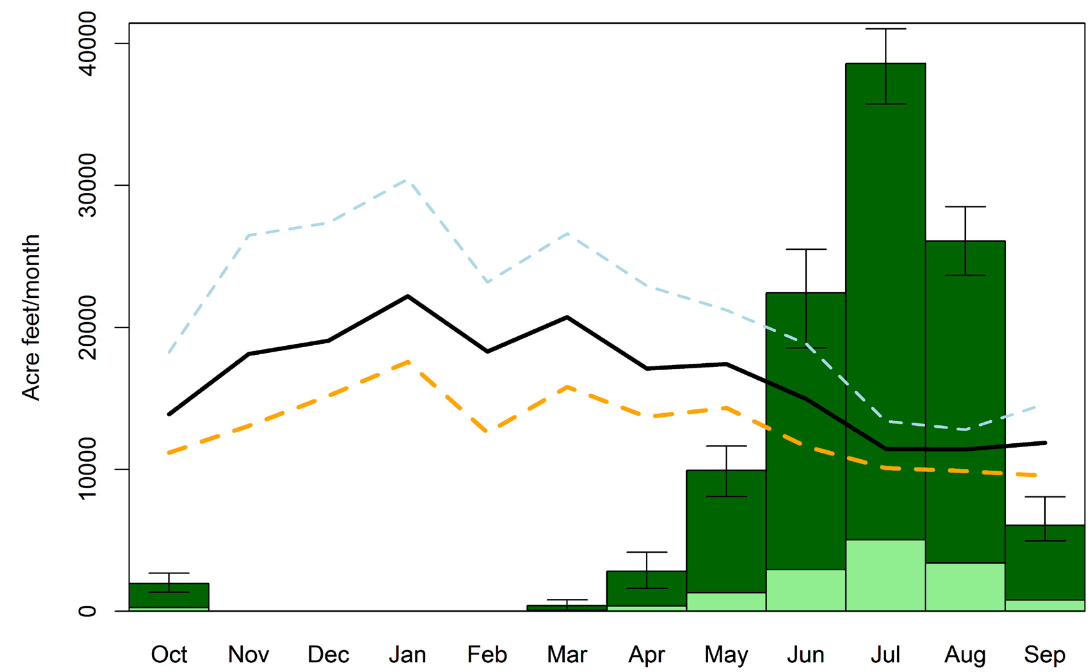
Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

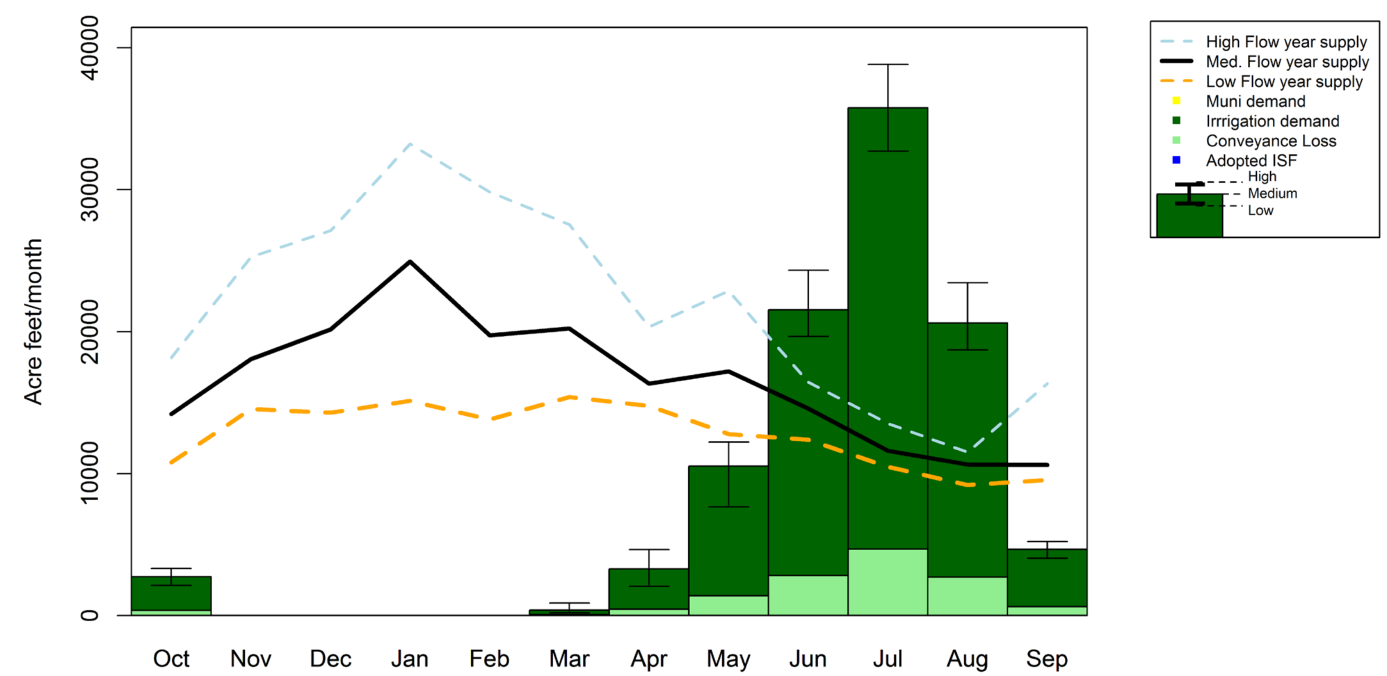
PLACEHOLDER

Awaiting Results

DRAFT
WRIA 33
Lower Snake

SUPPLY & DEMAND





Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Palouse is less certain with climate scenarios showing a range of increases and decreases from January through May, although the 80th supply year shows primarily increases in February and March.
- Irrigation is the primary demand, though municipal demands are also sizeable.
- Assuming no change in irrigated acreage, irrigation demands are forecasted to increase in most months of the irrigation season. Increase in demand is primarily attributed from climate change. Decrease in demand in June, August, and October are due to both crop mix changes and climate changes. Because of declining groundwater in the Odessa area, some irrigation demand is forecasted to shift by 2035 from groundwater to surface water. Municipal demands are projected to increase 24% by 2035, a smaller increase than in most other watersheds in eastern Washington.

PLACEHOLDER

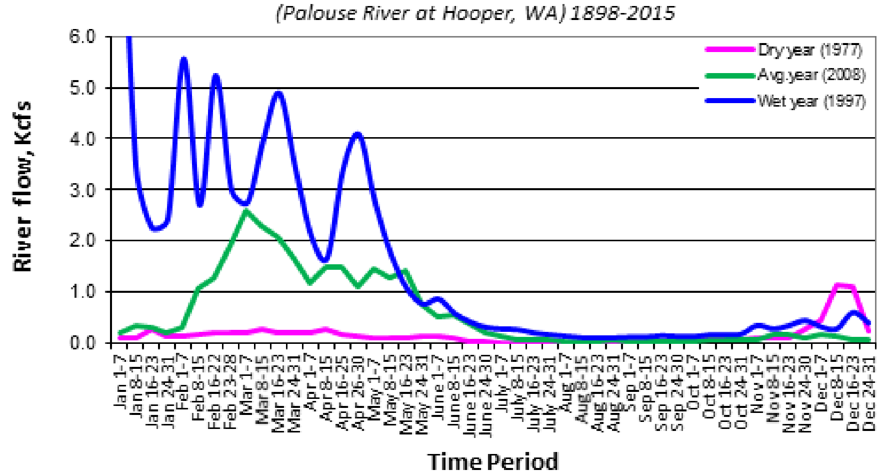
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Cow Creek & Sprague Lake
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	[Snake mainstem migratory corridor for Snake River Basin Steelhead, Snake River Fall Run Chinook, Snake River Spring and Summer Run Chinook and Snake River sockeye]
Groundwater Management Area	YES (Lincoln and Adams Co. portions are part of Columbia Basin GWMA, and a portion of this is in Odessa Subarea)

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

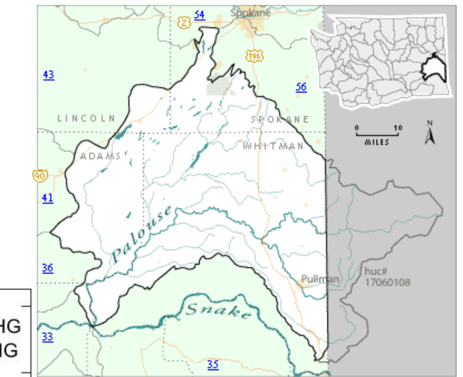
Palouse River Dry, Average and Wet Years Flow

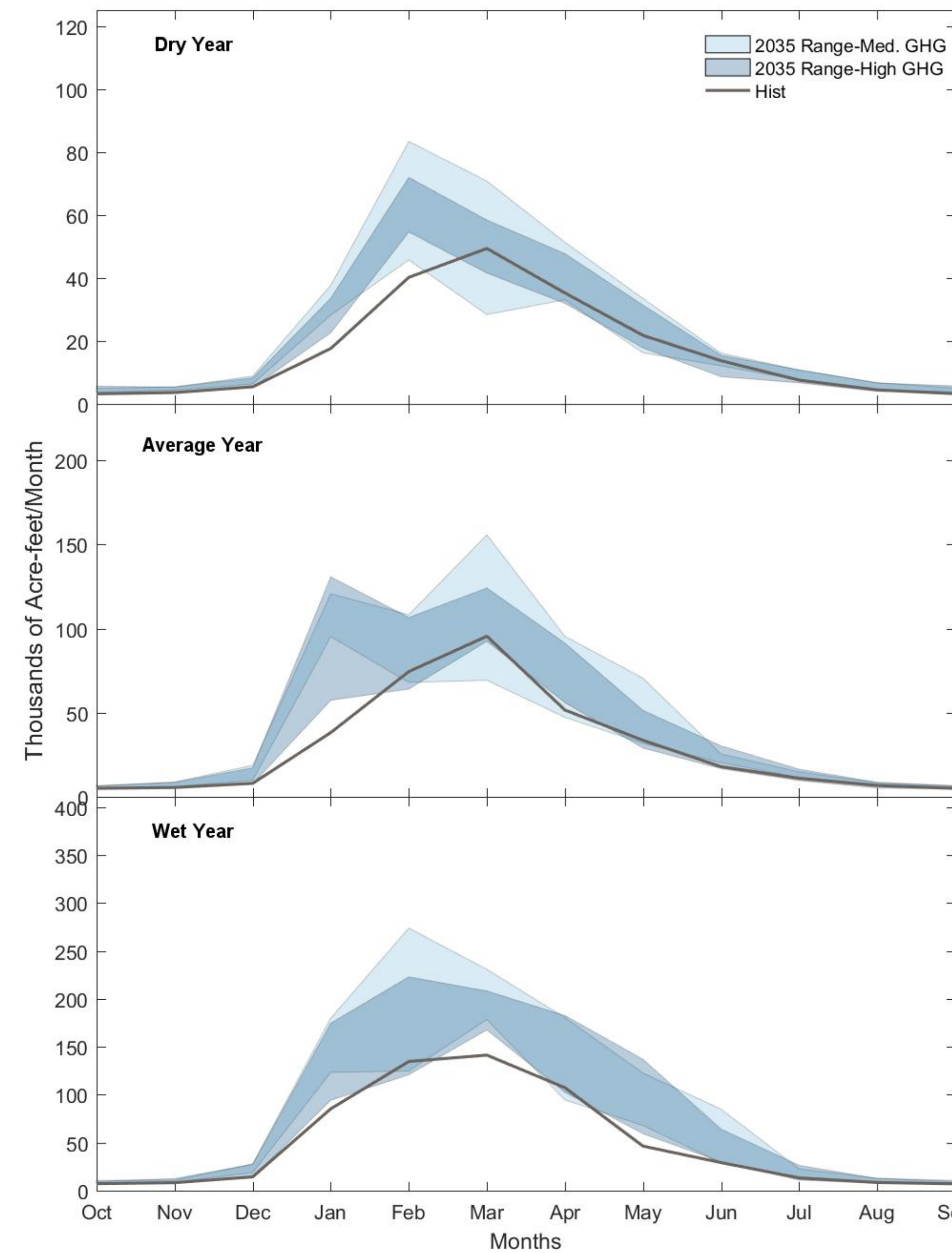
(Palouse River at Hooper, WA) 1898-2015



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

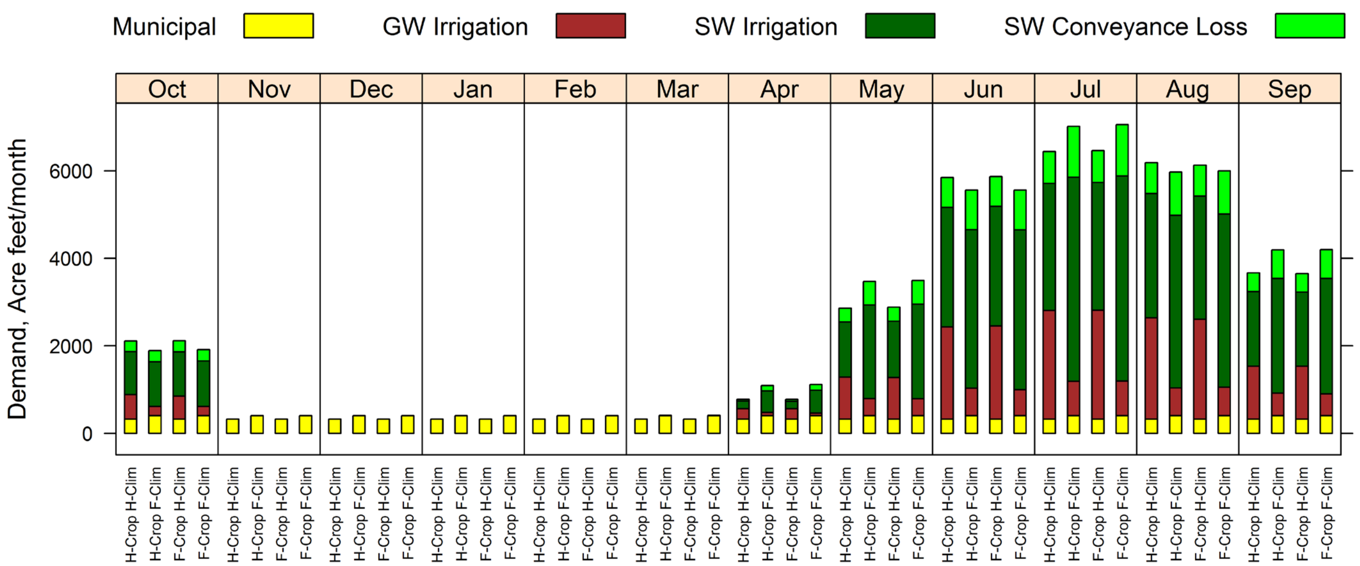
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

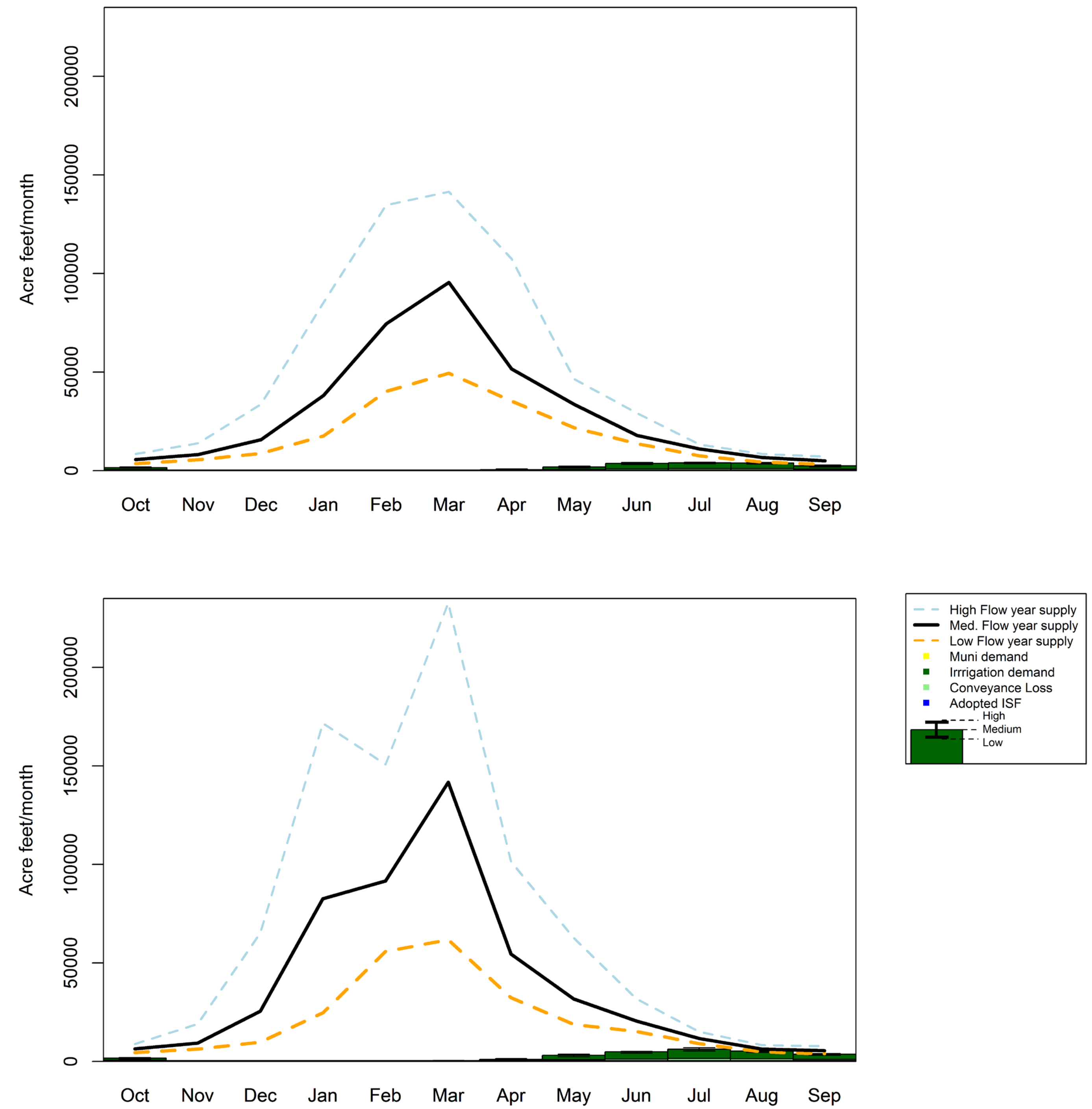


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Middle Snake is characterized mostly by increases from late fall through early spring, followed by decreases for March and April. While the 20th and 50th percentile supply years show decreases in June, the 80th percentile supply year shows primarily increases.
- Overall demands are relatively modest compared to other watersheds in eastern Washington, with municipal demands that are generally on par with irrigation demands, depending on the month.
- Assuming no change in irrigated acreage, irrigation demand is expected to increase in July only with decreases during the remainder of the irrigation season. Climate and crop mix changes are both contributing to decrease in June, August, and October while increase in only July, showing opposite results in rest of the irrigation months.
- This WRIA is included in the Columbia River Instream Atlas (Ecology Publication in preparation), which contains information on instream water demands for 12 WRIAs that provide habitat for ESA-listed anadromous salmonids.

PLACEHOLDER

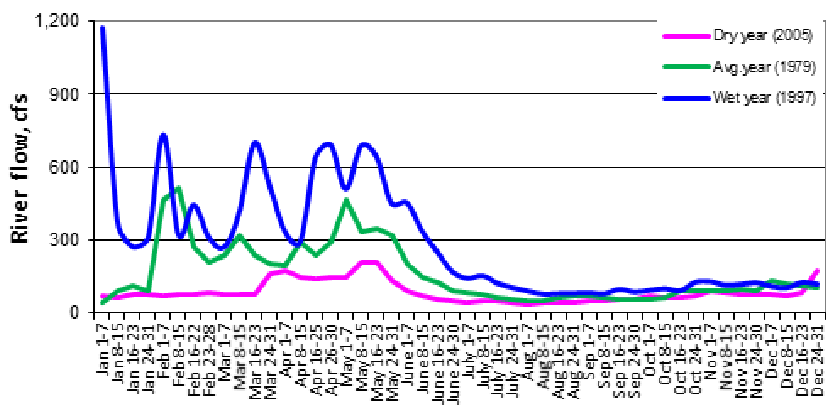
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Deadman Creek , Wawawai Creek, Meadow Gulch Creek, Alpowa Creek
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	Snake River Basin Steelhead, Snake River Bull Trout, Snake River Fall Run Chinook, Snake River Spring and Summer Run Chinook [Snake mainstem migratory corridor for Snake River sockeye]
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

Tucannon River Dry, Average and Wet Year Flows

(Tucannon River near Starbuck, WA) 1915-2015



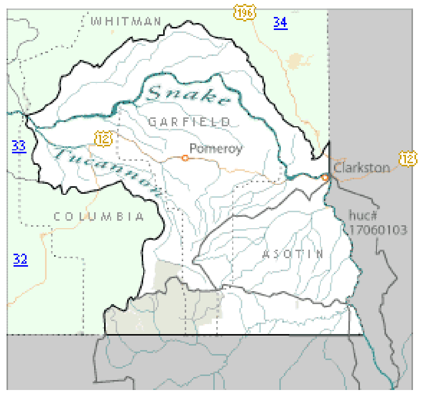
A table showing salmon, steelhead, and bull trout use of WRIA waters (provided by the Washington Department of Fish and Wildlife (WDFW)) is available on page 167. Summaries are also available online at http://apps.wdfw.wa.gov/salmonscape/.

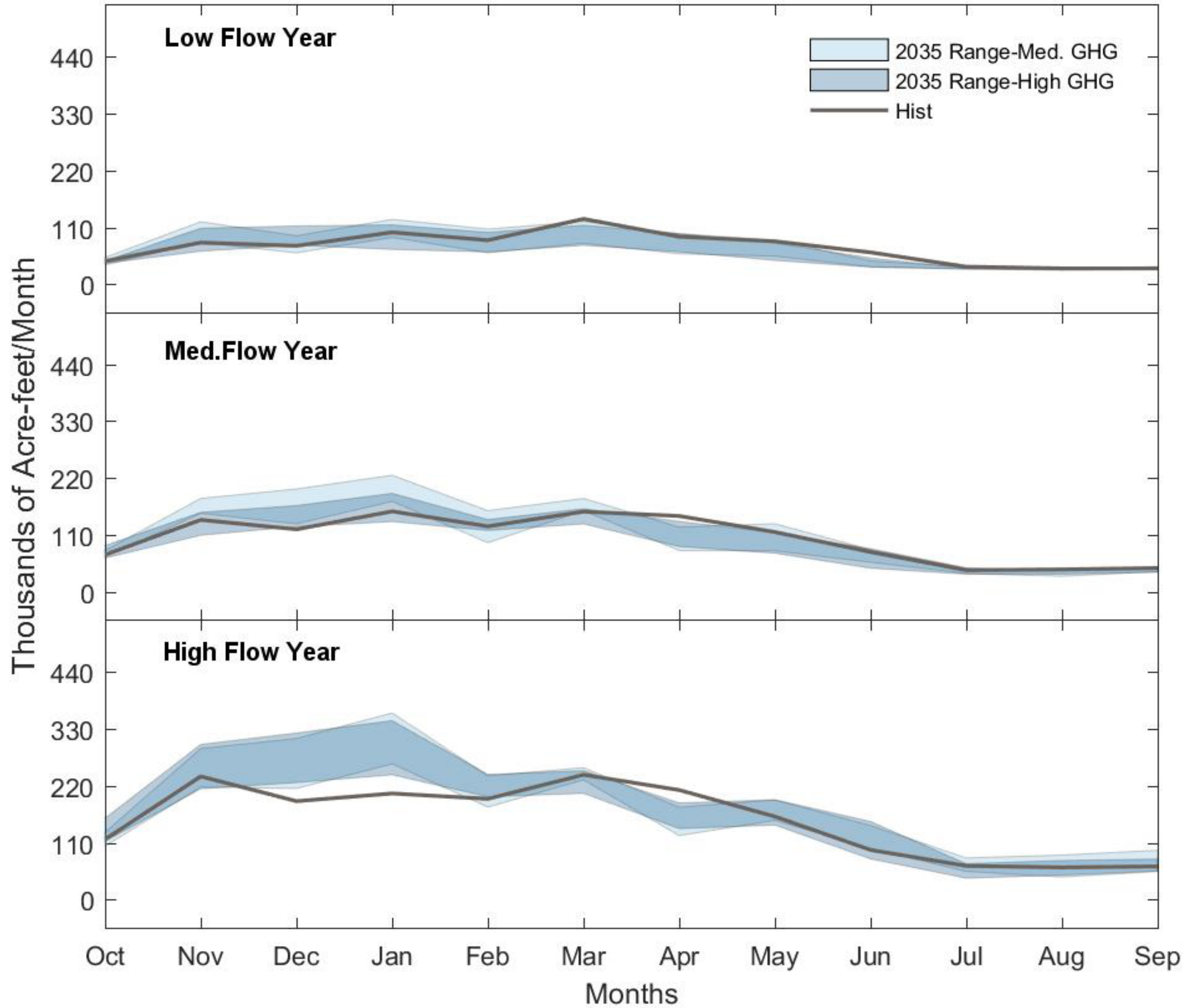
Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

WRIA 35

Middle Snake

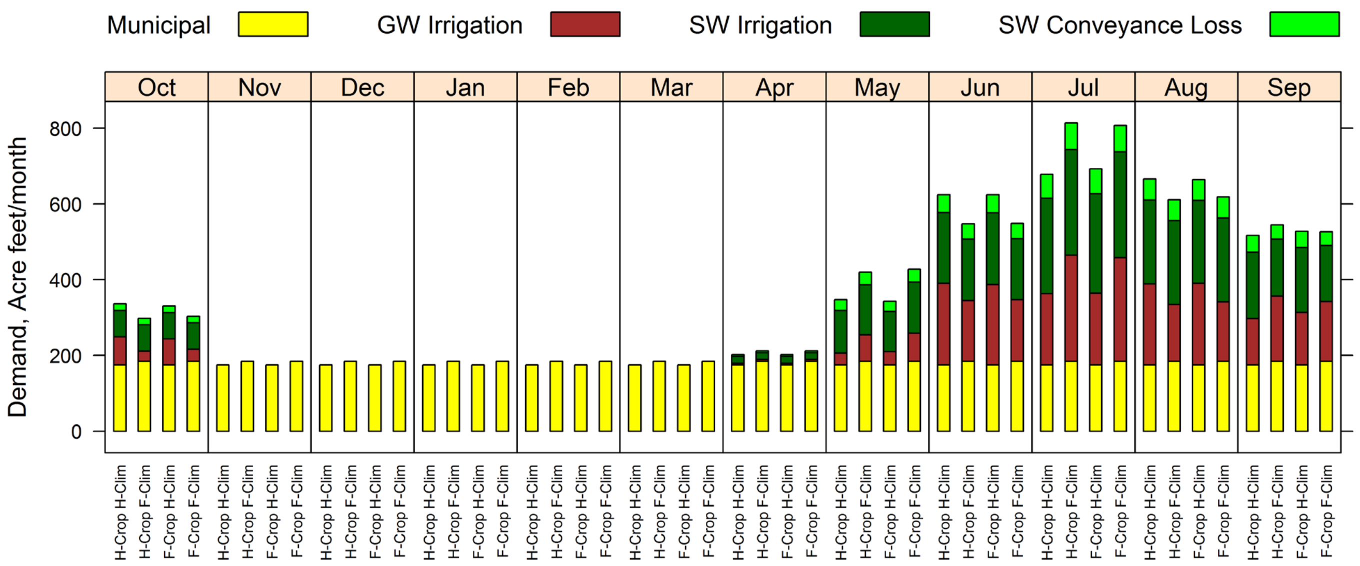
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

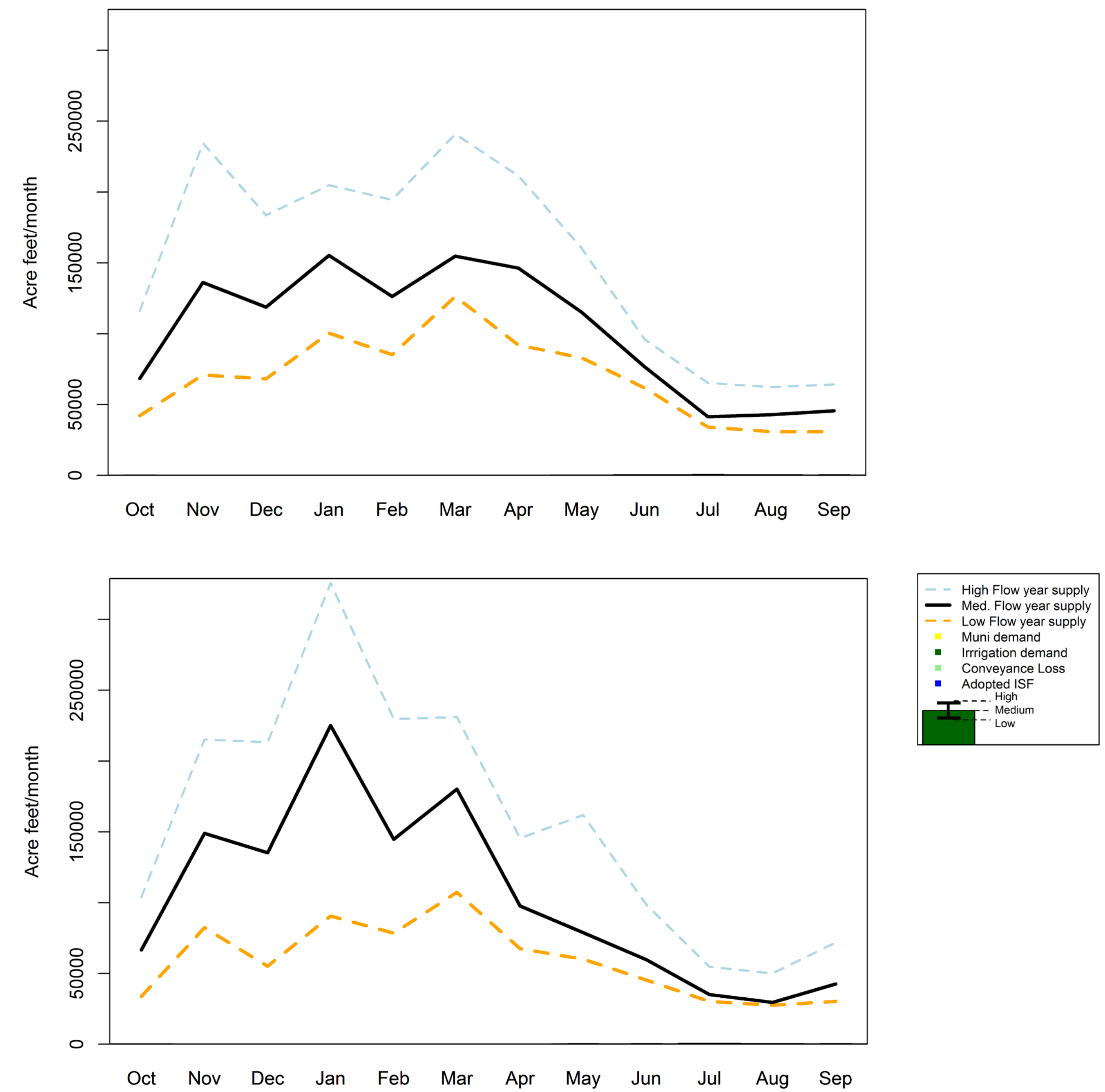


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Esquatzel Coulee shows little change, with possible slight increases throughout the year but primarily from September through January.
- Irrigation is the most significant source of demand. Municipal demands are quite small in comparison, though larger than those of many other eastern Washington WRIAs.
- Assuming no change in irrigated acreage, irrigation demand is expected to increase in April and May, but decrease in other future months. Decrease in demand in July is primarily contributed from climate change while in August and September from both climate change and crop mix change. Because of declining groundwater in the Odessa area, some irrigation demand is forecasted to shift by 2035 from groundwater to surface water.

PLACEHOLDER

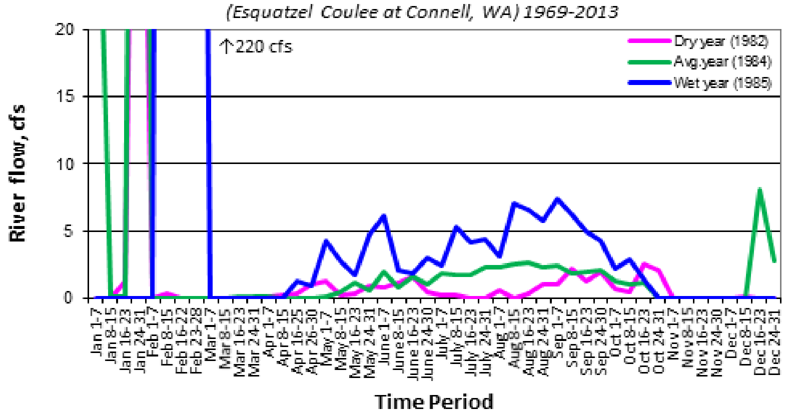
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	NO
Watershed Planning	NO
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	[Columbia mainstem migratory corridor]
Groundwater Management Area	YES (Columbia Basin GWMA and Odessa Subarea)

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

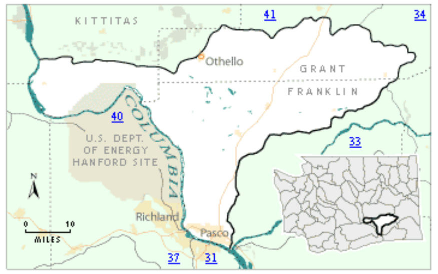
Esquatzel Coulee Dry, Average and Wet Years Flow

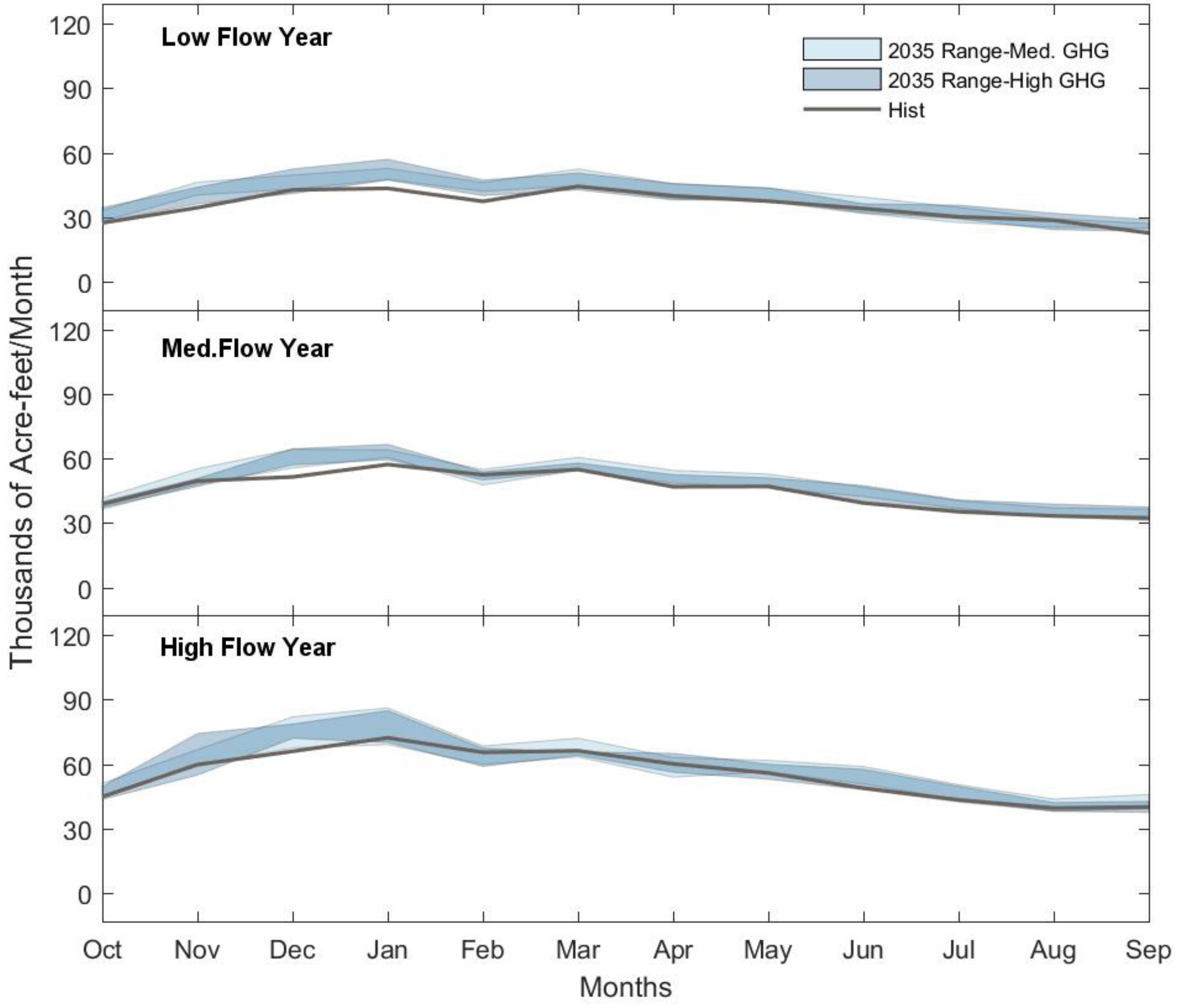
(Esquatzel Coulee at Connell, WA) 1969-2013



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

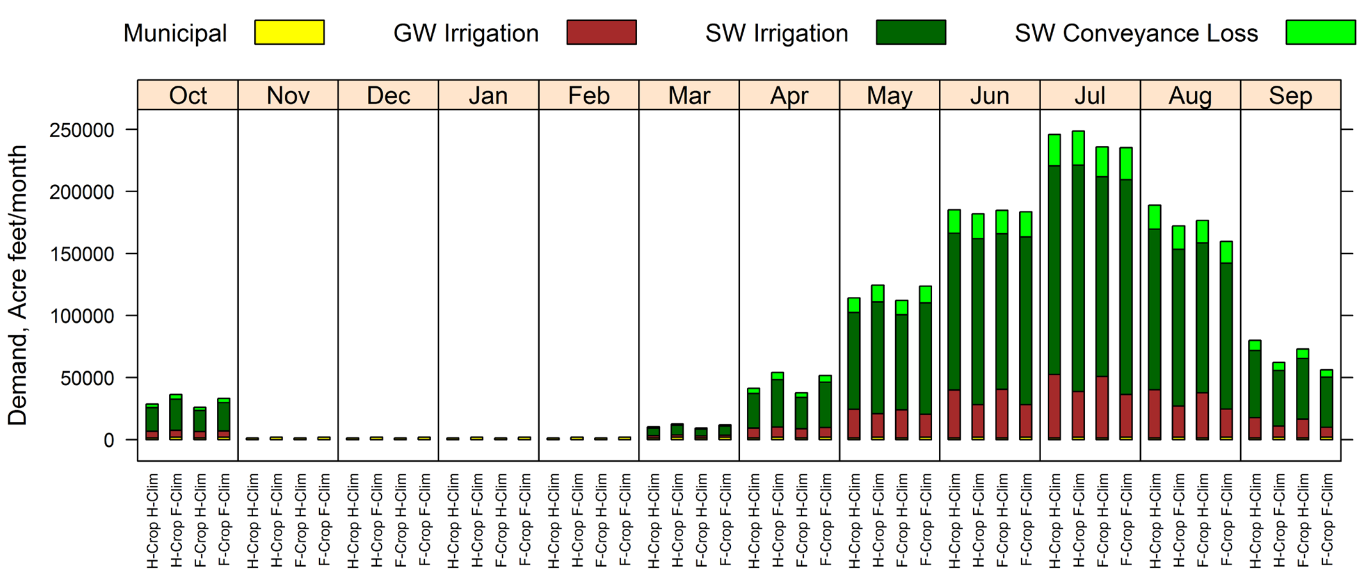
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

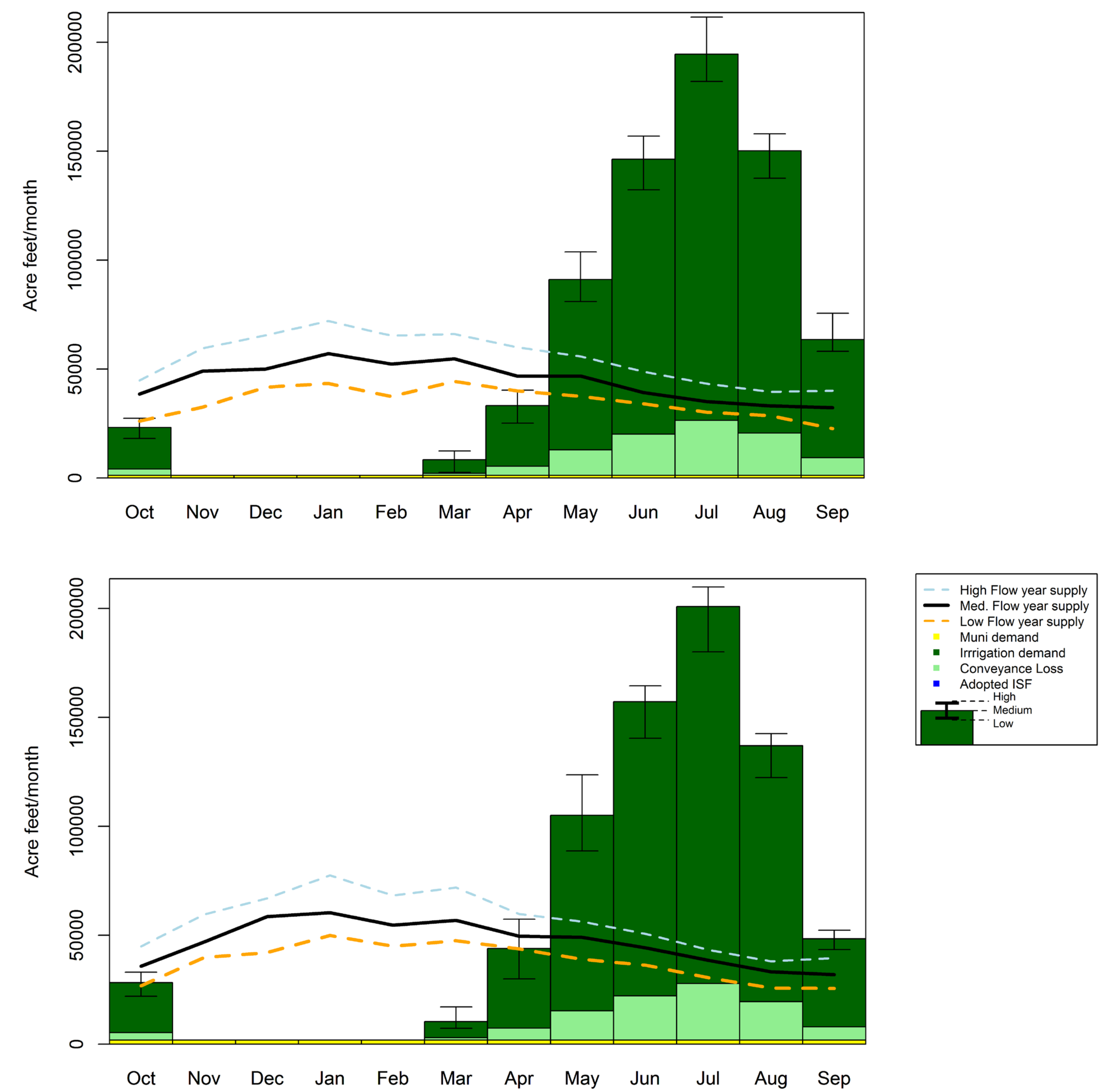


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

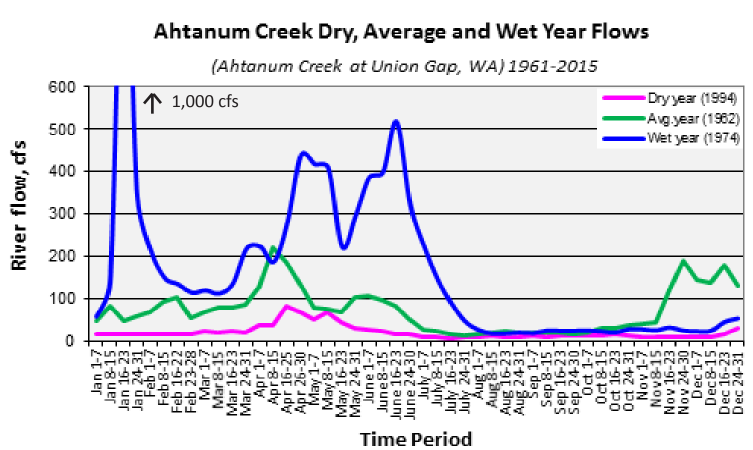
- The regulated tributary surface water supply forecast for the Yakima is characterized by increases from November through March, followed by decreases primarily in May and June.
- Irrigation is the primary source of demand in these WRIAs. Federal flow targets, shown for Yakima River at Parker for both the historical and the future case, are also important. While small in comparison with irrigation demands, municipal demands in WRIA 37 are significantly larger than most other WRIAs of eastern Washington.
- Assuming no change in irrigated acreage, irrigation demand is forecasted to increase during March through May and decrease during June through September. These changes are somewhat equally due to both climate and crop mix changes.
- Municipal demand is projected to grow by 17%, 9%, and 10% for WRIAs 37, 38, and 39, respectively, by 2035.
- These WRIAs are included in the Columbia River Instream Atlas (Ecology Publication in preparation), which contains information on instream water demands for 12 WRIAs that provide habitat for ESA-listed anadromous salmonids.

PLACEHOLDER

Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Ahtanum Creek, Cowiche Creek, Wenas Creek, Tenaway River, Cooke Creek, Big Creek, Basin-wide adjudication in process
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	NO (Target flows, enacted by Congress, and instream flow tribal treaty rights, affirmed by the Yakima Superior Court, are in place, both managed by the U.S. Bureau of Reclamation)
Fish Listed Under the Endangered Species Act[1]	Bull Trout, Middle Columbia Steelhead, [WRIA 37 is also Columbia mainstem migratory corridor]
Groundwater Management Area	YES (Upper Kittitas Groundwater Rule and Lower Yakima Valley Groundwater Management Area). For additional information on groundwater decline areas within WRIA 37, see Module xx.

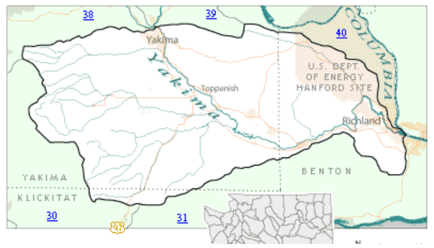
[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

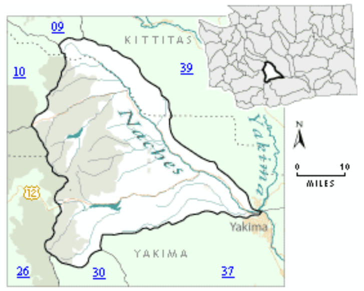


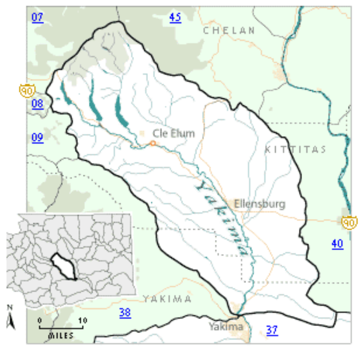
A table showing salmon, steelhead, and bull trout use of WRIA waters (provided by the Washington Department of Fish and Wildlife (WDFW)) is available on page 168. Summaries are also available online at http://apps.wdfw.wa.gov/salmonscape/.

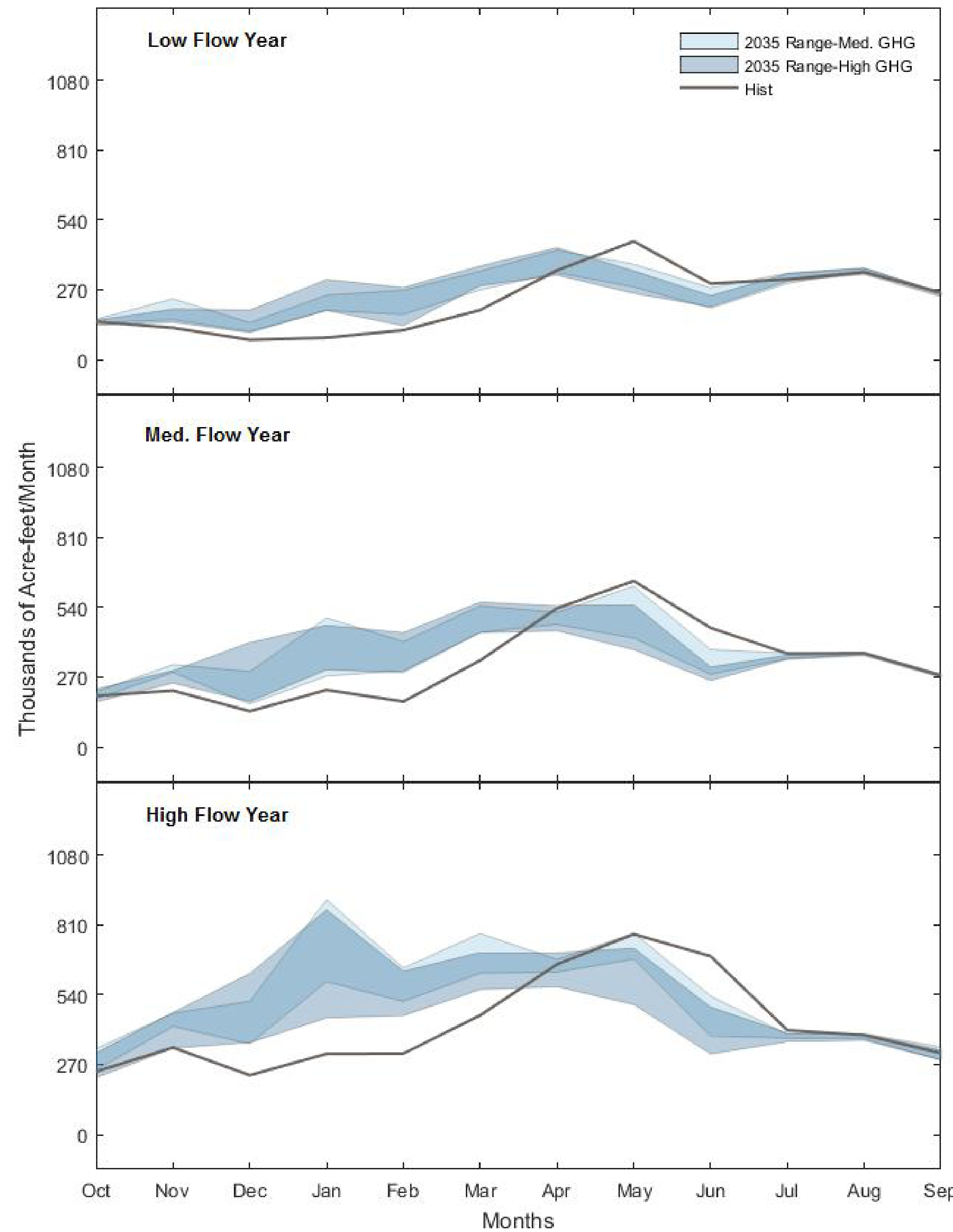
Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

SUPPLY





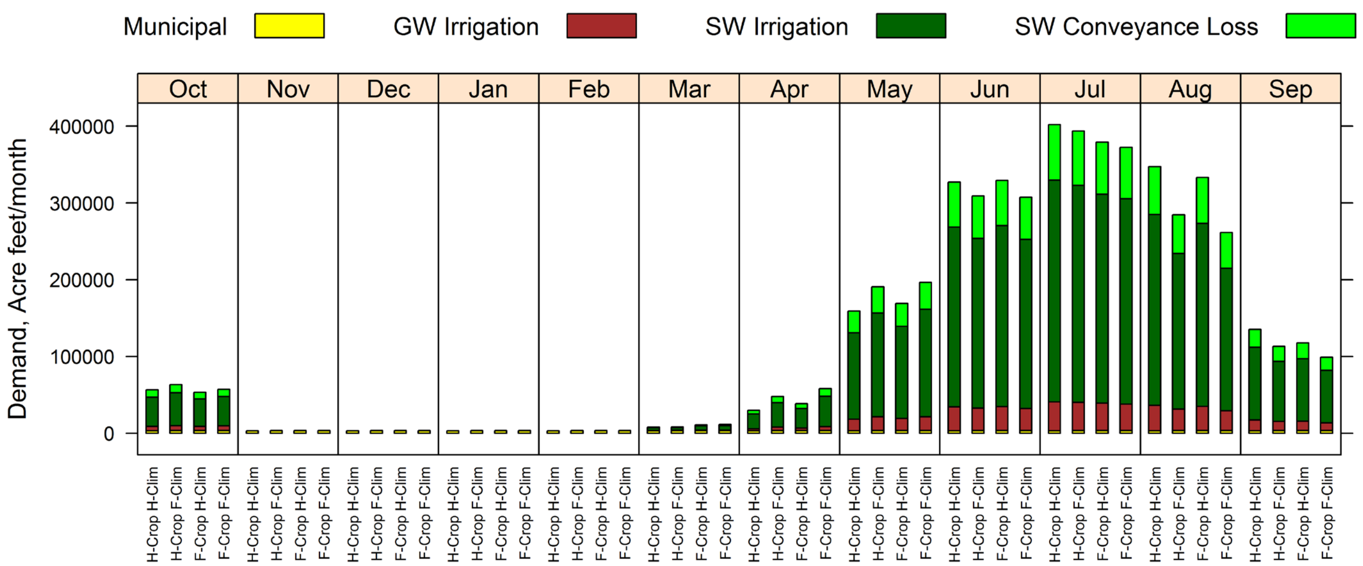




Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

Lower Yakima, Naches & Upper Yakima

DEMAND



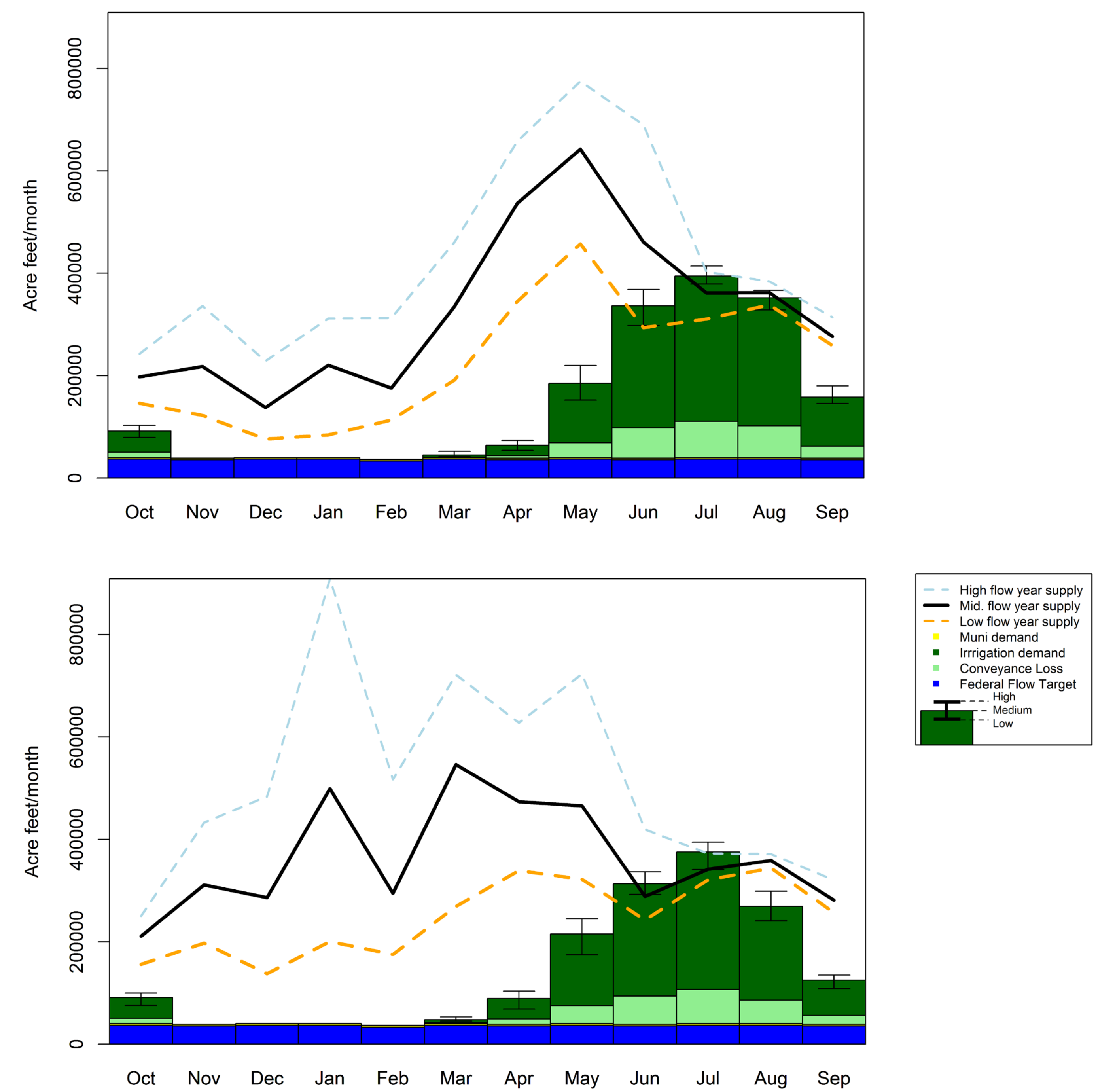
Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

DRAFT
WRIA 37, 38, 39

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Alkali-Squilchuck and Stemilt Squilchuck is characterized by small increases from late fall through winter, and decreases from Spring through mid-Summer.
- Primary demands in these WRIAs are irrigation and municipal.
- Assuming no change in irrigated acreage, irrigation demand is forecasted to increase in April and May and decrease from June through September. These changes are primarily in response to climate change rather than crop mix changes.
- Municipal demands are expected to increase roughly 4%, a smaller increase than in many other WRIAs of eastern Washington.

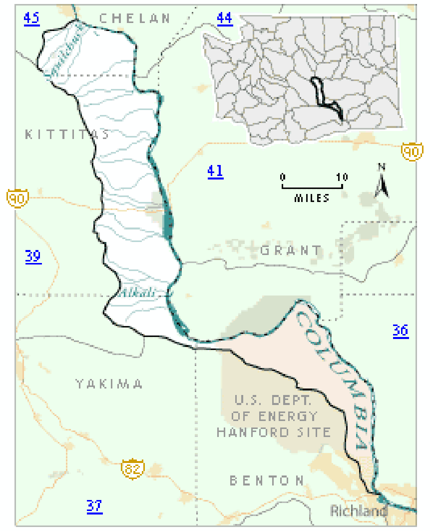
PLACEHOLDER

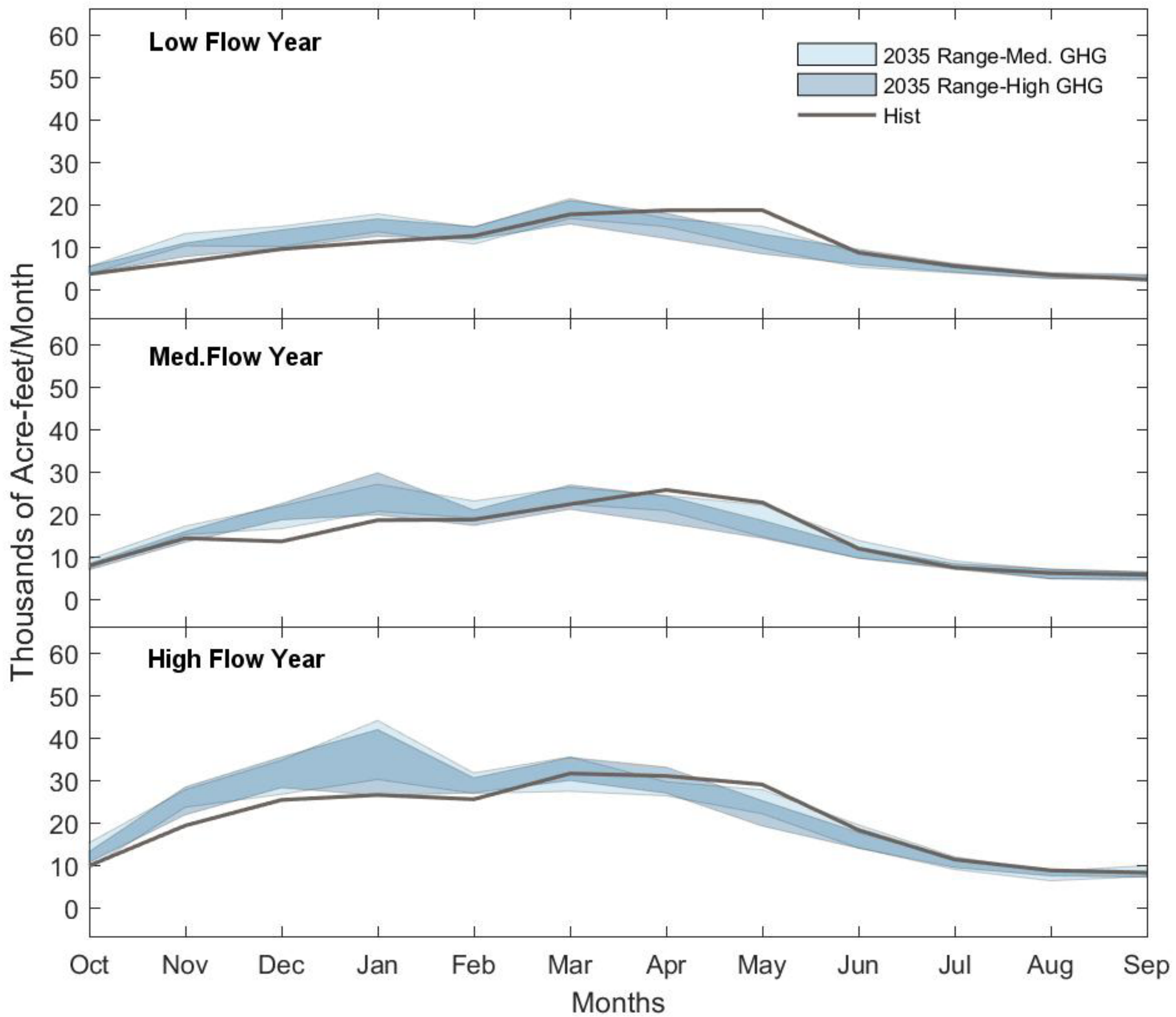
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Stemilt Creek, Squillchuck Creek, Cummings Canyon Creek
Watershed Planning	WRIA 40a: Phase 4 (Implementation), WRIA 40: NO
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	[Columbia mainstem migratory corridor]
Groundwater Management Area	YES (references listed in WSU's technical report)

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

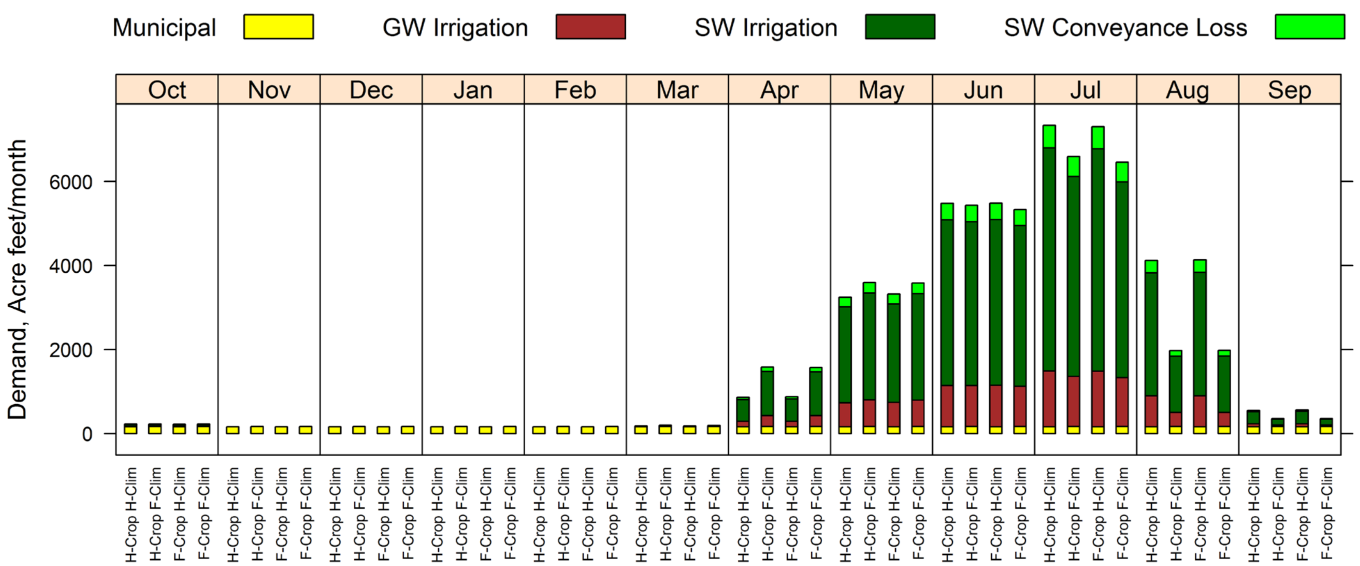
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND



Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

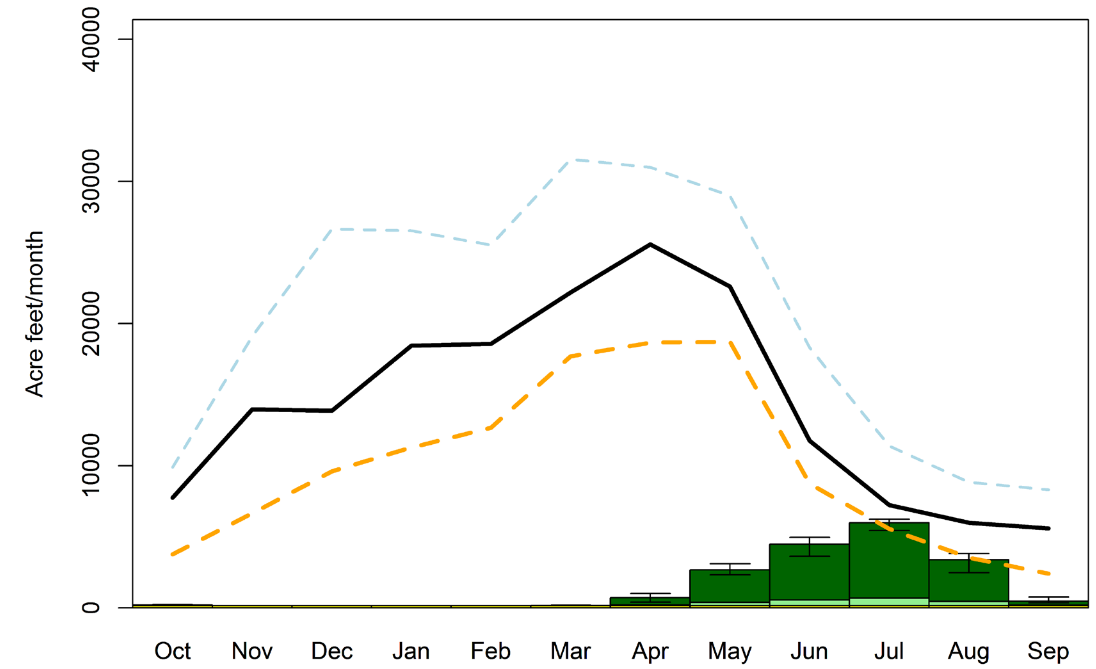
PLACEHOLDER

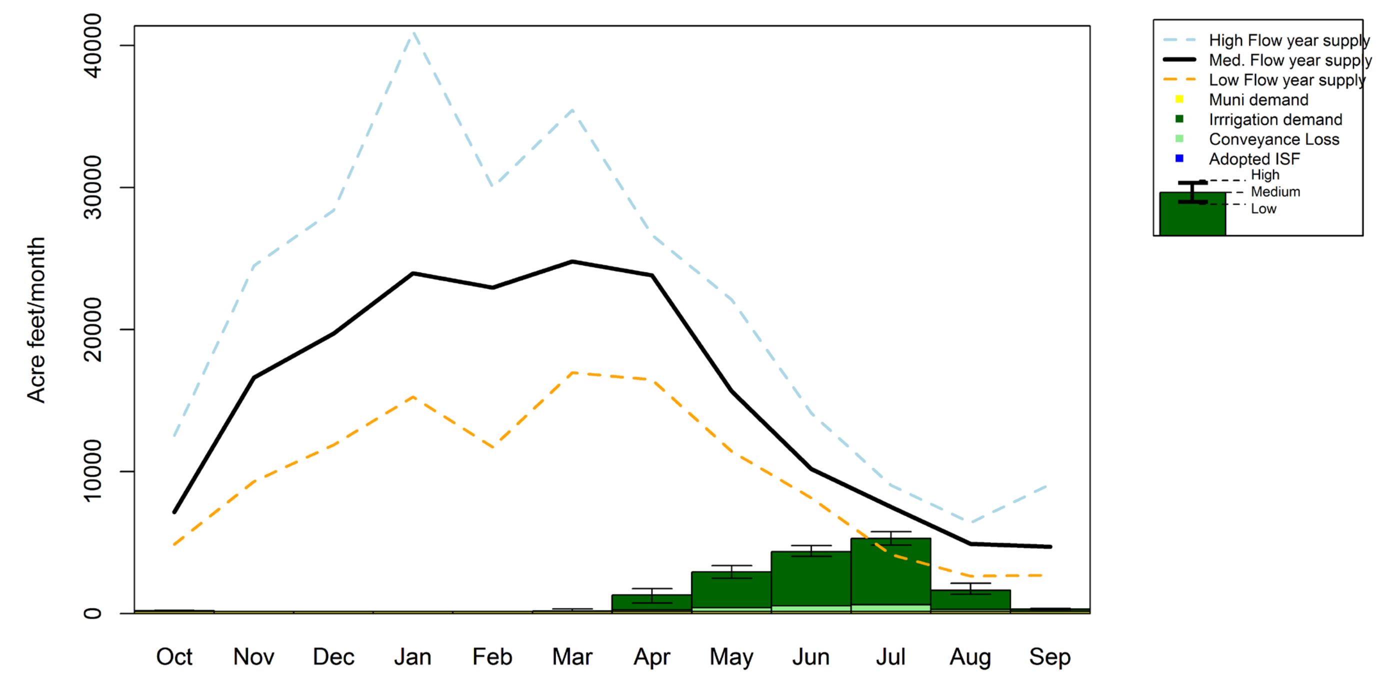
Awaiting Results

DRAFT

WRIA 40 & 40A

SUPPLY & DEMAND





Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

Alkali-Squilchuck & Stemilt-Squilchuck

DRAFT - ALL RESULTS ARE PRELIMINARY AND SUBJECT TO CHANGE

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Lower Crab is characterized mostly by increases from November through January for all percentiles, and in February for the 20th and 50th percentiles. The remaining months are less certain with a combination of increases and decreases, depending on climate scenario.
- Irrigation is the primary source of demand, with much smaller municipal demands.
- Assuming no change in irrigated acreage, irrigation demand is projected to increase in April, May and July with decrease in rest of the months. Increasing change is primarily contributed from the climate change. Because of declining groundwater in the Odessa area, some irrigation demand is forecasted to shift by 2035 from groundwater to surface water. Municipal demands are projected to grow by 35% by 2035.

PLACEHOLDER

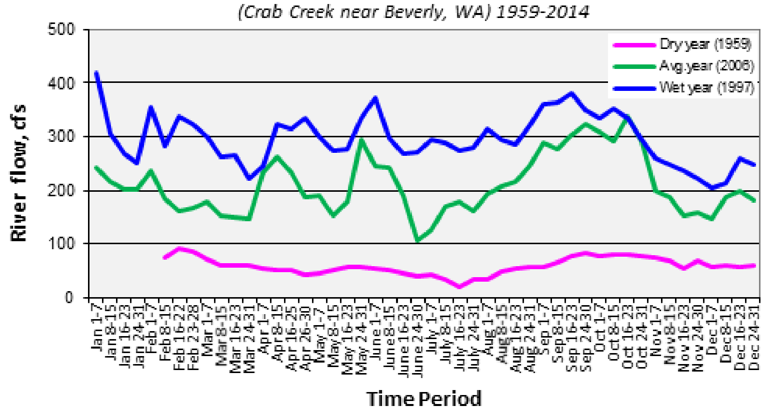
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Crab Creek & Moses Lake
Watershed Planning	NO
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	No ESA-listed fish spawn or rear in WRIA waters
Groundwater Management Area	YES (Columbia Basin GWMA, Odessa Subarea, and Quincy Subarea. For additional information on groundwater decline areas within this WRIA, see Module xx.

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

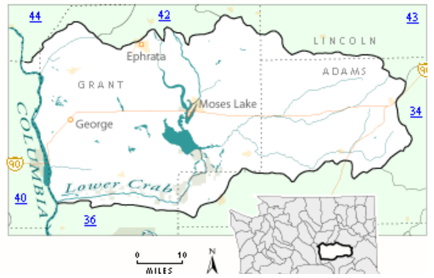
Crab Creek Dry, Average and Wet Year Flows

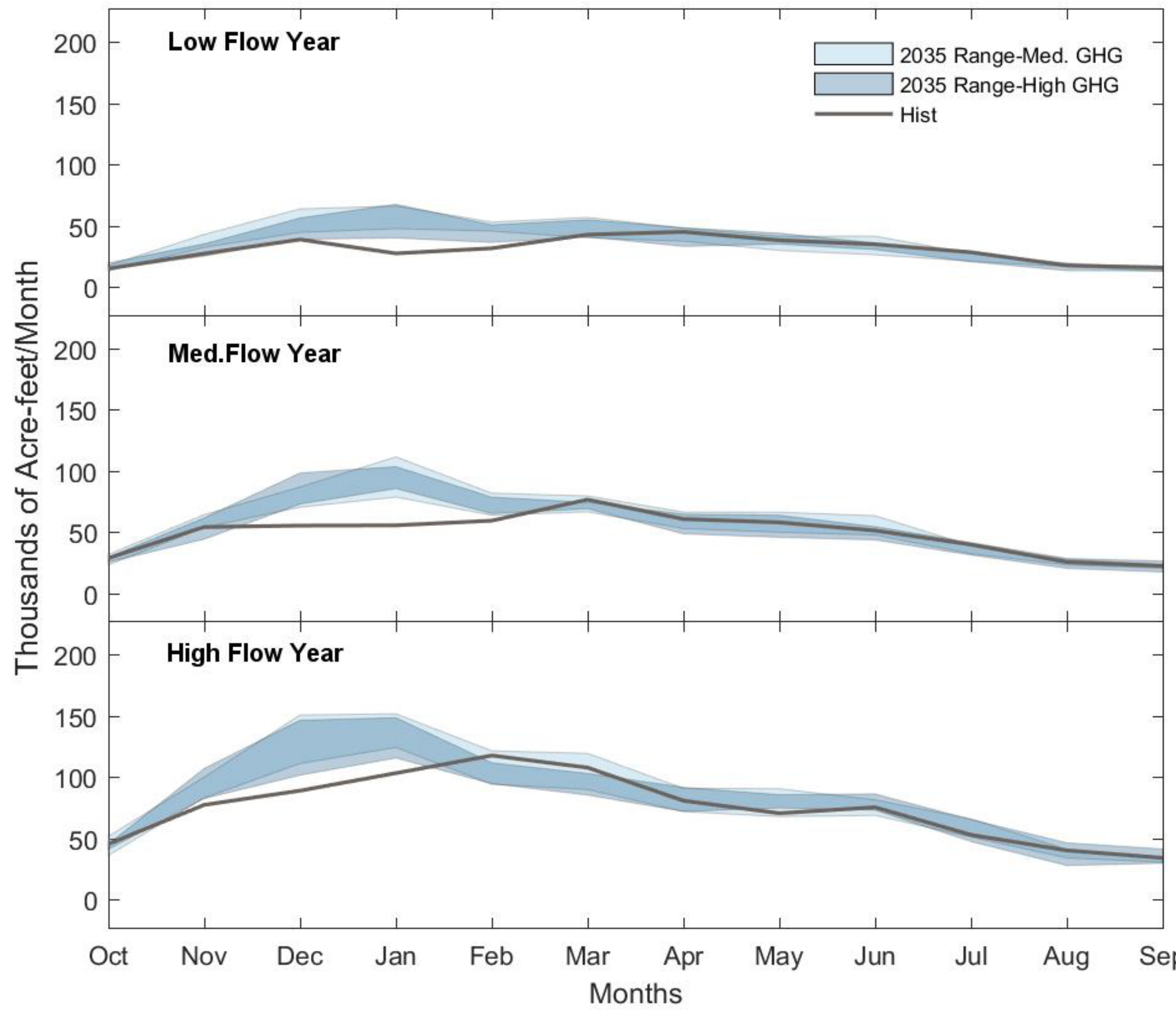
(Crab Creek near Beverly, WA) 1959-2014



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

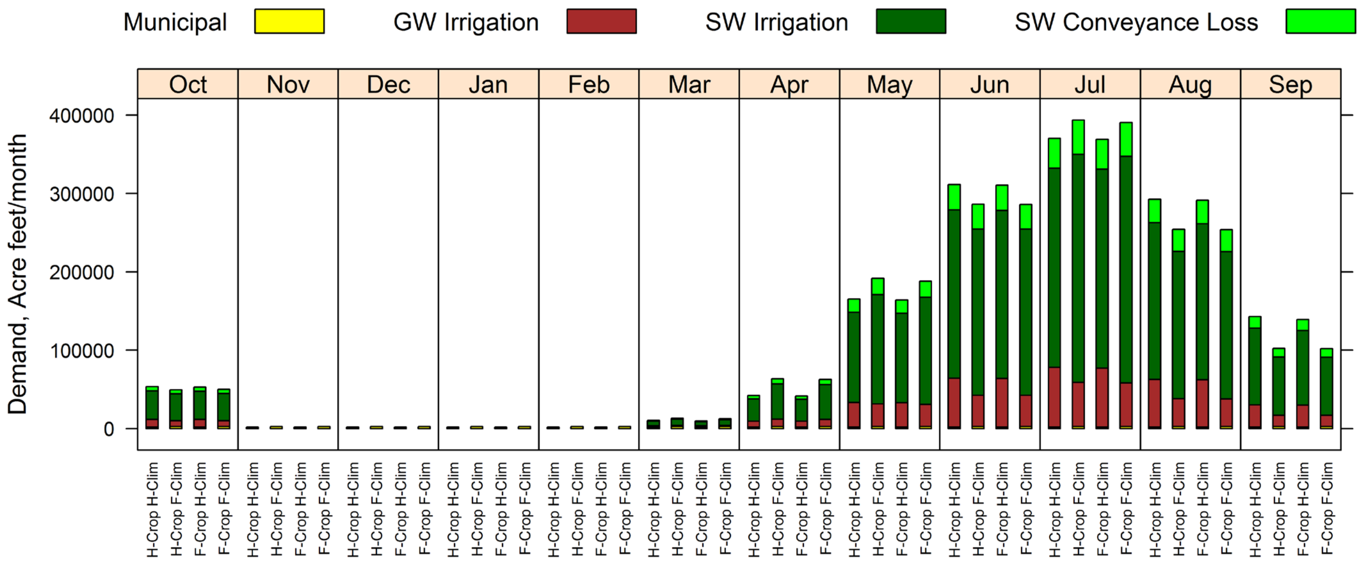
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND



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PLACEHOLDER

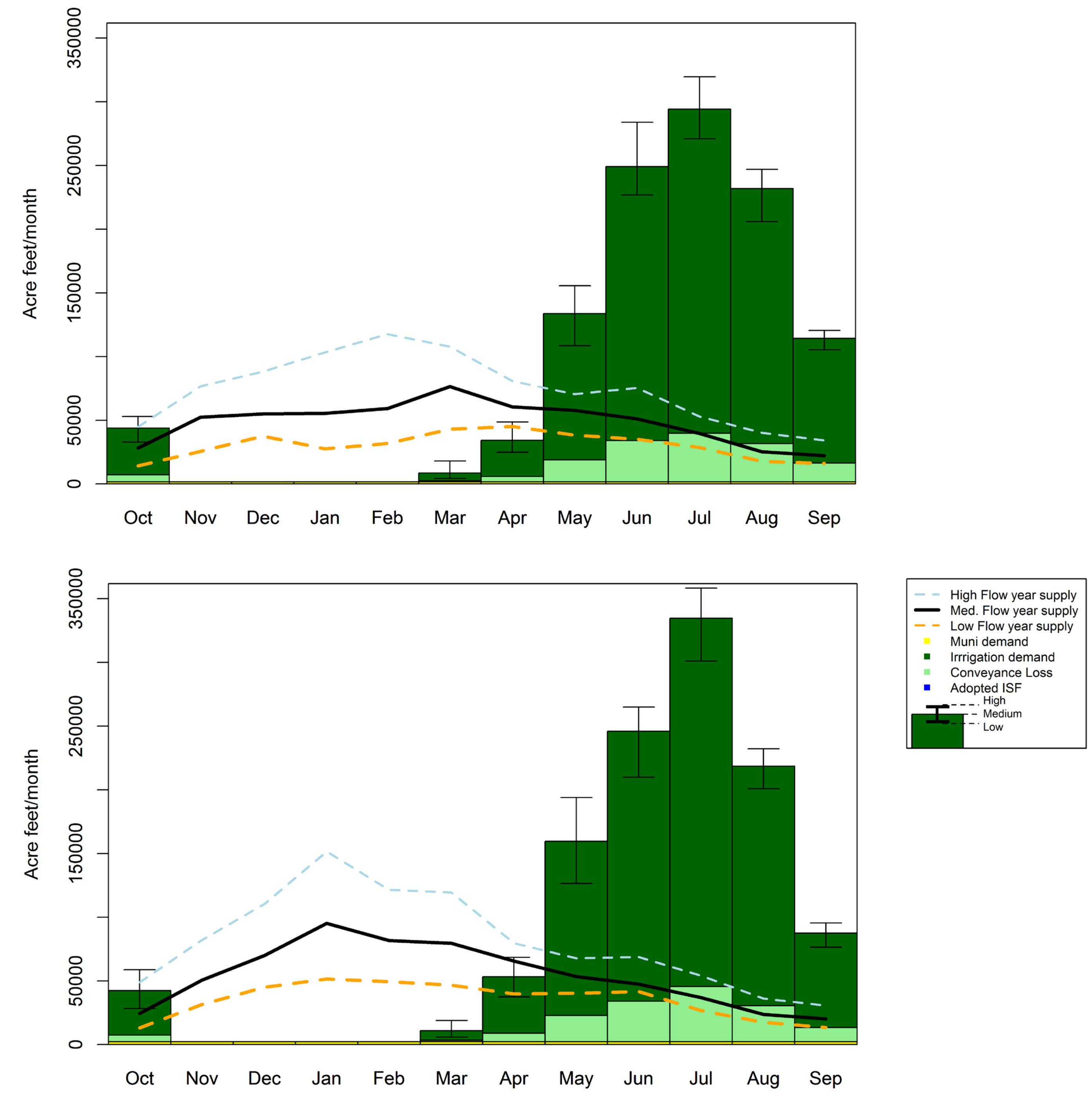
Awaiting Results

DRAFT

WRIA 41

Lower Crab

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

DRAFT - ALL RESULTS ARE PRELIMINARY AND SUBJECT TO CHANGE

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Grand Coulee is characterized mostly by increases from November through January for all percentiles, and in February as well for the 20th and 50th percentiles. The other months are less certain with a combination of increases and decreases, depending on climate scenario.
- As in many other WRIAs of eastern Washington, municipal demands are much smaller than irrigation demands.
- Assuming no change in irrigated acreage, irrigation demands are forecasted to increase in some months in the future and decrease in others. Increase in demand in April, May and July is primarily in response to climate change while crop changes mostly contributed to decrease. Because of declining groundwater in the Odessa area, some irrigation demand is forecasted to shift by 2035 from groundwater to surface water. Municipal demands are projected to grow by 15%, a smaller increase than in many other watersheds of eastern Washington.

PLACEHOLDER

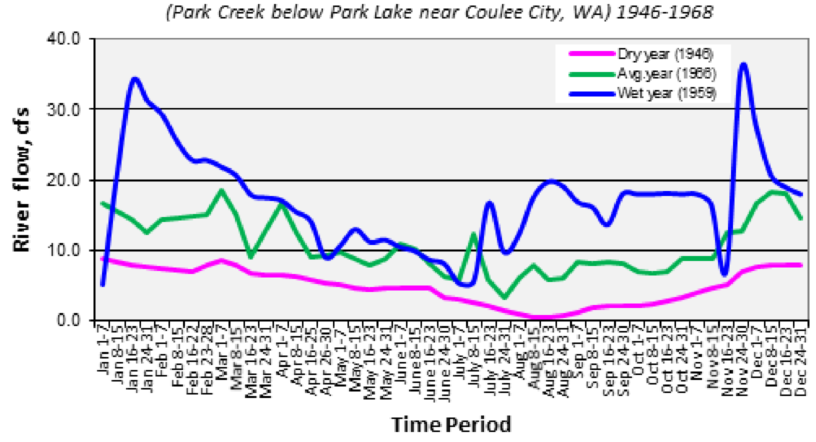
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	NO
Watershed Planning	NO
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	No ESA-listed fish spawn or rear in WRIA waters
Groundwater Management Area	YES (Columbia Basin GWMA, Quincy Subarea and small portion of Odessa Subarea)

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

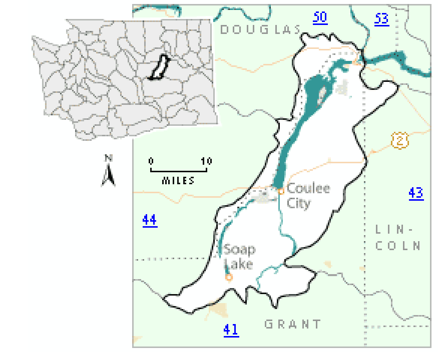
Park Creek Dry, Average and Wet Year Flows

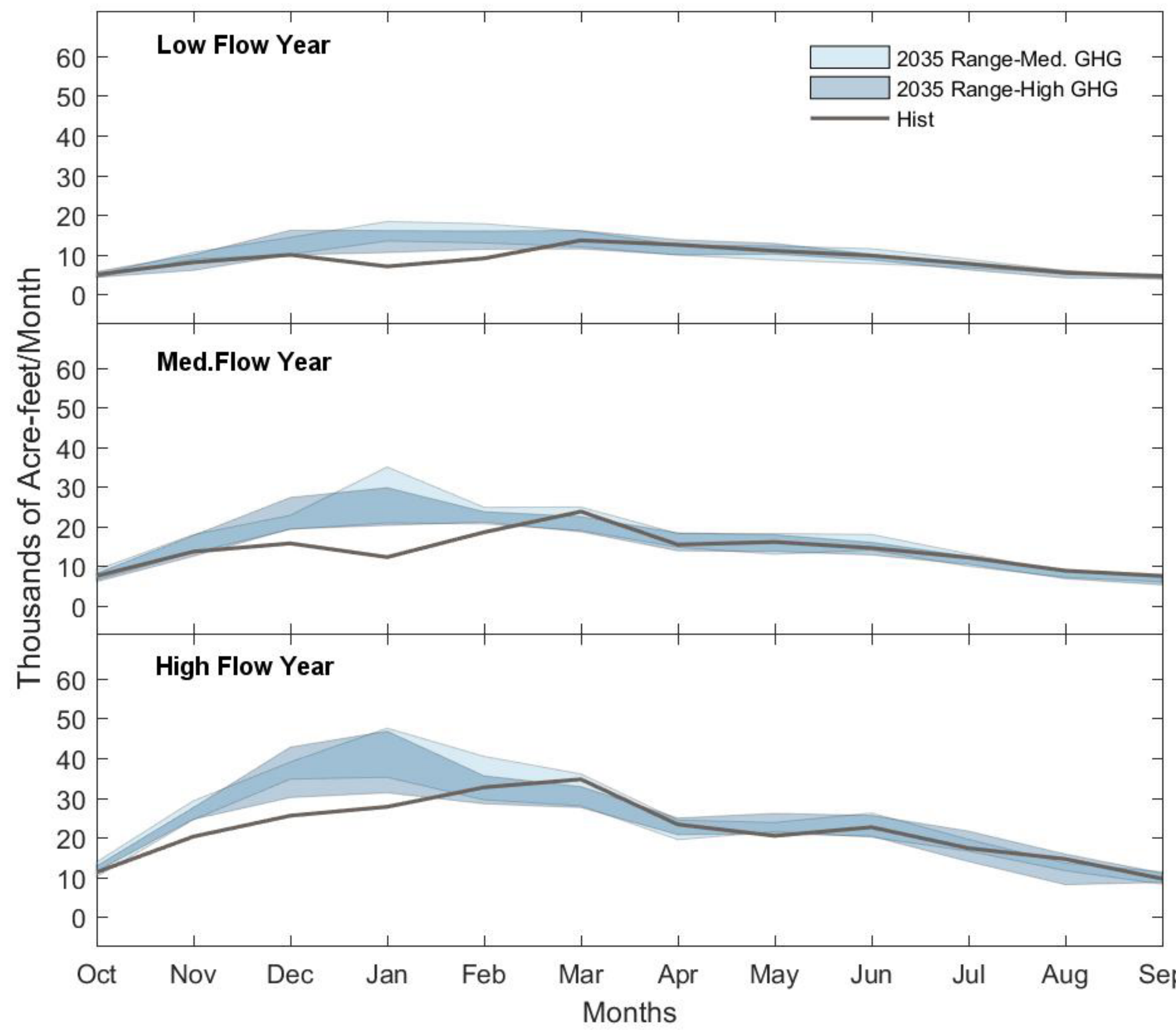
(Park Creek below Park Lake near Coulee City, WA) 1946-1968



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

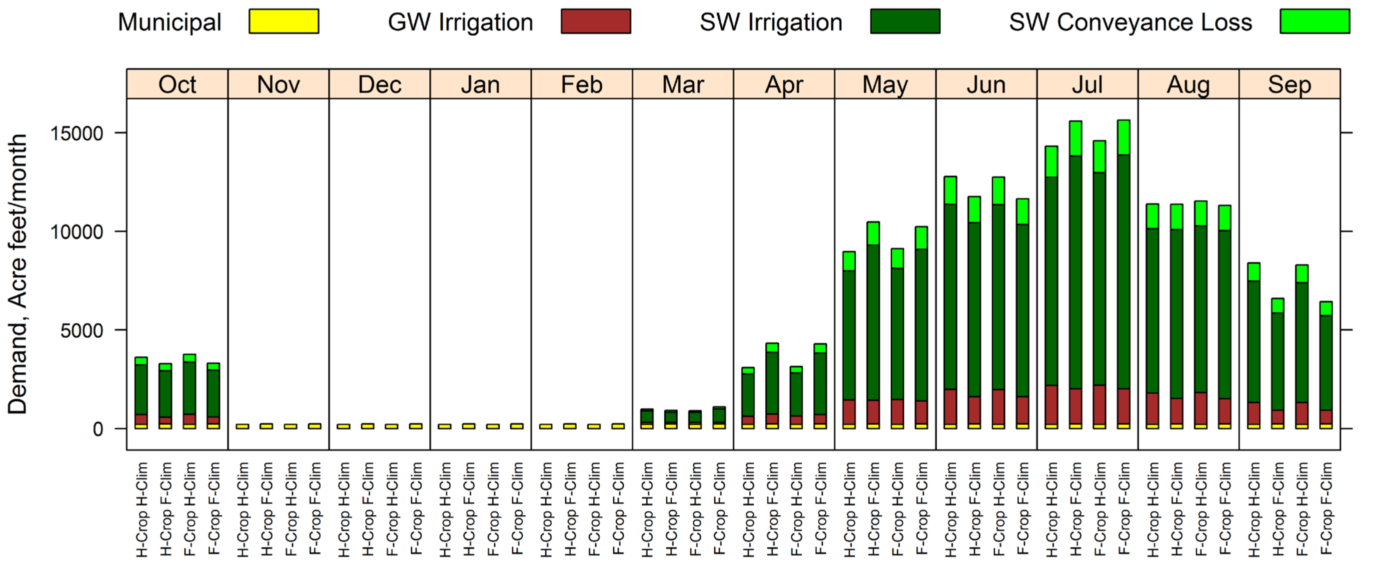
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

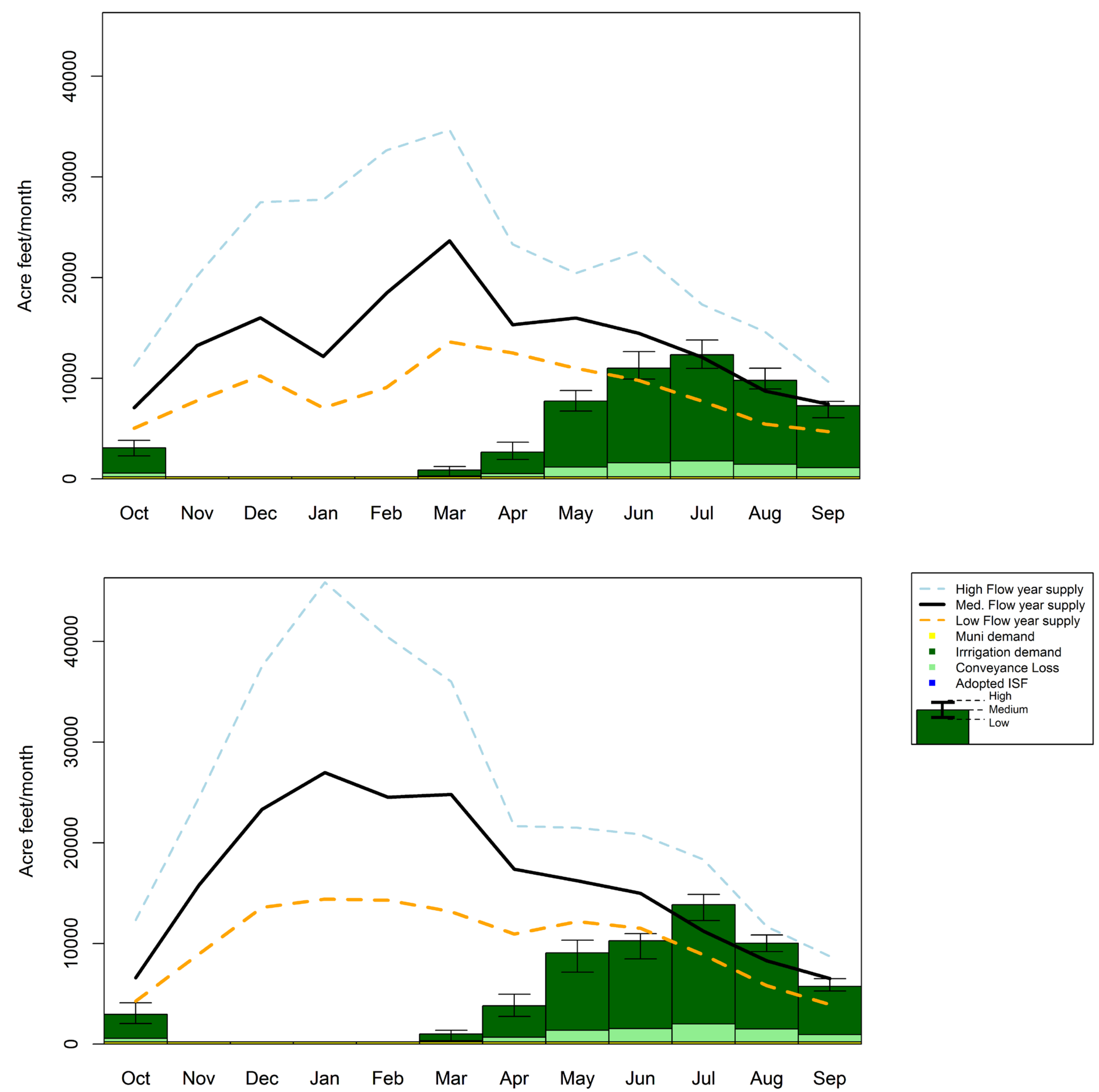


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Upper Crab-Wilson is characterized mostly by increases from October through January for the 80th year percentile year, and in January and February for the 20th and 50th percentiles. The other months are less certain with a combination of increases and decreases, depending on climate scenario.
- As in many other WRIAs of eastern Washington, municipal demands are much smaller than irrigation demands.
- Assuming no change in irrigated acreage, irrigation demands are forecasted to increase substantially in all months in the future. These changes are primarily due to climate changes. Because of declining groundwater in the Odessa area, irrigation demand is forecasted to shift by 2035 from predominantly groundwater to nearly all surface water.
- Municipal demands are projected to shrink by 1%, the only WRIA in eastern Washington for which we projected a decrease based upon population projections.

PLACEHOLDER

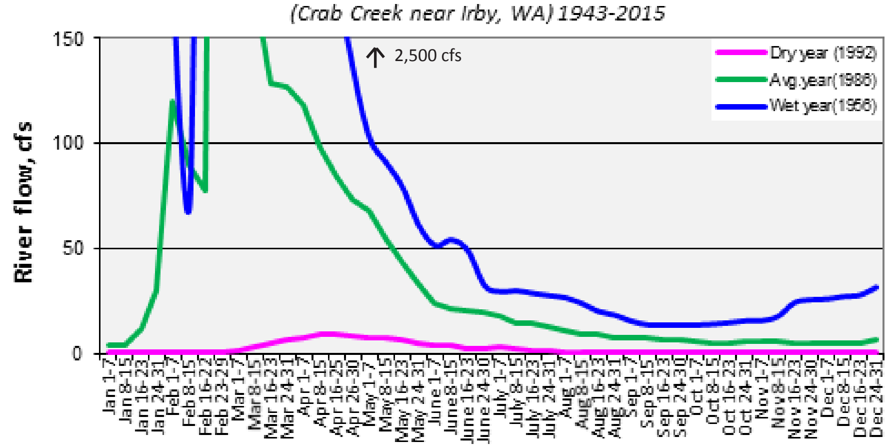
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Crab Creek between Sylvan Lake & Odessa , Crab Creek, South Fork
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	No ESA-listed fish spawn or rear in WRIA waters
Groundwater Management Area	YES (references listed in WSU's technical report) For additional information on groundwater decline areas within this WRIA, see Module xx.

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

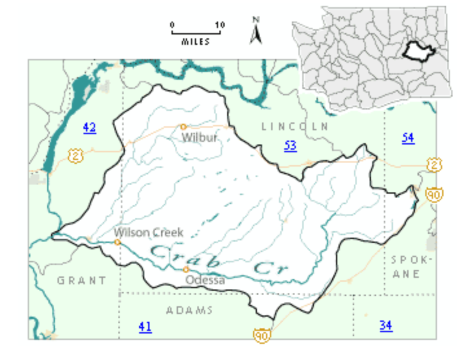
Crab Creek Dry, Average, Wet Year Flows

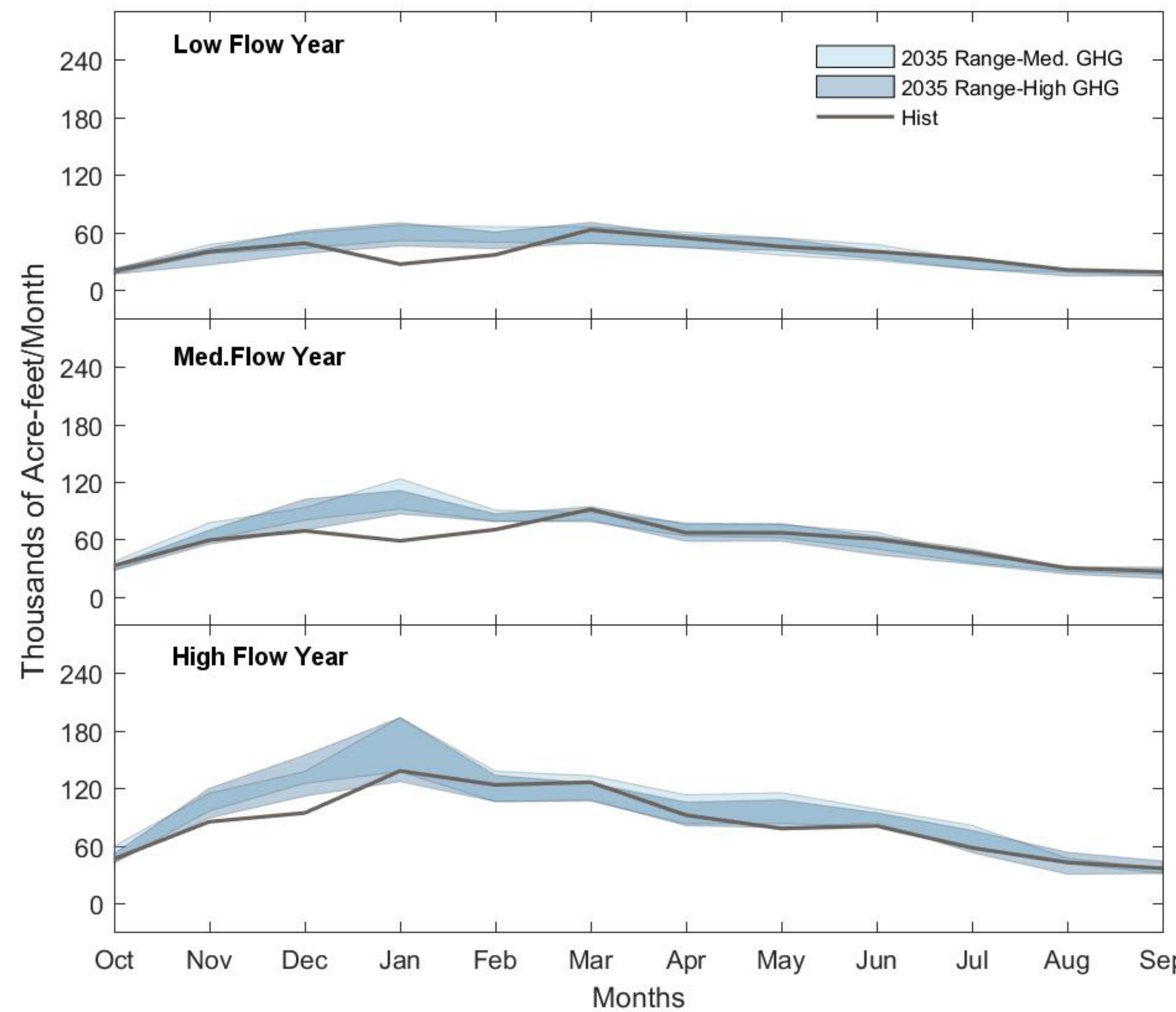
(Crab Creek near Irby, WA) 1943-2015



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

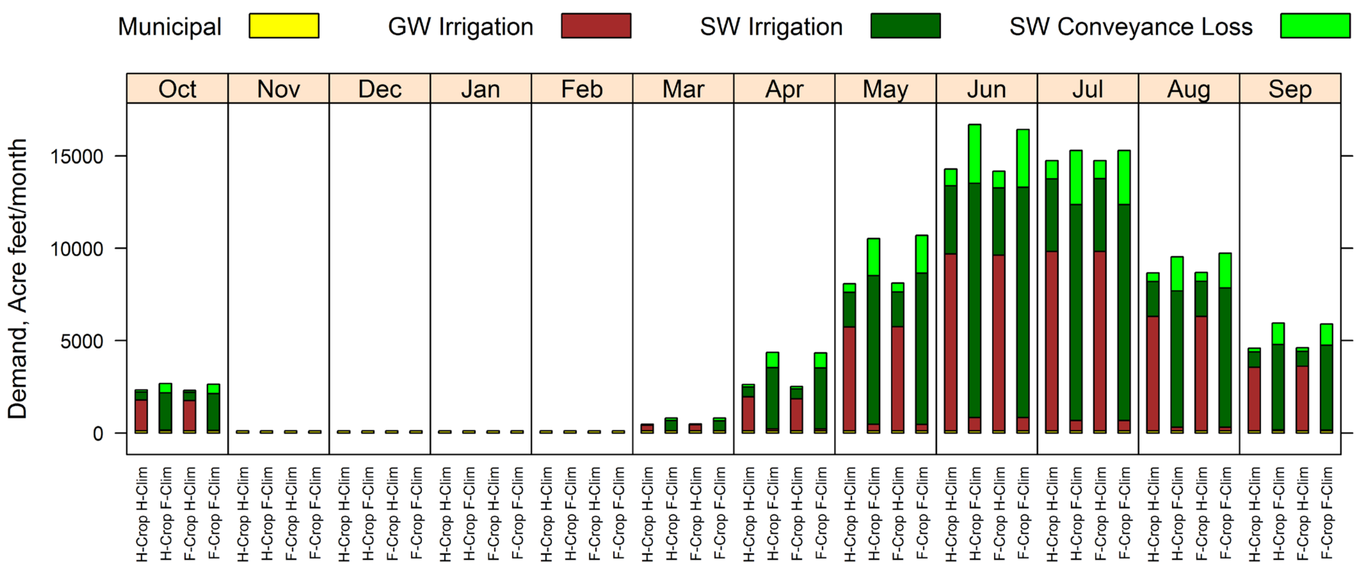
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

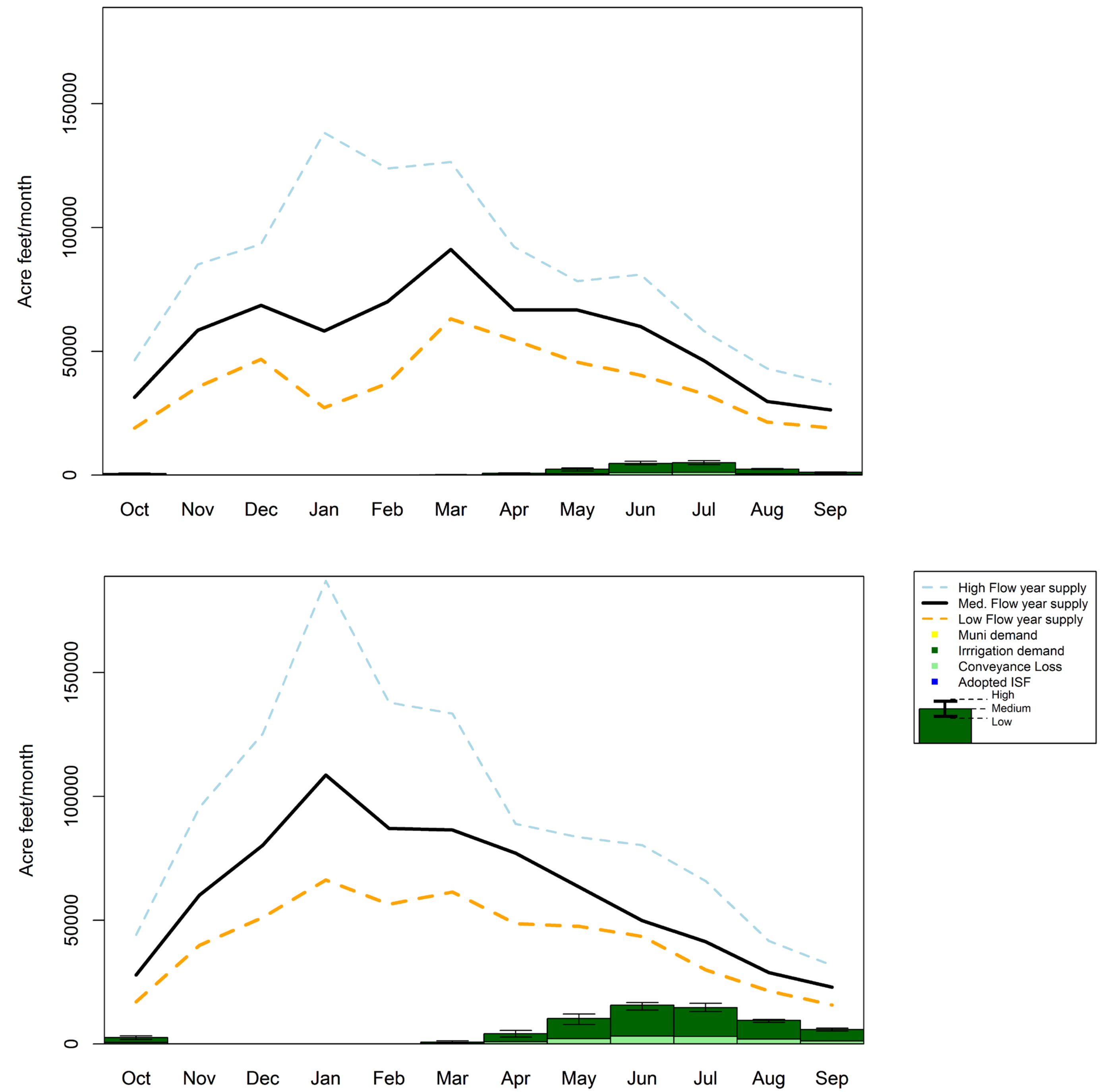


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) “H-Crop H-Clim”, b)”H-Crop F-Clim”, c)“F-Crop H-Clim”, and d) ”F-Crop F-Clim” where “H-Crop” represents historic crop mix; “F-Crop” as future crop mix under medium economic scenario,”H-Clim” as historic climate and “F-Clim” values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the “top of crop” and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Moses Coulee and Foster is characterized mostly by increases from late fall through winter and decreases in March for the 80th percentile supply year.
- As in many other watersheds of eastern Washington, municipal demands in these WRIAs are much smaller than irrigation demands.
- Assuming no change in irrigated acreage, irrigation demands are forecasted to increase in April and May and decrease from June through October. These changes are primarily in response to climate changes.
- Municipal demands are forecasted to grow by 11% and 21% for WRIAs 44 and 50, respectively, by 2035.
- WRIA 50 is included in the Columbia River Instream Atlas (Ecology Publication in preparation), which contains information on instream water demands for 12 WRIAs that provide habitat for ESA-listed anadromous salmonids.

PLACEHOLDER

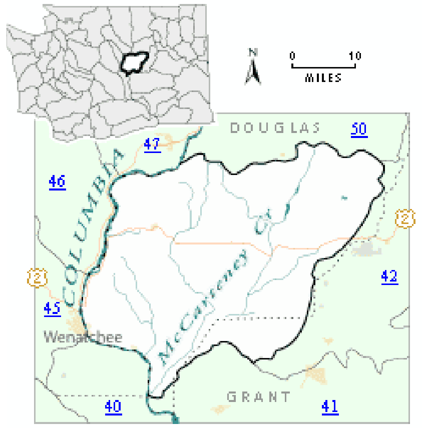
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

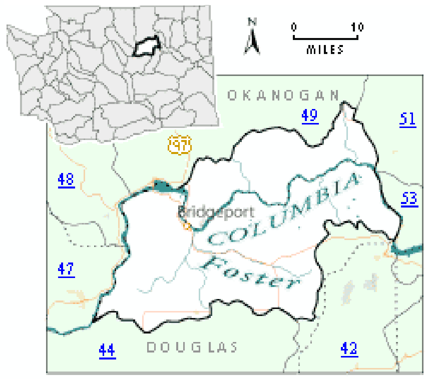
MANAGEMENT CONTEXT	
Adjudicated Areas	NO
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	WRIA 44: No ESA-listed fish spawn or rear in WRIA waters, WRIA 50: Upper Columbia River Spring Run Chinook, Upper Columbia Steelhead, [Columbia mainstem migratory corridor]
Groundwater Management Area	NO

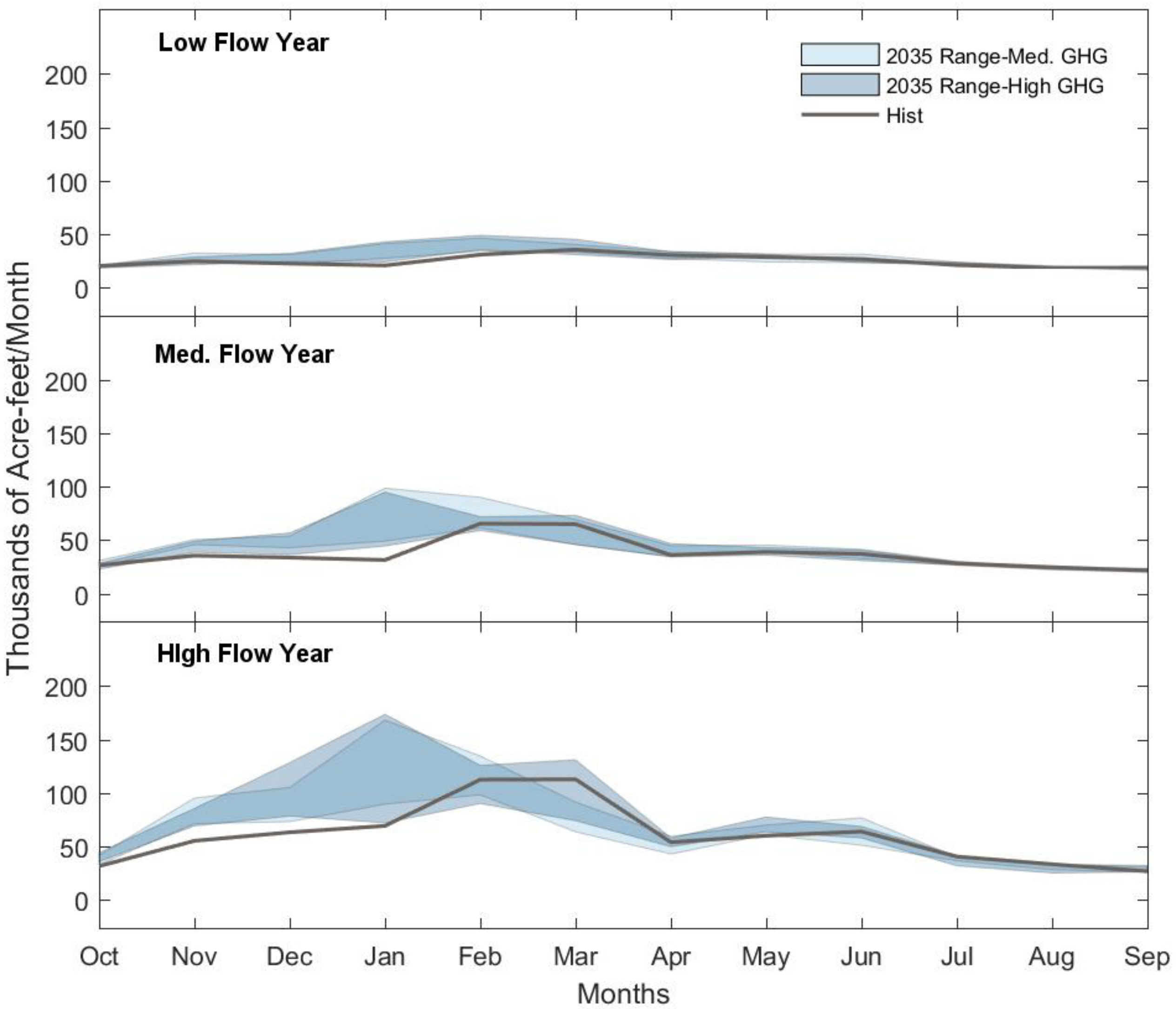
[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

DRAFT
WRIA 44 & 50

SUPPLY



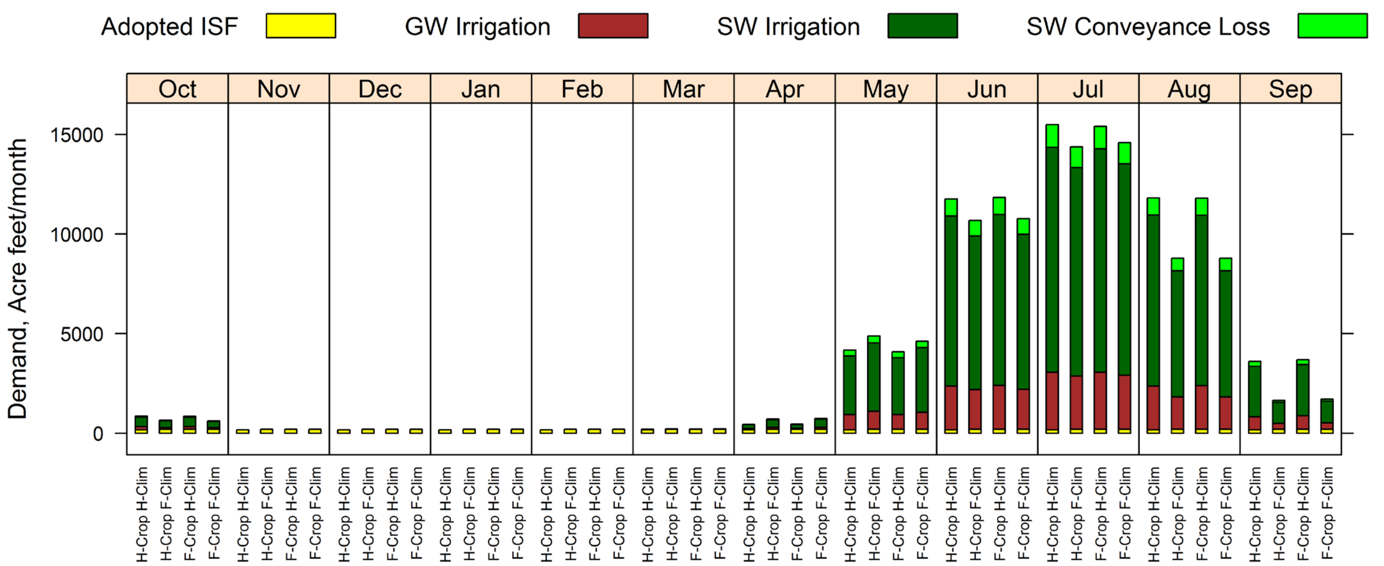




Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

Moses Coulee & Foster

DEMAND

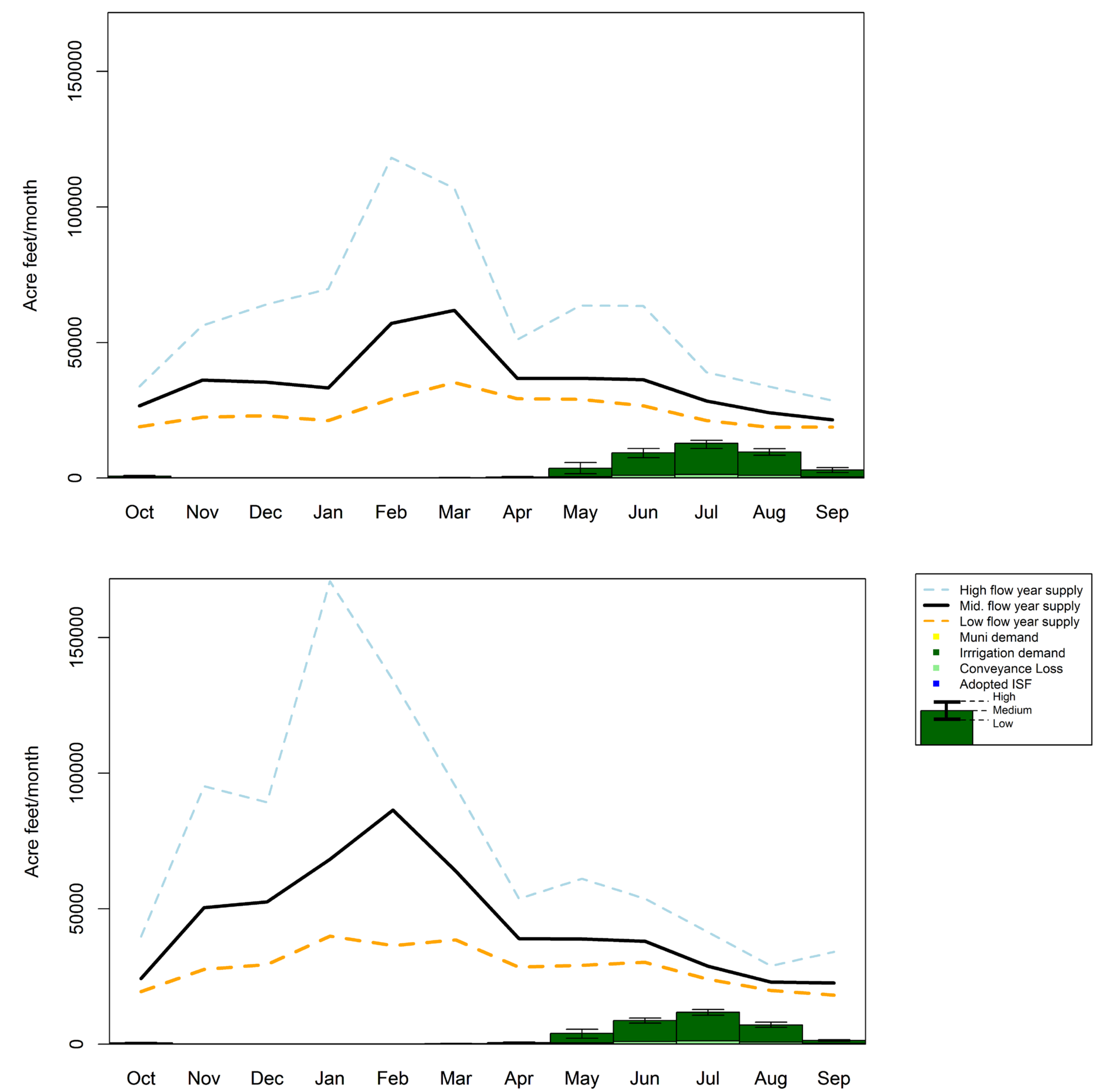


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Wenatchee is uncertain with a combination of both increases and decreases depending on climate scenario, with the exception of primarily decreases during the months of May through July for the 50th percentile supply years.
- Instream flow requirements are the largest water demand, which has smaller irrigation demands and even smaller municipal demands.
- Assuming no change in irrigated acreage, irrigation demand is projected to increase in May, with small change in June and July, and large decreases in August through October. The large decreases are in response to crop mix changes.
- Municipal demands are forecasted to increase by 11% by 2035.
- This WRIA is included in the Columbia River Instream Atlas (Ecology Publication in preparation), which contains information on instream water demands for 12 WRIAs that provide habitat for ESA-listed anadromous salmonids.

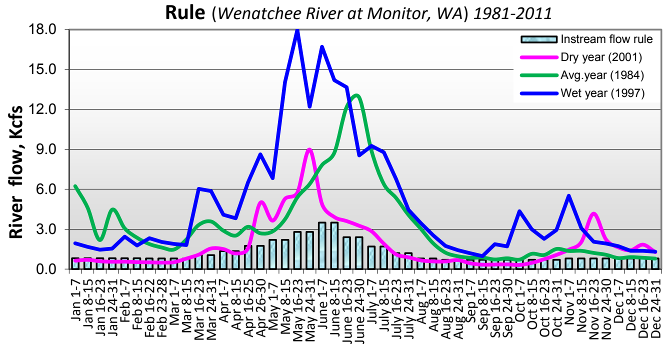
PLACEHOLDER

Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Icicle Creek, Joe Creek, Chumstick Creek, Nahahum Canyon
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	Yes (Chapter 173-545 WAC). 47 interruptible water rights curtailed periodically. Weekly frequency of interruption from 1984-2014 ranged from 0 to 5 years from November to June (80% to 100% reliable), and from 5 to 22 years from July to October (25% to 80% reliable).
Fish Listed Under the Endangered Species Act[1]	Bull Trout, Upper Columbia River Spring Run Chinook, Upper Columbia Steelhead [Columbia mainstem migratory corridor]
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

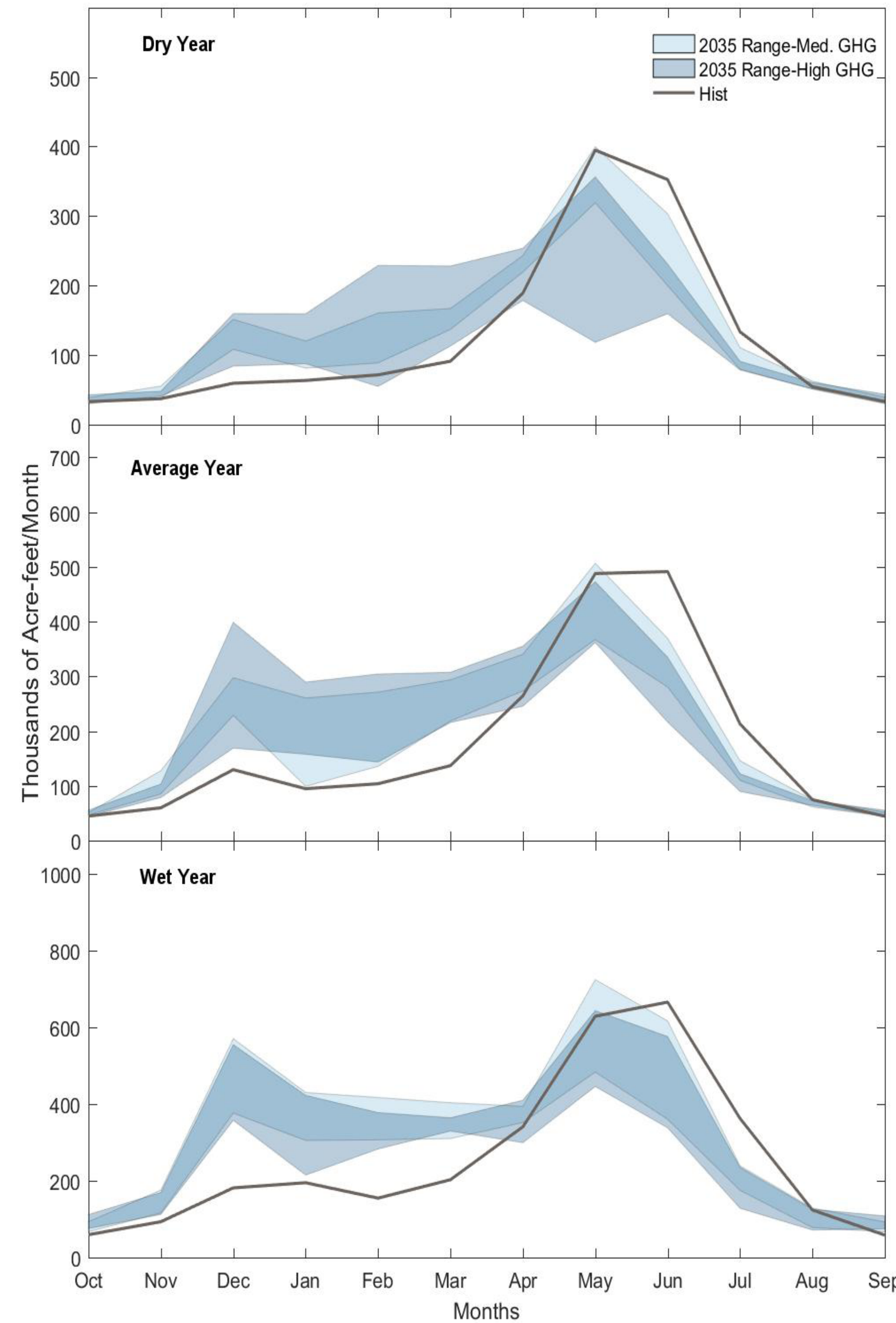
Comparison of Dry, Average and Wet Year Flows to Instream Flow Rule *(Wenatchee River at Monitor, WA) 1981-2011*

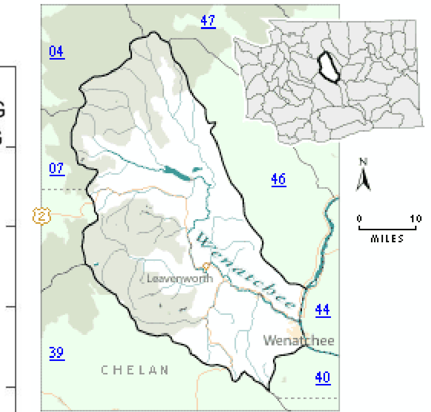


A table showing salmon, steelhead, and bull trout use of WRIA waters (provided by the Washington Department of Fish and Wildlife (WDFW)) is available on page 169. Summaries are also available online at http://apps.wdfw.wa.gov/salmonscape/.

Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

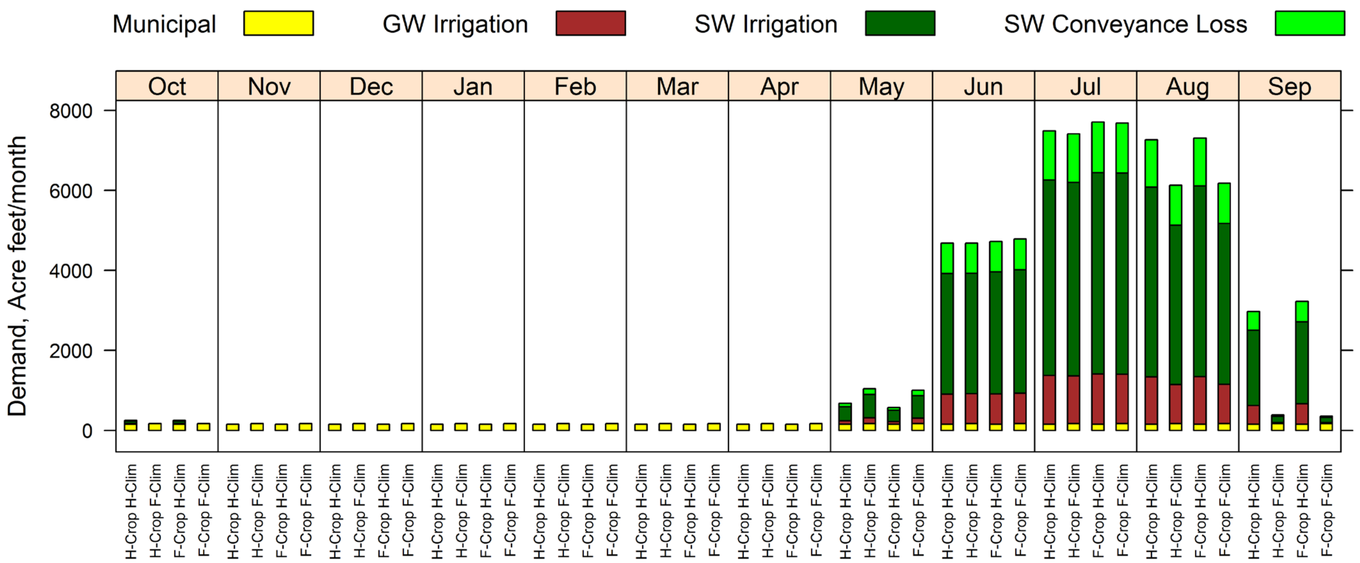
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

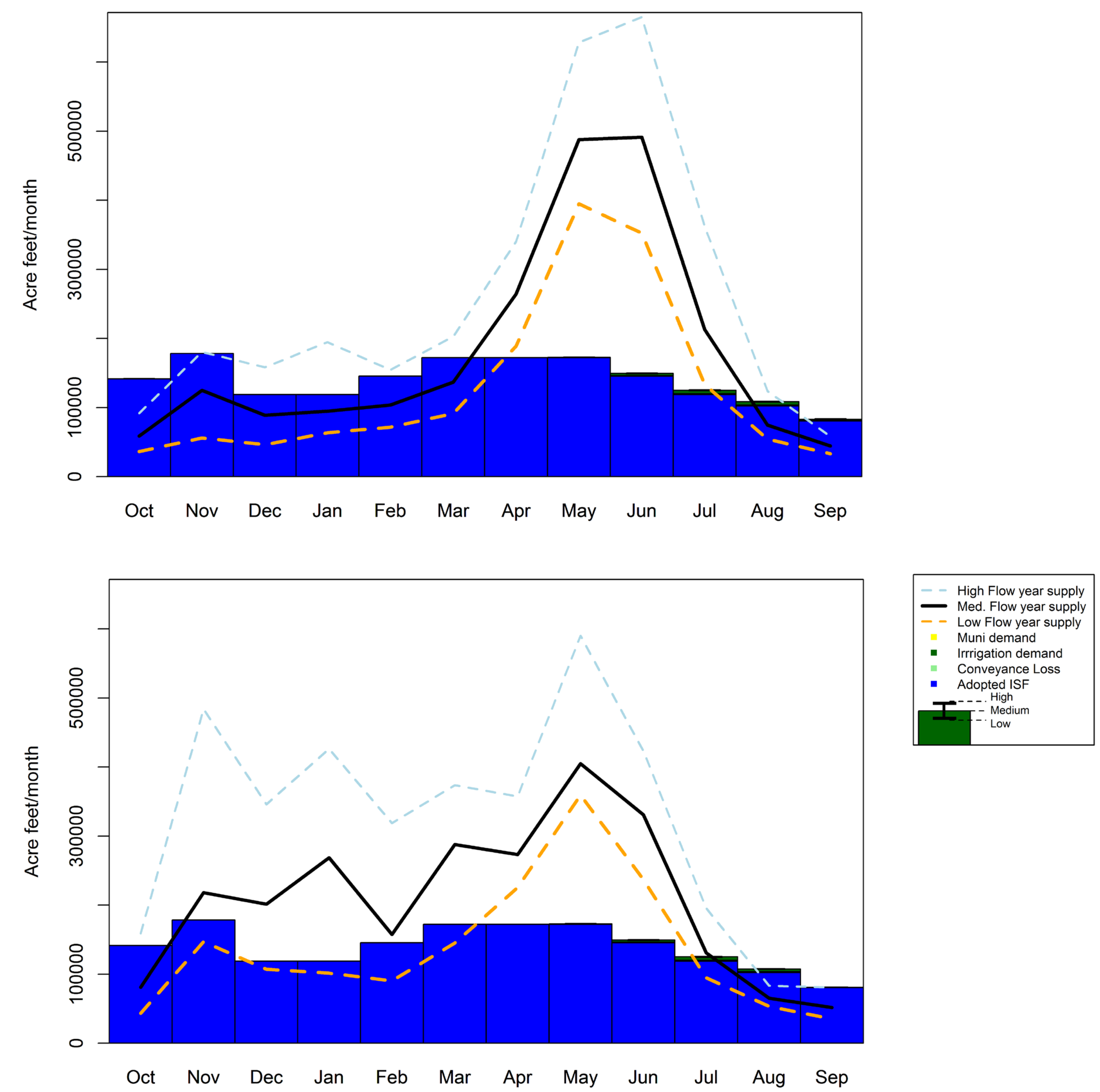


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Entiat shows one of the most pronounced supply timing changes in response to warming among all of the WRIAs. It is characterized by increases from November through March and decreases from May through July.
- Instream flow requirements are the largest demand, with much smaller irrigation and municipal demands.
- Assuming no change in irrigated acreage, irrigation demand is projected to increase in May, remain unchanged in June, and decrease from July through September. The decreases are in response to climate change.
- Municipal demands are forecasted to increase by 6% by 2035.
- This WRIA is included in the Columbia River Instream Atlas (Ecology Publication in preparation), which contains information on instream water demands for 12 WRIAs that provide habitat for ESA-listed anadromous salmonids.

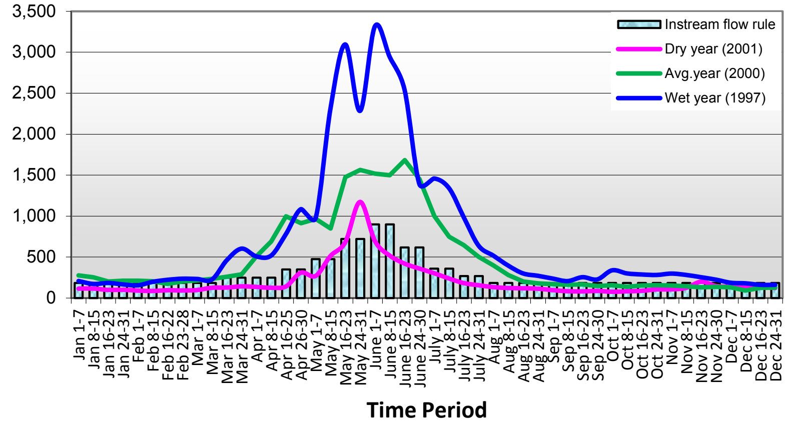
PLACEHOLDER

Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Roaring Creek, Johnson Creek
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	Yes (Chapter 173-546 WAC). 12 interruptible water rights curtailed periodically. Weekly frequency of interruption from 1984-2014 ranged from 3 to 9 years from August to March (70% to 90% reliable), and from 0 to 2 years from April to July (93% to 100% reliable).
Fish Listed Under the Endangered Species Act[1]	Bull Trout, Upper Columbia River Spring Run Chinook, Upper Columbia Steelhead, [Columbia mainstem migratory corridor]
Groundwater Management Area	NO

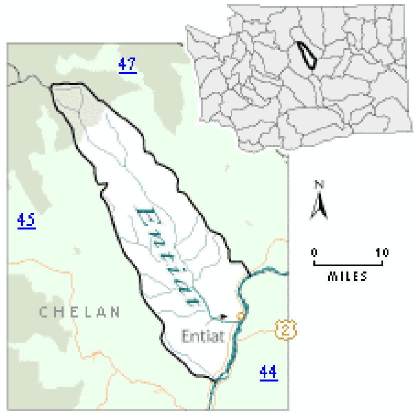
[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

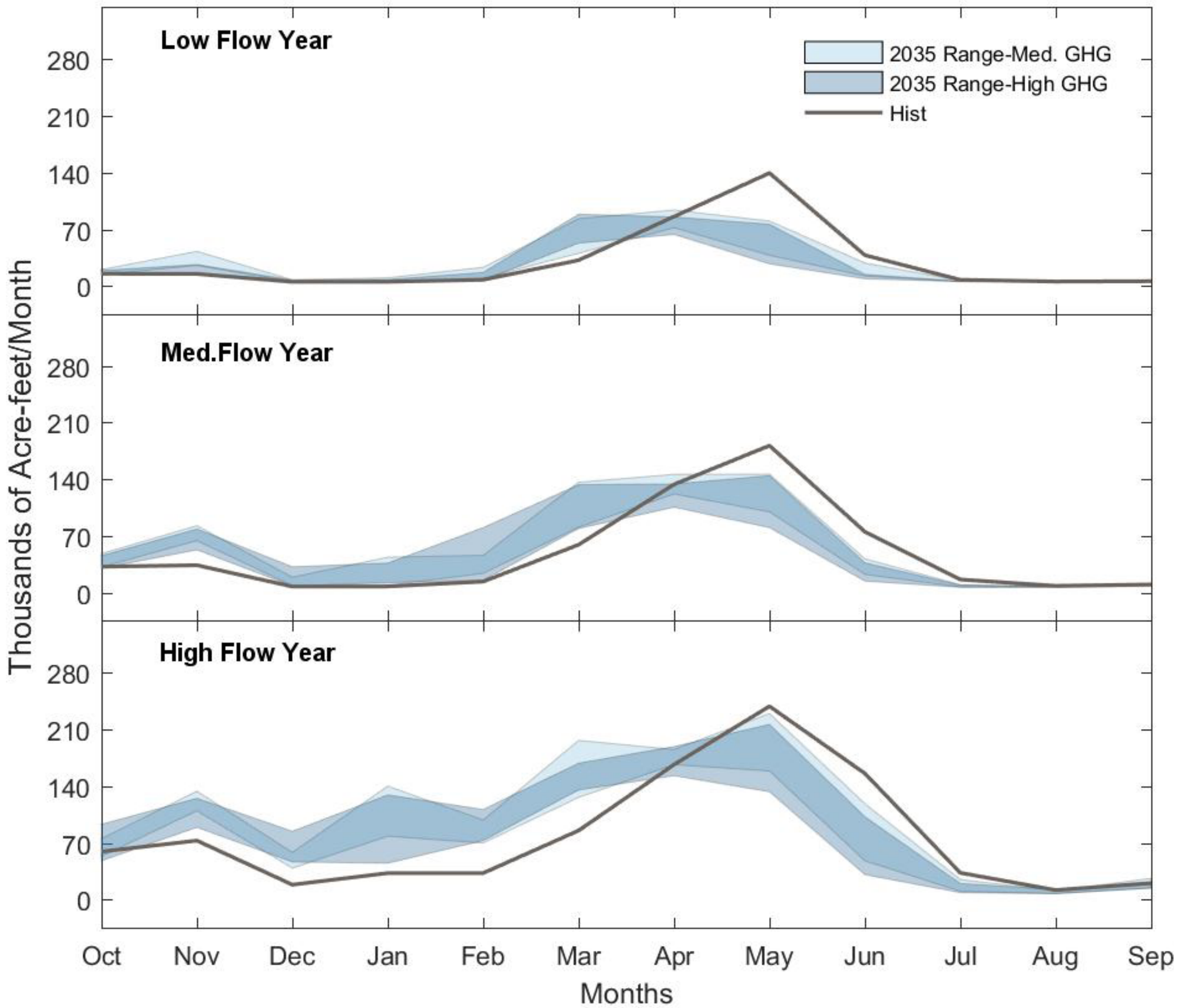
Comparison of Dry, Average and Wet Year Flows to Instream Flow Rule *(Entiat River near Entiat, WA) 1981-2011*



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

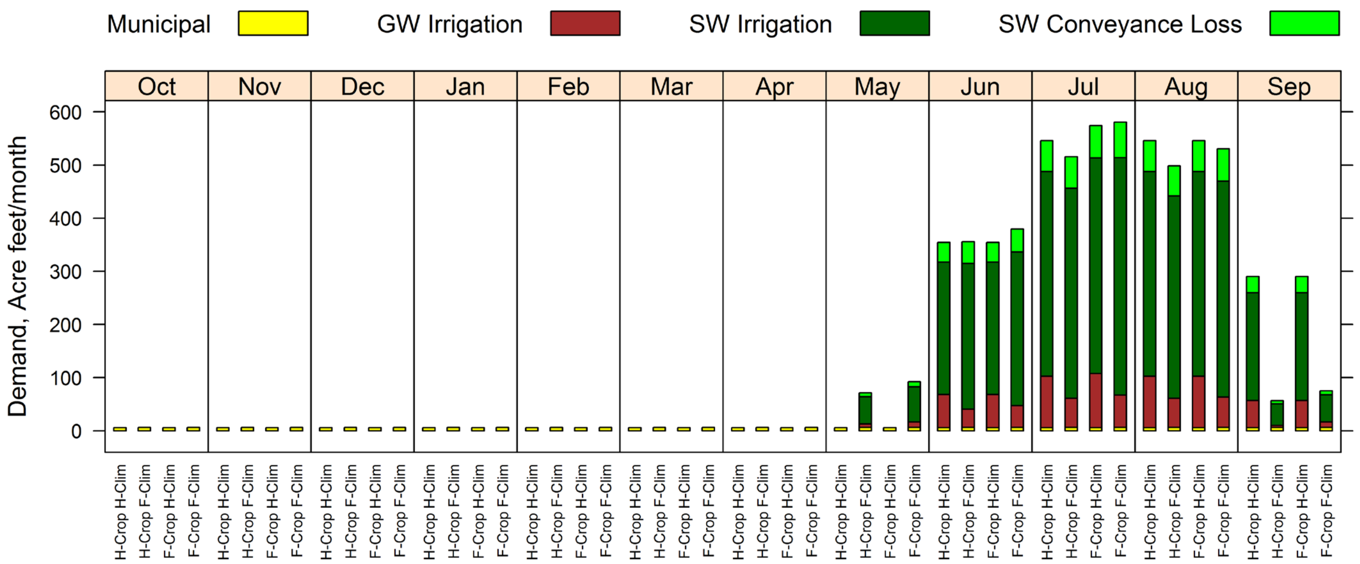
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

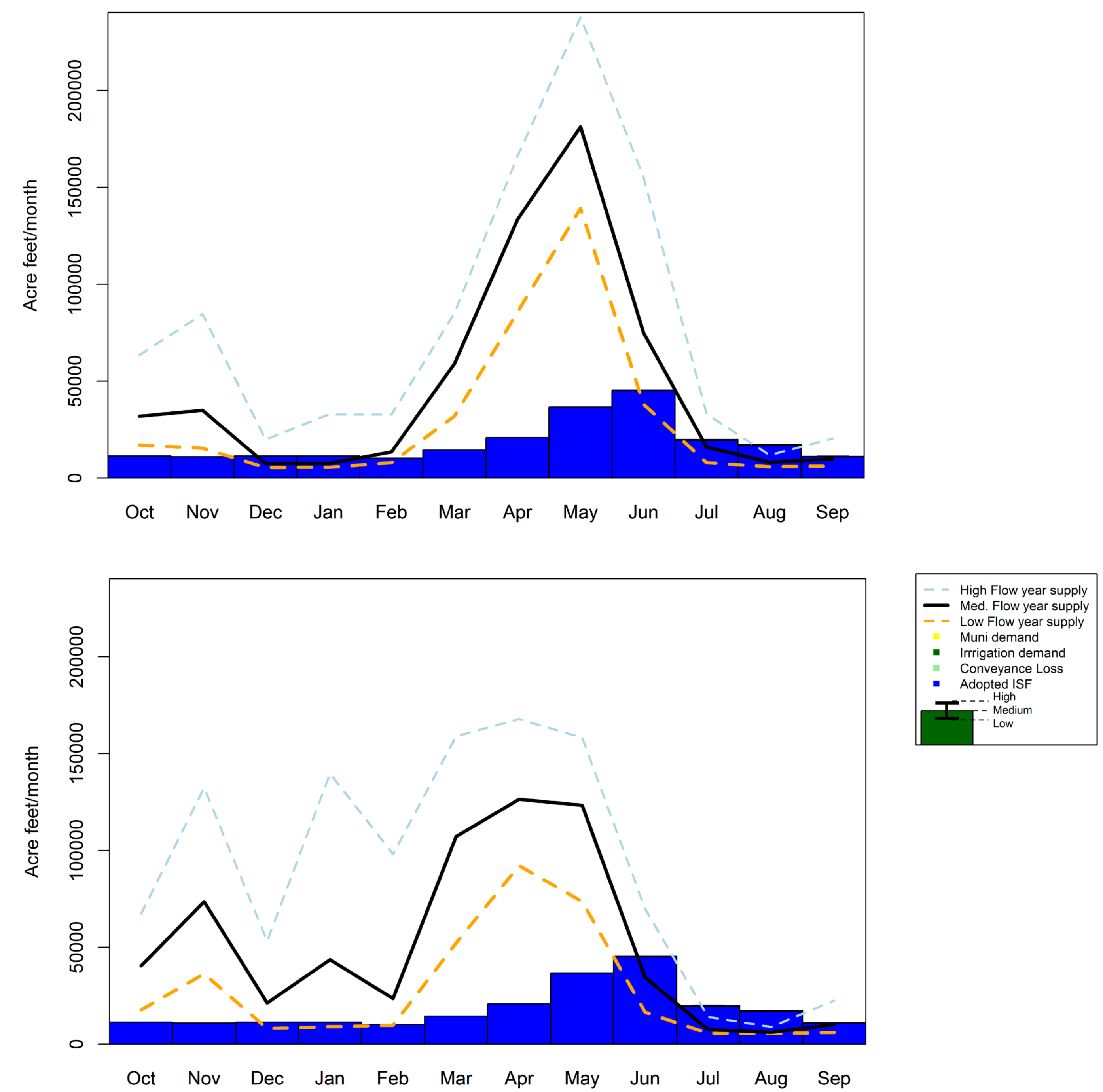


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) “H-Crop H-Clim”, b)”H-Crop F-Clim”, c)“F-Crop H-Clim”, and d) ”F-Crop F-Clim” where “H-Crop” represents historic crop mix; “F-Crop” as future crop mix under medium economic scenario,”H-Clim” as historic climate and “F-Clim” values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the “top of crop” and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

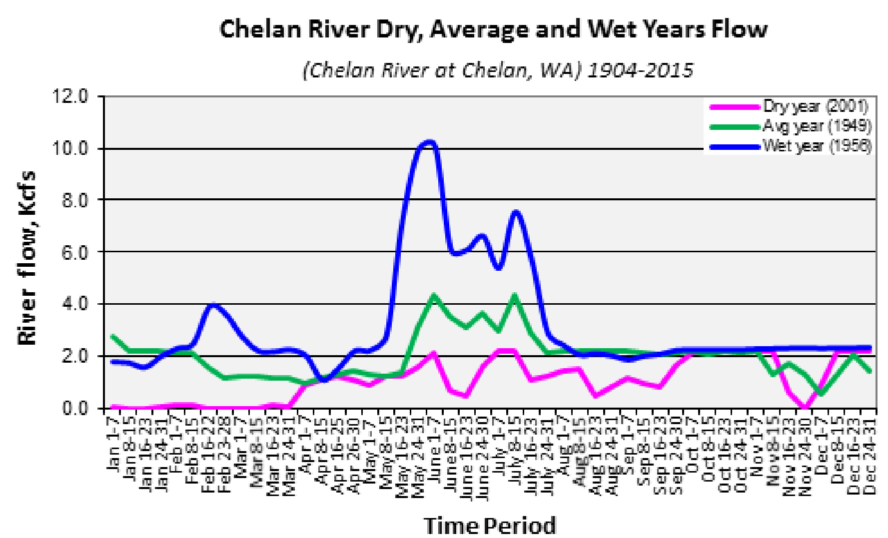
- The tributary surface water supply forecast for Chelan is less certain with a combination of increases and decreases, depending on climate scenario. Most of the scenarios, however, project a decrease from May through August, particularly for the 20th and 50th percentile supply years.
- Irrigation is the primary demand, with much smaller municipal demands.
- Assuming no change in irrigated acreage, irrigation demand is projected to increase in May and decrease from June through October. These changes are primarily in response to climate change.
- Municipal demand projected to grow by roughly 20% by 2035.

PLACEHOLDER

Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

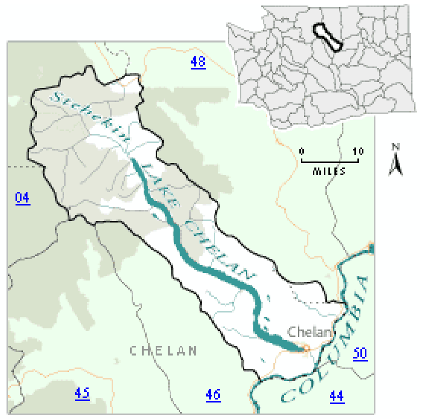
MANAGEMENT CONTEXT	
Adjudicated Areas	Antoine Creek , Safety Harbor Creek
Watershed Planning	Phase 2 (Assessment)
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	[Columbia mainstem migratory corridor]
Groundwater Management Area	NO

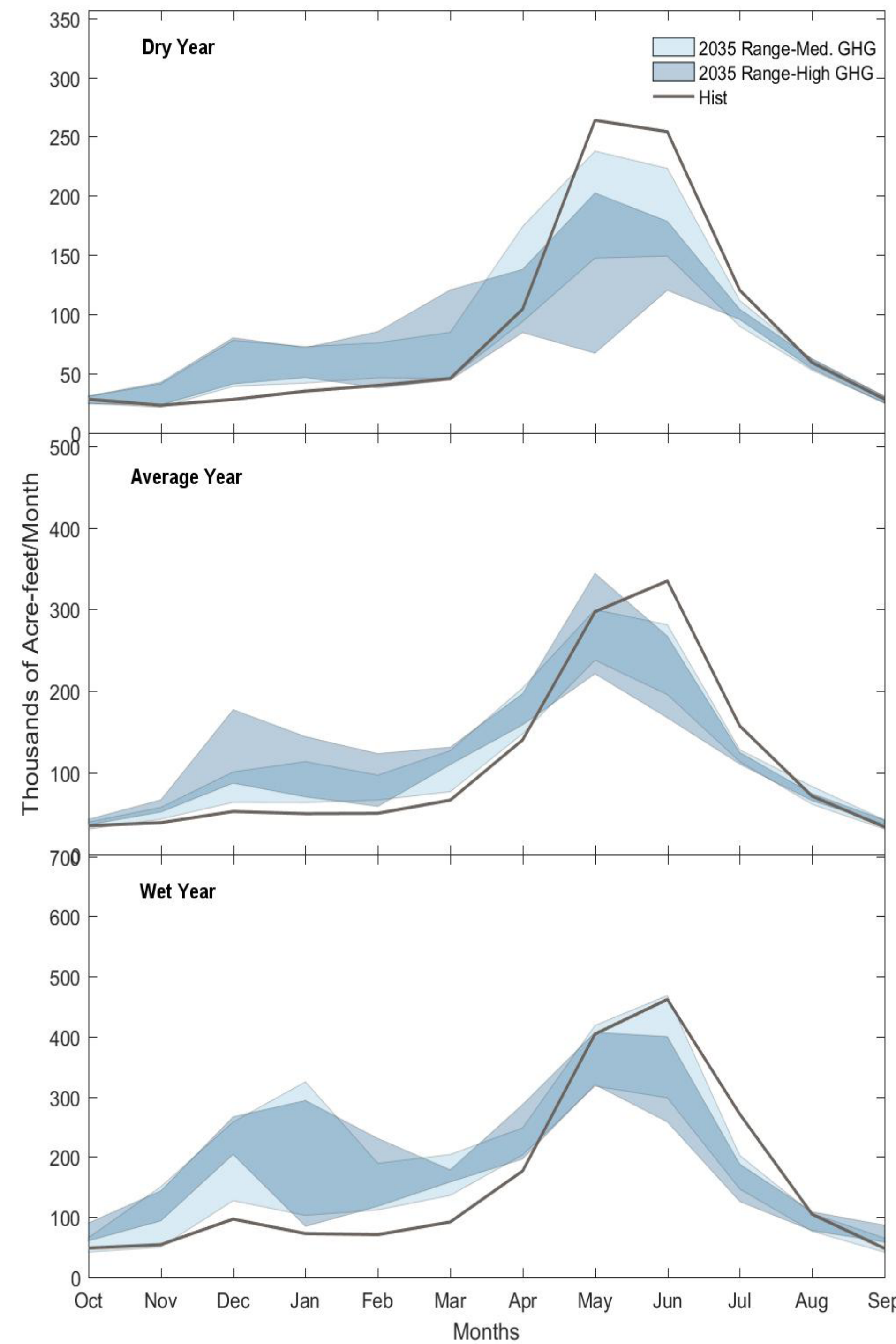
[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

SUPPLY

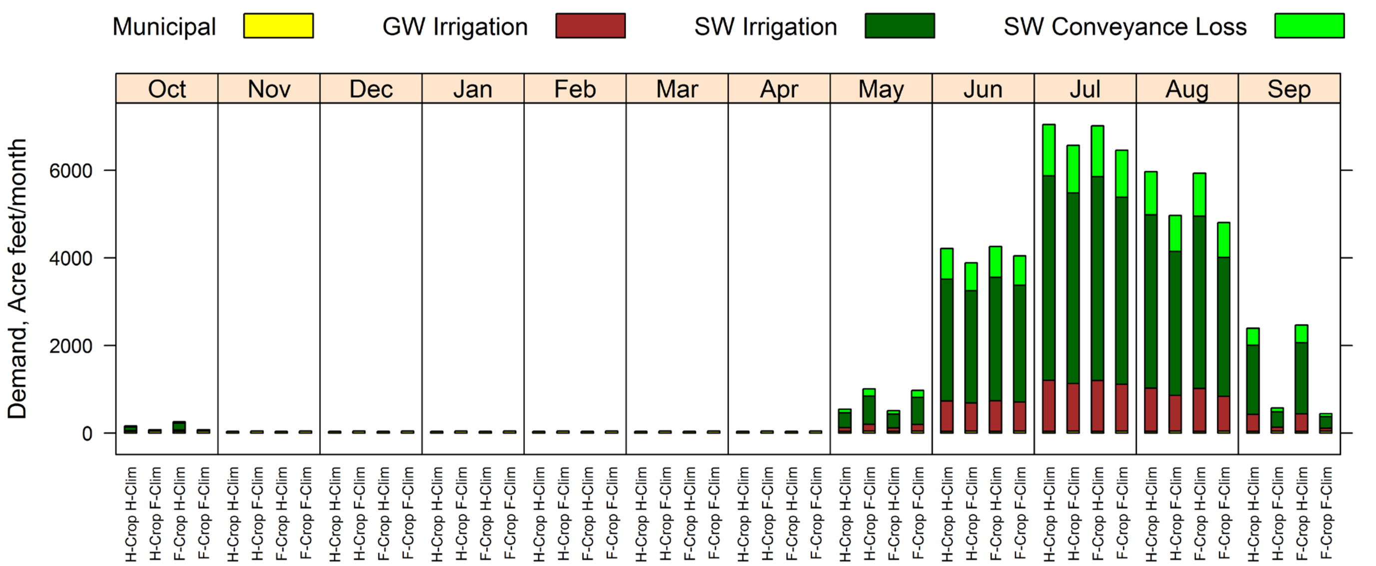




Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

Chelan

DEMAND

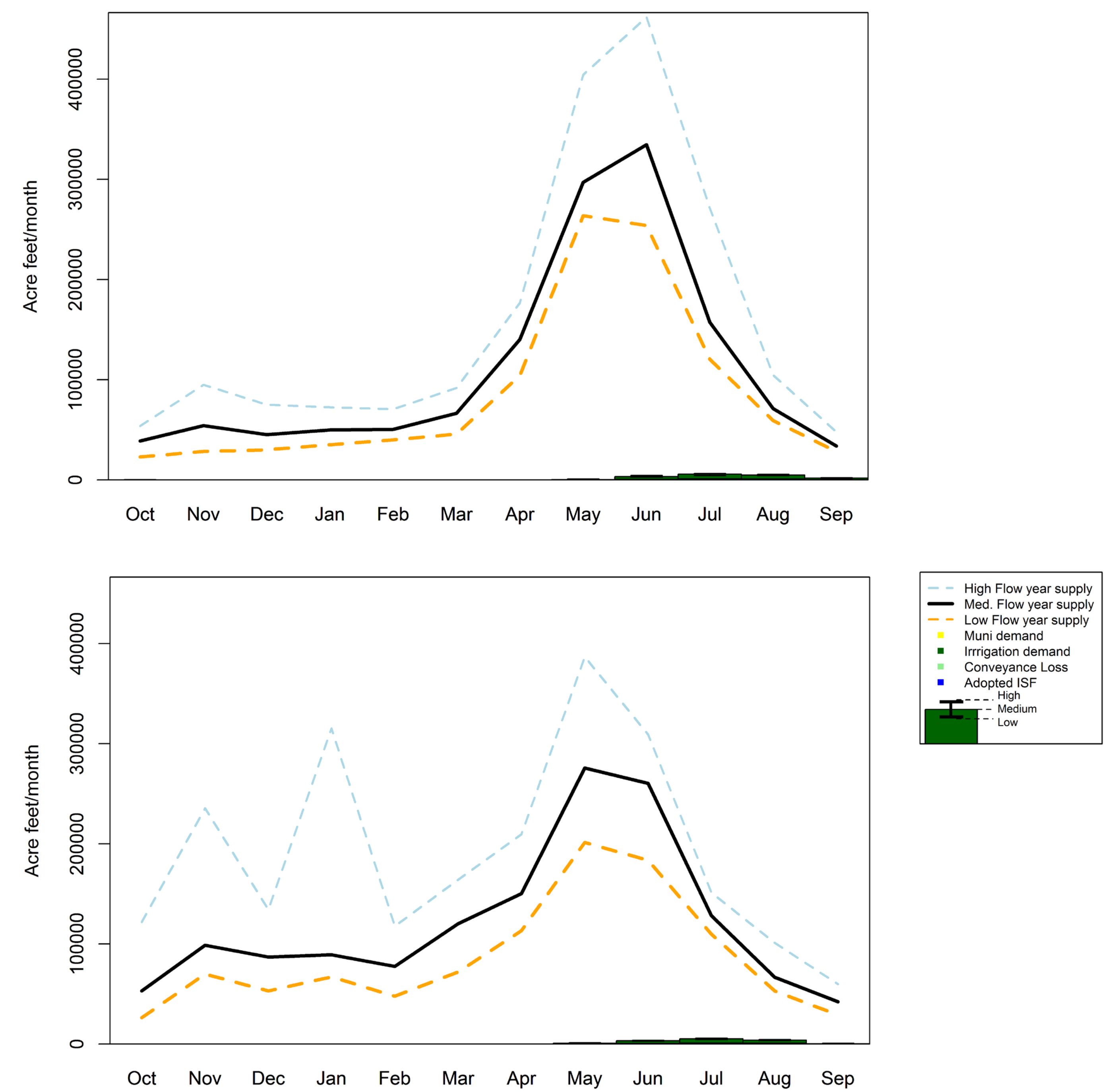


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) “H-Crop H-Clim”, b)”H-Crop F-Clim”, c)“F-Crop H-Clim”, and d) ”F-Crop F-Clim” where “H-Crop” represents historic crop mix; “F-Crop” as future crop mix under medium economic scenario,”H-Clim” as historic climate and “F-Clim” values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the “top of crop” and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Methow is less certain with a combination of increases and decreases, depending on climate scenario. Most of the scenarios, project a decrease from May through August for the 80th percentile supply years.
- This WRIA has much larger instream flow requirements than irrigation demands, and even smaller municipal demands.
- Assuming no change in irrigated acreage, irrigation demand is projected to decrease for all months during the irrigation season. These changes are primarily in response to both climate change and crop mix changes for June through September and in response to crop mix changes in May and October.
- Municipal demands are forecasted to grow by 19% by 2035.
- This WRIA is included in the Columbia River Instream Atlas (Ecology Publication in preparation), which contains information on instream water demands for 12 WRIAs that provide habitat for ESA-listed anadromous salmonids.

PLACEHOLDER

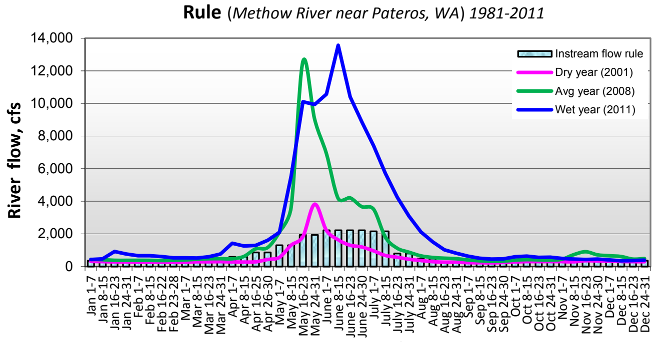
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Beaver Creek, Bear Creek & Davis Lake, Libby Creek, Gold Creek, McFarland Creek, Black Canyon Creek, Wolf Creek, Thompson Creek (incomplete)
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	Yes (Chapter 173-548 WAC). 48 interruptible water rights curtailed periodically. Weekly frequency of interruption from 1984-2014 ranged from 0 to 4 years from April to May (90% to 100% reliable), and 15 years from June to March (50% reliable).
Fish Listed Under the Endangered Species Act[1]	Bull Trout, Upper Columbia River Spring Run Chinook, Upper Columbia Steelhead [Columbia mainstem migratory corridor]
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

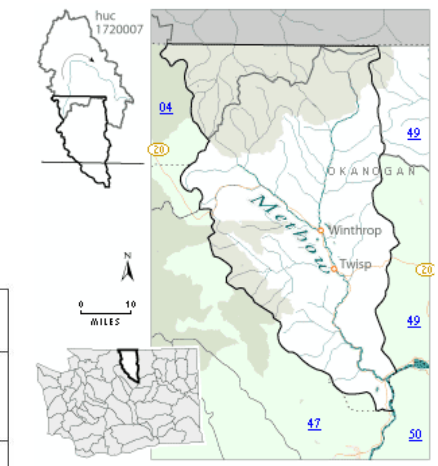
A table showing salmon, steelhead, and bull trout use of WRIA waters (provided by the Washington Department of Fish and Wildlife (WDFW)) is available on page 170. Summaries are also available online at http://apps.wdfw.wa.gov/salmonscape/.

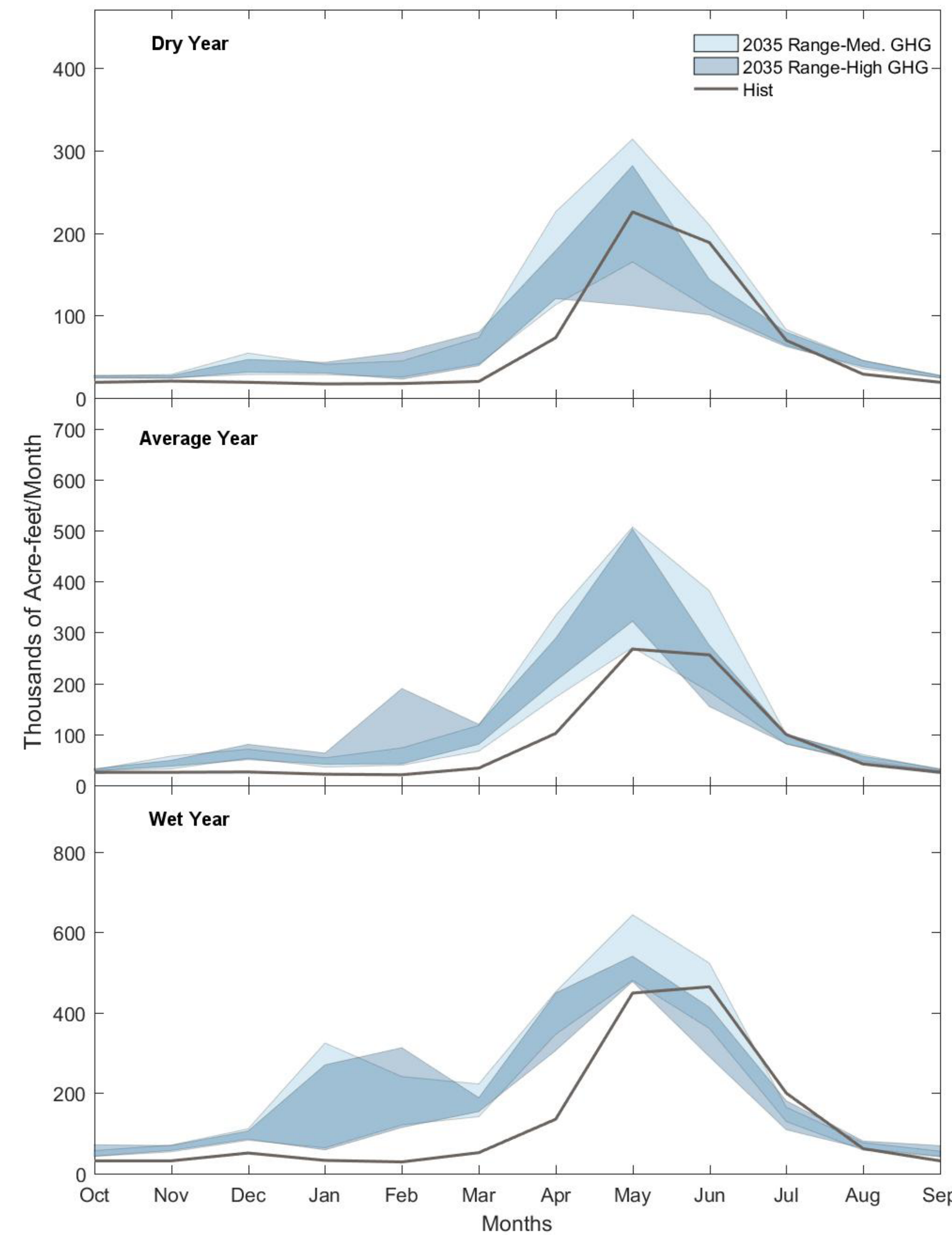
Comparison of Dry, Average and Wet Year Flows to Instream Flow Rule *(Methow River near Pateros, WA) 1981-2011*



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

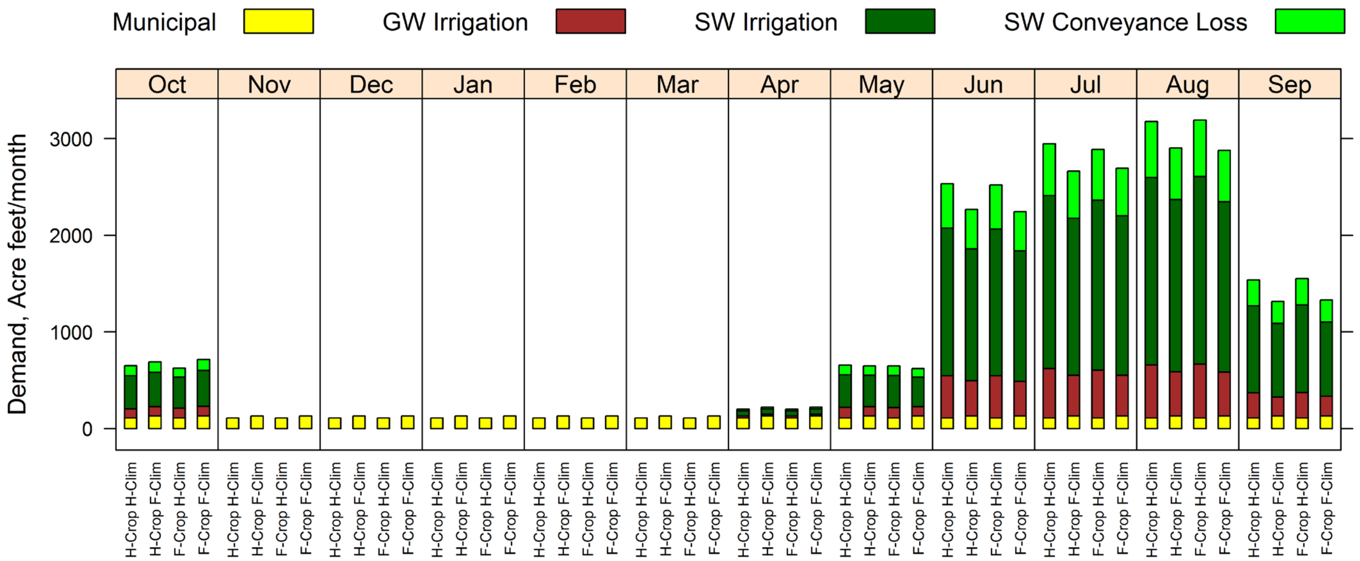
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

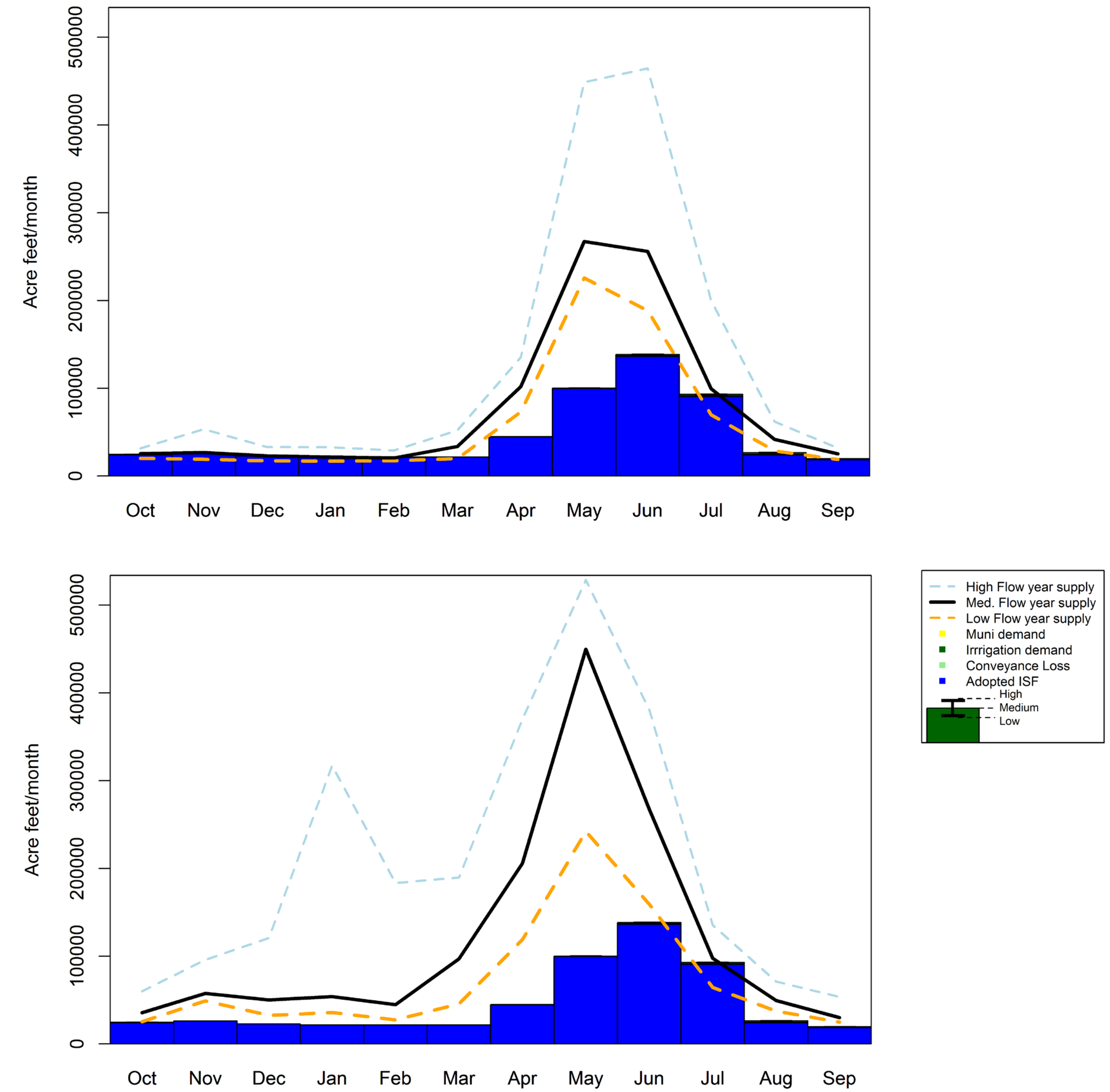


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Okanogan is characterized mostly by increases from October through March (although the 20th percentile supply years show a combination of increases and decreases in March), followed by decreases in April for the 80th supply year and in June for the 20th and 50th supply years.
- The largest demands are from instream demands, though irrigation demands are also important. Municipal demands are much smaller.
- Assuming no change in irrigated acreage, irrigation demand is projected to decrease from June through October due to both climate and crop mix changes. April and May changes are less certain with climate change causing a increase in demands and crop mix changes causing an decrease in demands.
- Municipal demands are forecasted to grow by 5% by 2035.
- This WRIA is included in the Columbia River Instream Atlas (Ecology Publication in preparation), which contains information on instream water demands for 12 WRIAs that provide habitat for ESA-listed anadromous salmonids.

PLACEHOLDER

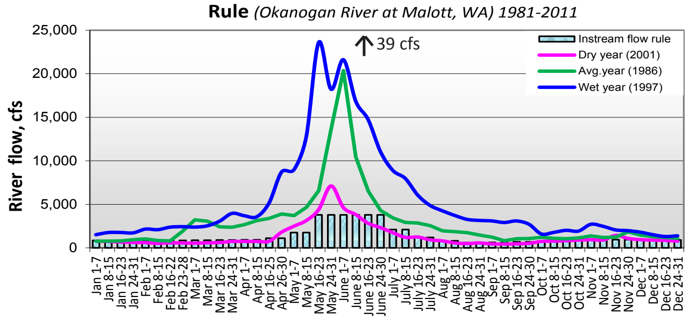
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Simikameen River, Salmon Creek, North Fork, Johnson Creek, Lower Antoine Creek, Sinlahekin Creek, Myers Creek, Whitestone Lake, Chiliwist Creek, Bonaparte Creek & Lake, Duck Lake Ground Water Subarea
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	Yes (Chapter 173-549 WAC). 96 interruptible water rights curtailed periodically. Weekly frequency of interruption from 1984-2014 ranged from 1 to 4 years from April to May (90% to 97% reliable), and averaged 10 years in June to March (67% reliable).
Fish Listed Under the Endangered Species Act[1]	Upper Columbia Steelhead, [Columbia mainstem migratory corridor]
Groundwater Management Area	YES (Duck Lake subarea)

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

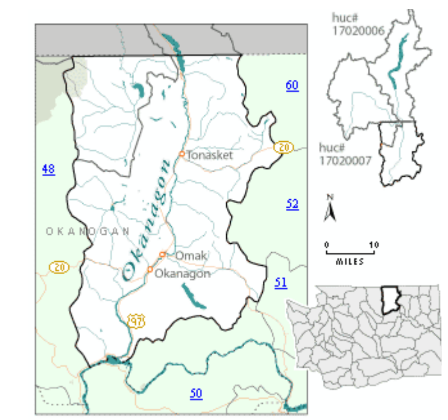
A table showing salmon, steelhead, and bull trout use of WRIA waters (provided by the Washington Department of Fish and Wildlife (WDFW)) is available on page 170. Summaries are also available online at http://apps.wdfw.wa.gov/salmonscape/.

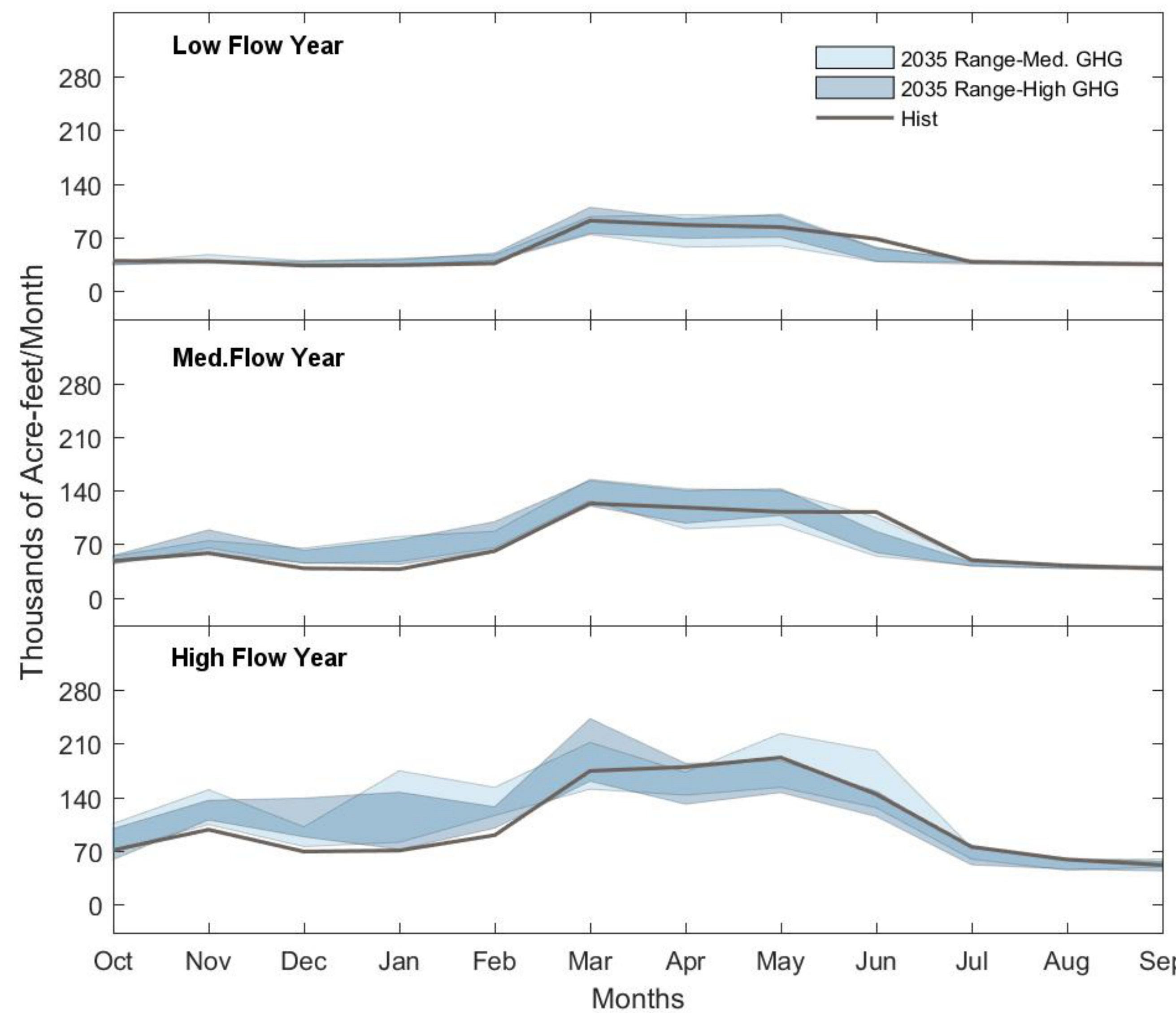
Comparison of Dry, Average and Wet Year Flows to Instream Flow Rule *(Okanogan River at Malott, WA) 1981-2011*



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

SUPPLY

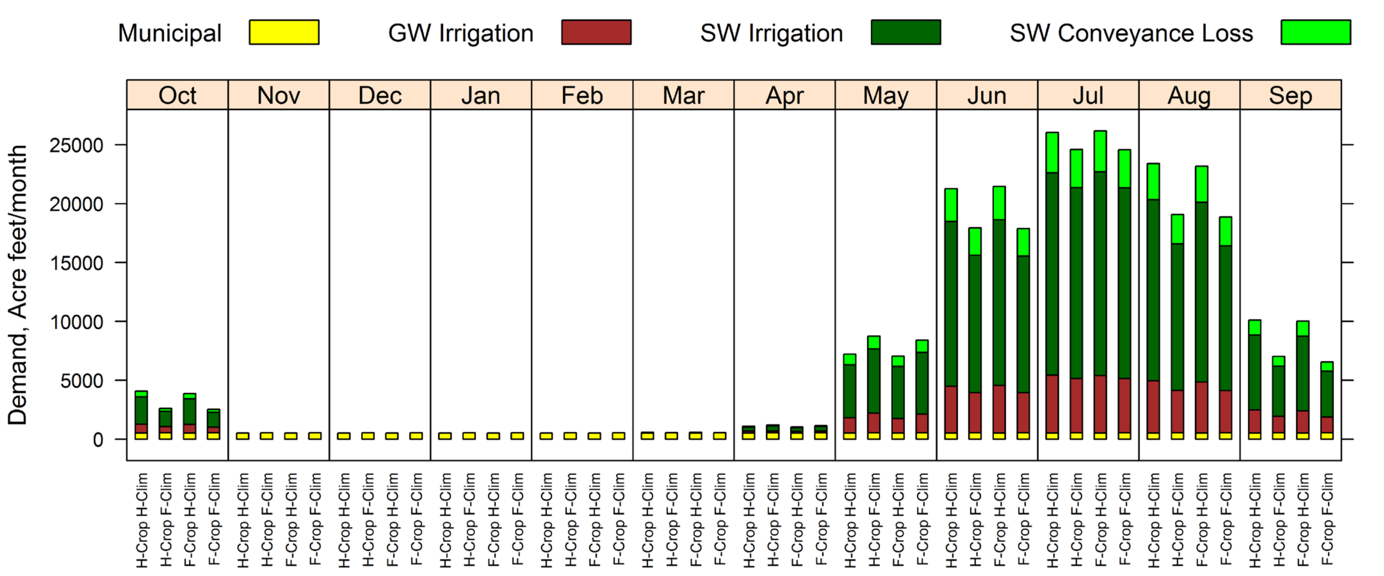




Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

Okanogan

DEMAND



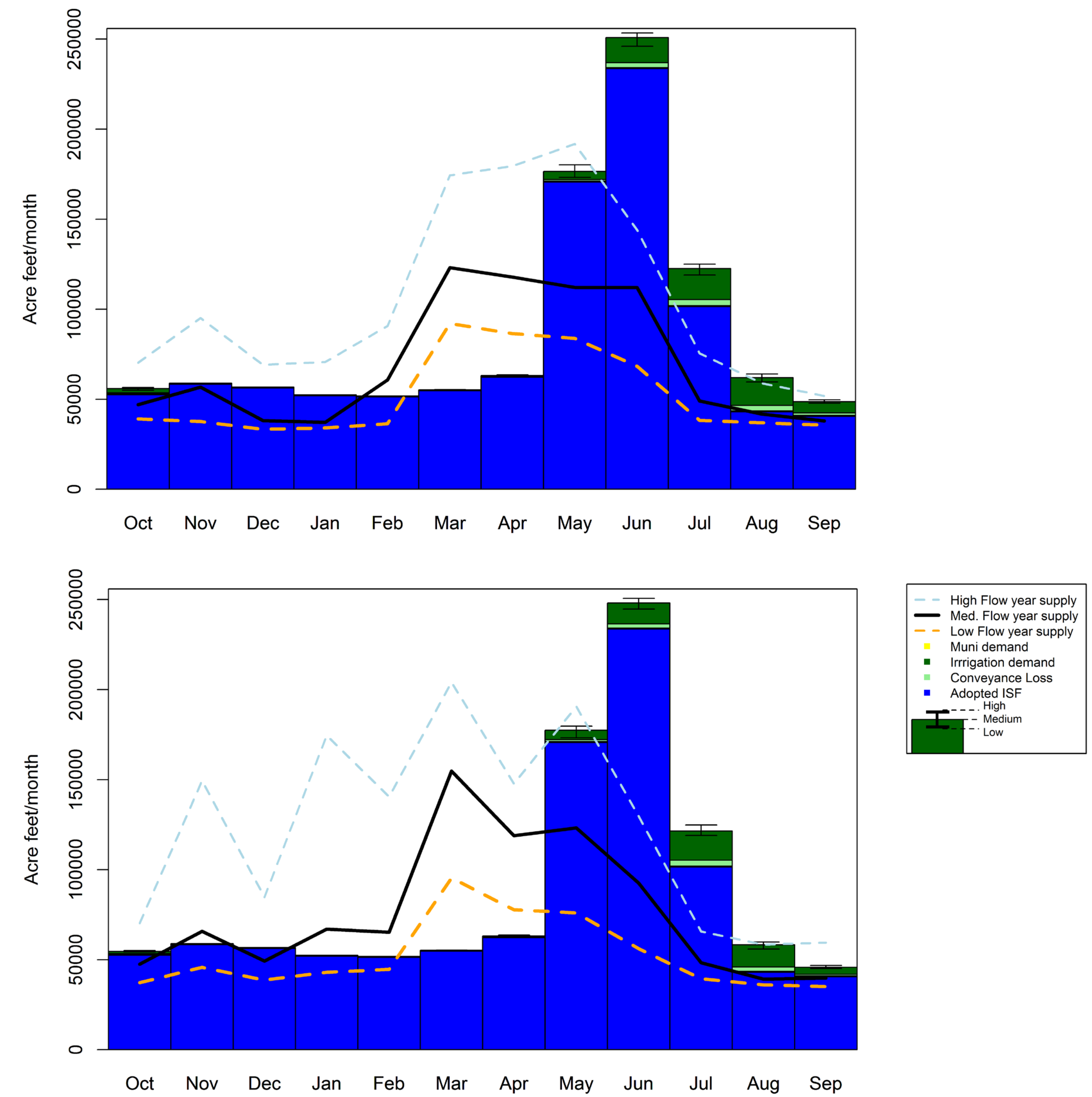
Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

Okanogan

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The supply forecast for Nespelem is characterized by increases in supply from November through January, with decreases in March for most scenarios, and a mix of increases and decreases the remaining months, depending on climate scenario.
- Municipal/domestic demands are quite small in this watershed compared to other watersheds in eastern Washington, and there were very small modeled irrigation demands in either the historical or the future period.
- Municipal demands are forecasted to grow 3% by 2035, a smaller increase than in many other watersheds of eastern Washington.
- Assuming no change in irrigated acreage, irrigation demands are projected to decrease in July, and September and increase in other months in response due to climate changes.

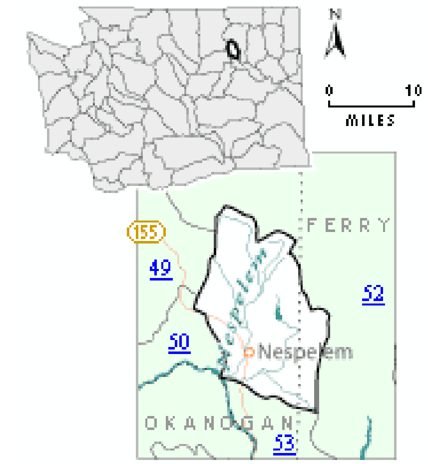
PLACEHOLDER

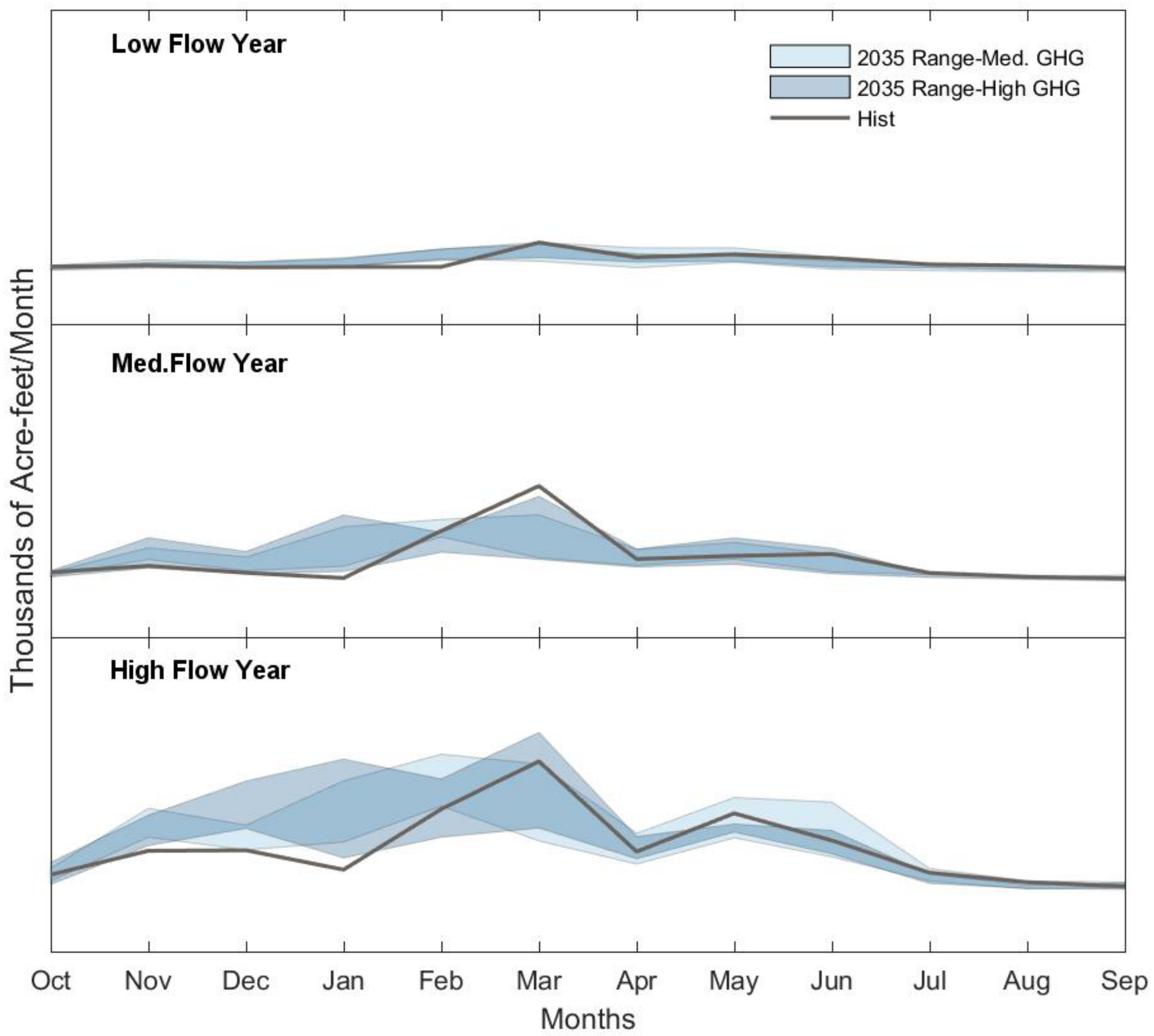
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	NO
Watershed Planning	NO
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	Bull Trout spawning and rearing unknown
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

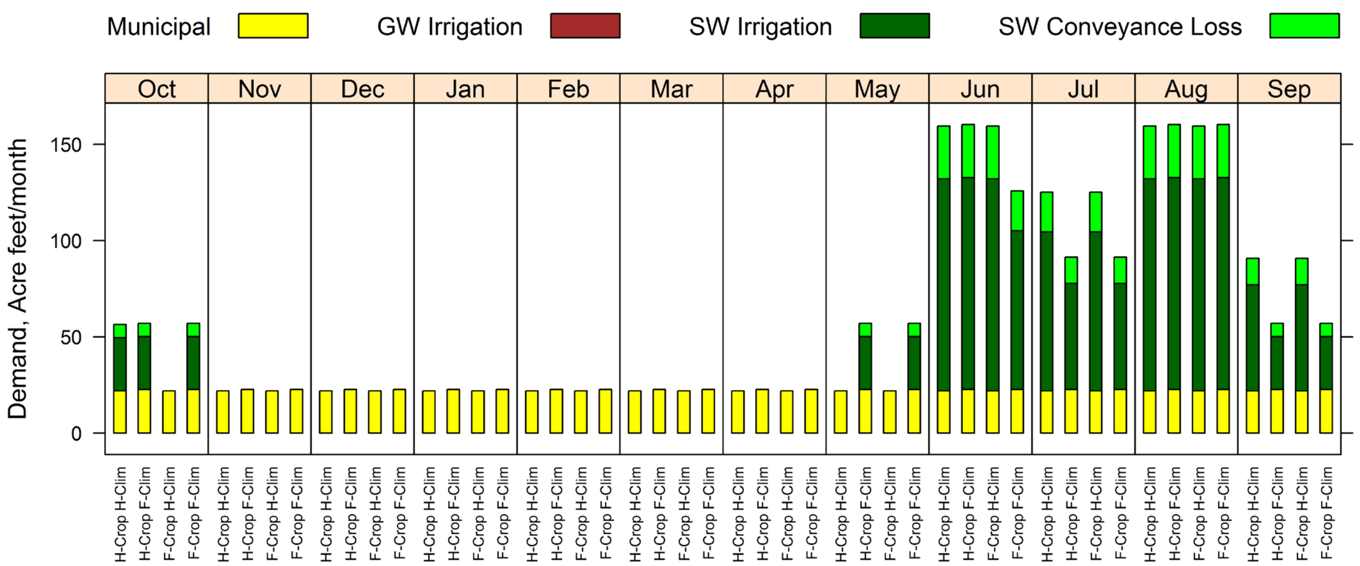
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the “2035 Range-Med. GHG” and the “2035 Range-Med. High” values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

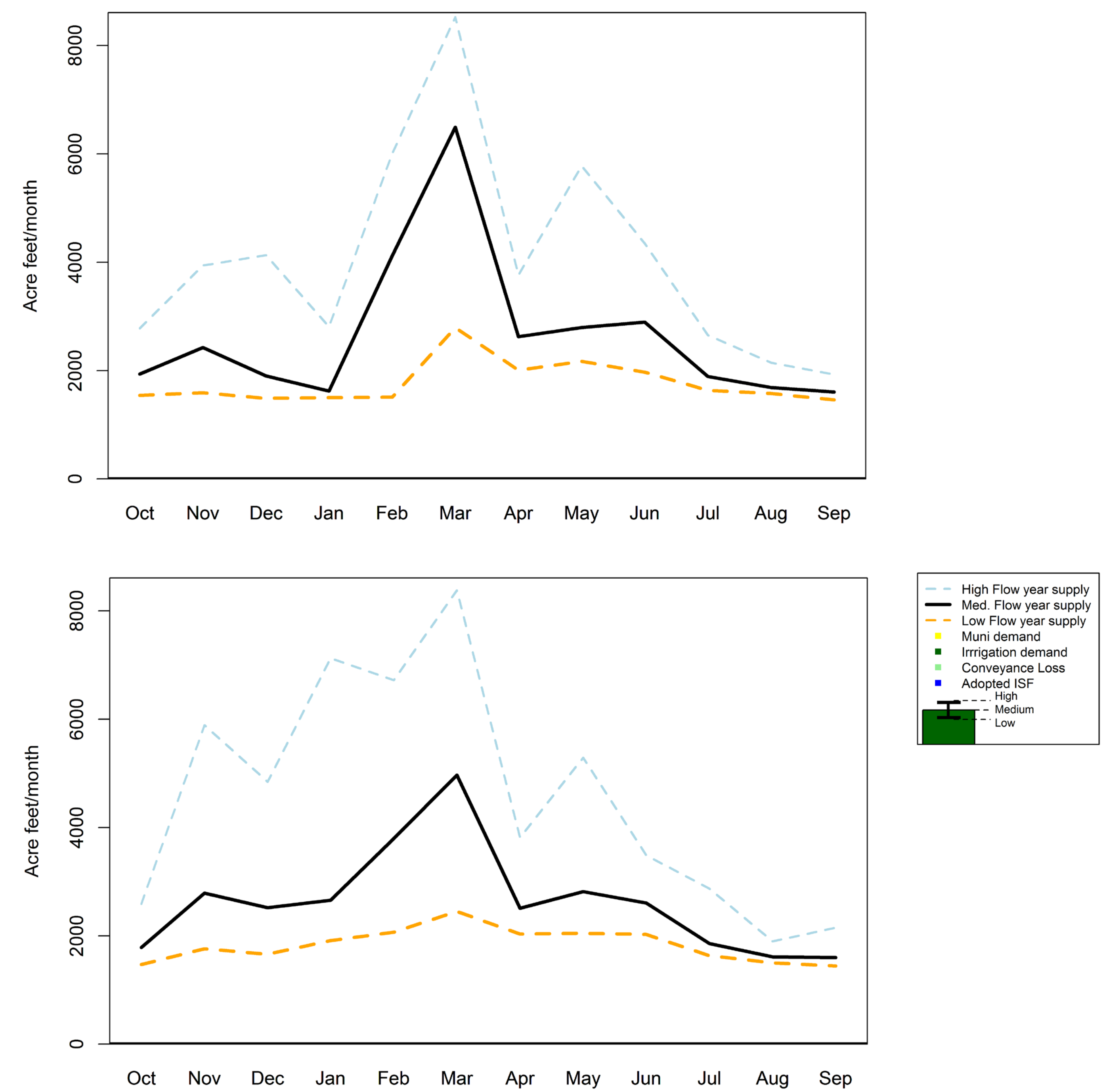


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) “H-Crop H-Clim”, b)”H-Crop F-Clim”, c)“F-Crop H-Clim”, and d) ”F-Crop F-Clim” where “H-Crop” represents historic crop mix; “F-Crop” as future crop mix under medium economic scenario,”H-Clim” as historic climate and “F-Clim” values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the “top of crop” and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Sanpoil is characterized mostly by increases from October through March and decreases from April through July.
- Both irrigation and municipal/domestic demands are quite small in this watershed.
- Assuming no change in irrigated acreage, irrigation demands are projected to increase in August and decrease in September, and October in response to mainly climate changes.
- Municipal demands are forecasted to grow 16% by 2035.

PLACEHOLDER

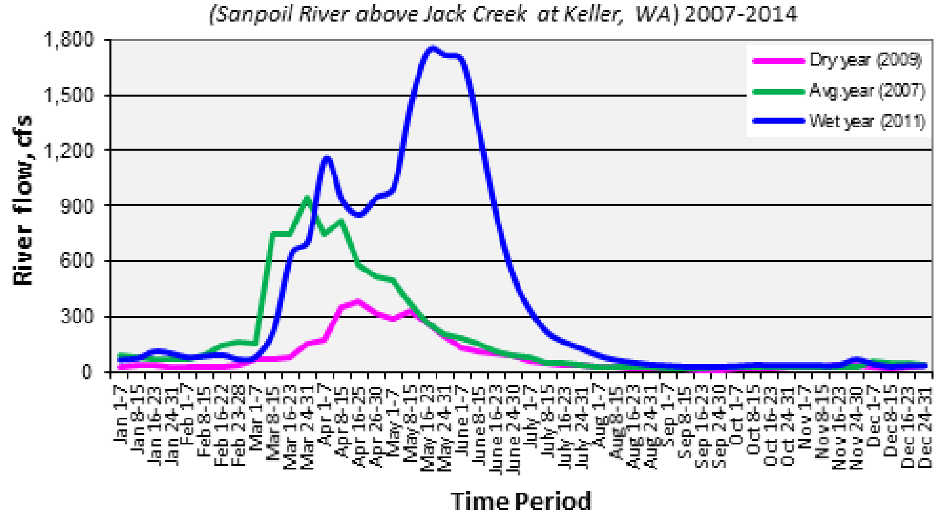
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	NO
Watershed Planning	NO
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	Bull Trout spawning and rearing unknoown
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

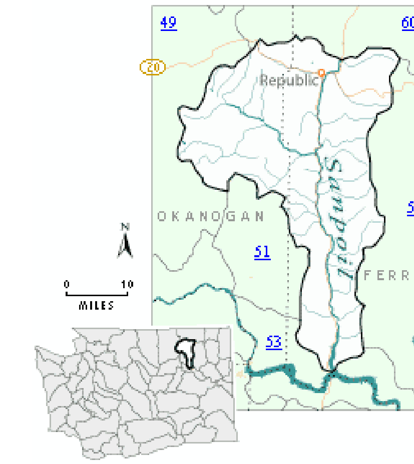
Sanpoil River Dry, Average and Wet Year Flows

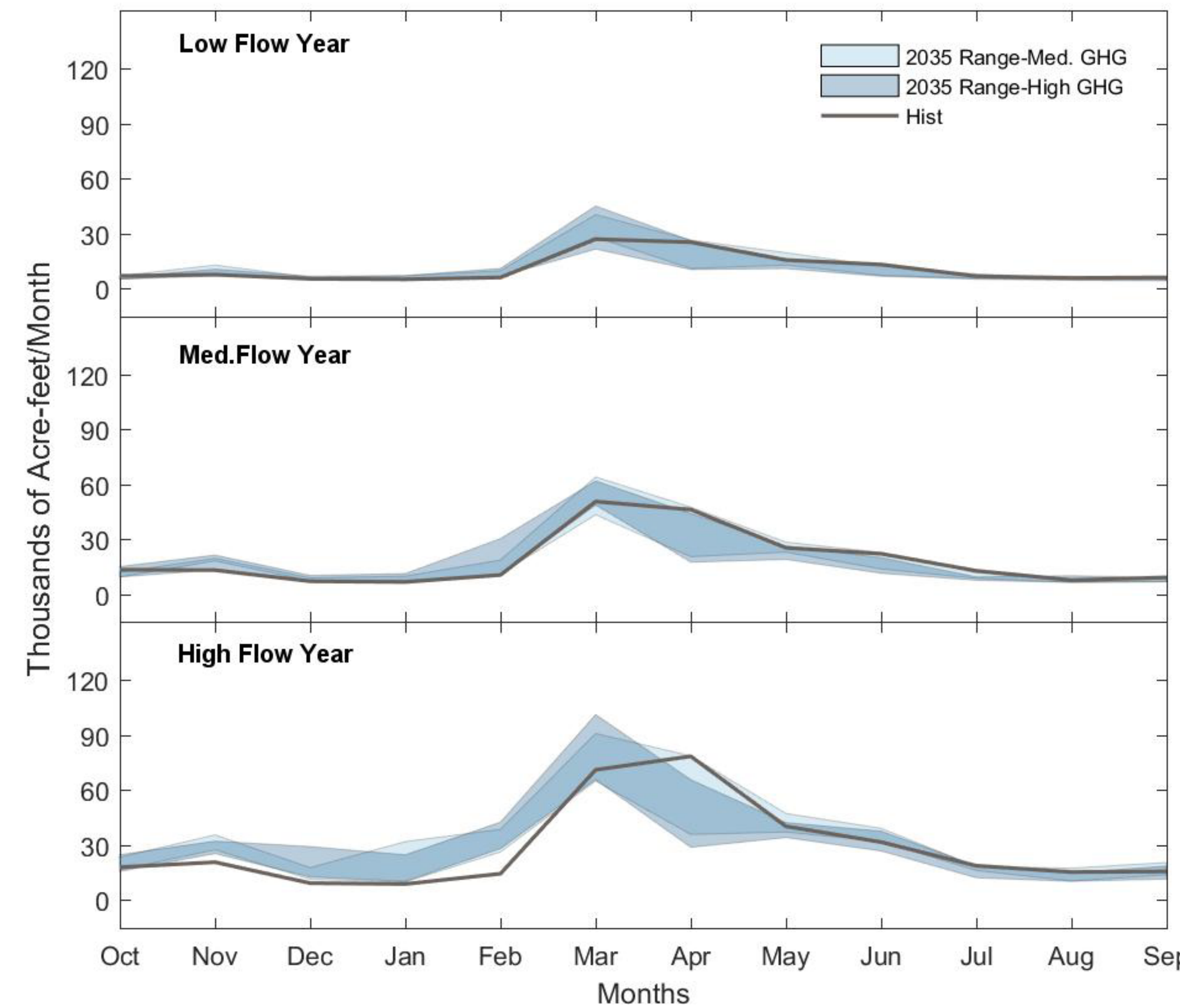
(Sanpoil River above Jack Creek at Keller, WA) 2007-2014



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

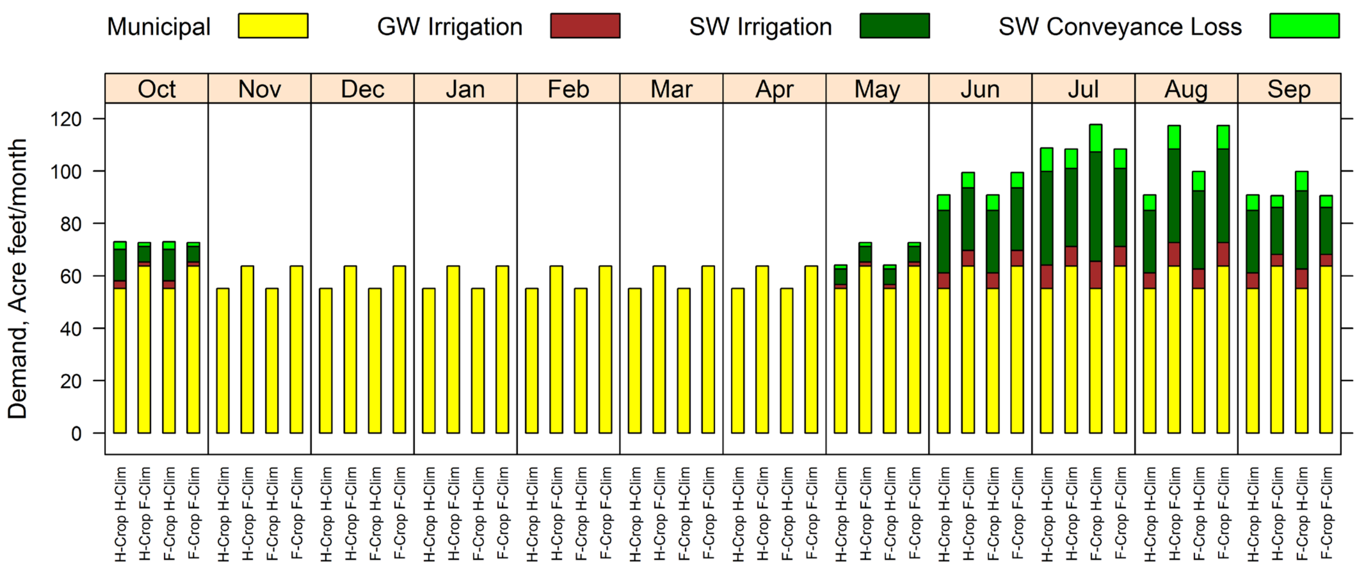
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

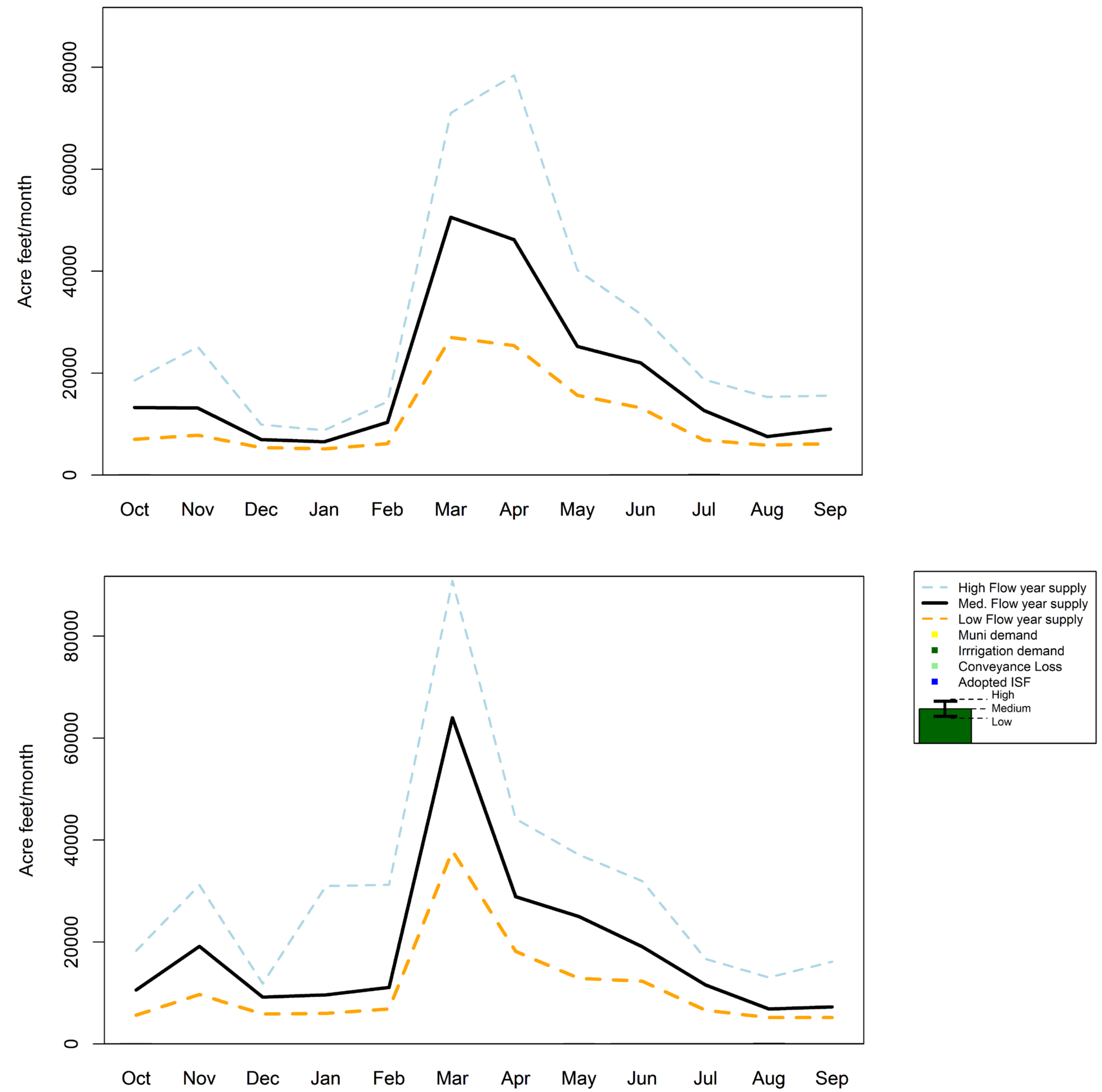


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Lower Lake Roosevelt is characterized mostly by increases from October through May for all percentiles, and also in June for the 80th percentile supply year. The 20th supply year is projected to decrease in June.
- Irrigation is the primary source of demand, though overall demands are modest in comparison to other watersheds within eastern Washington.
- Assuming no change in irrigated acreage, irrigation demands are projected to decrease from June through August and in April, in response to climate change. Changes during May and September are projected to increase.
- Municipal demands are forecasted to grow by 12% by 2035.

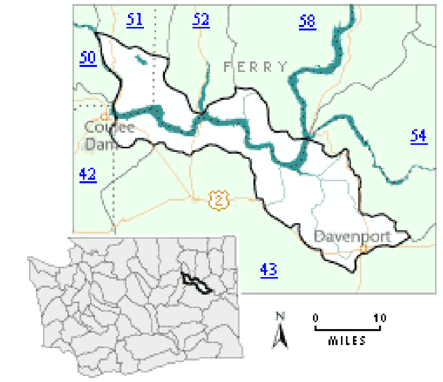
PLACEHOLDER

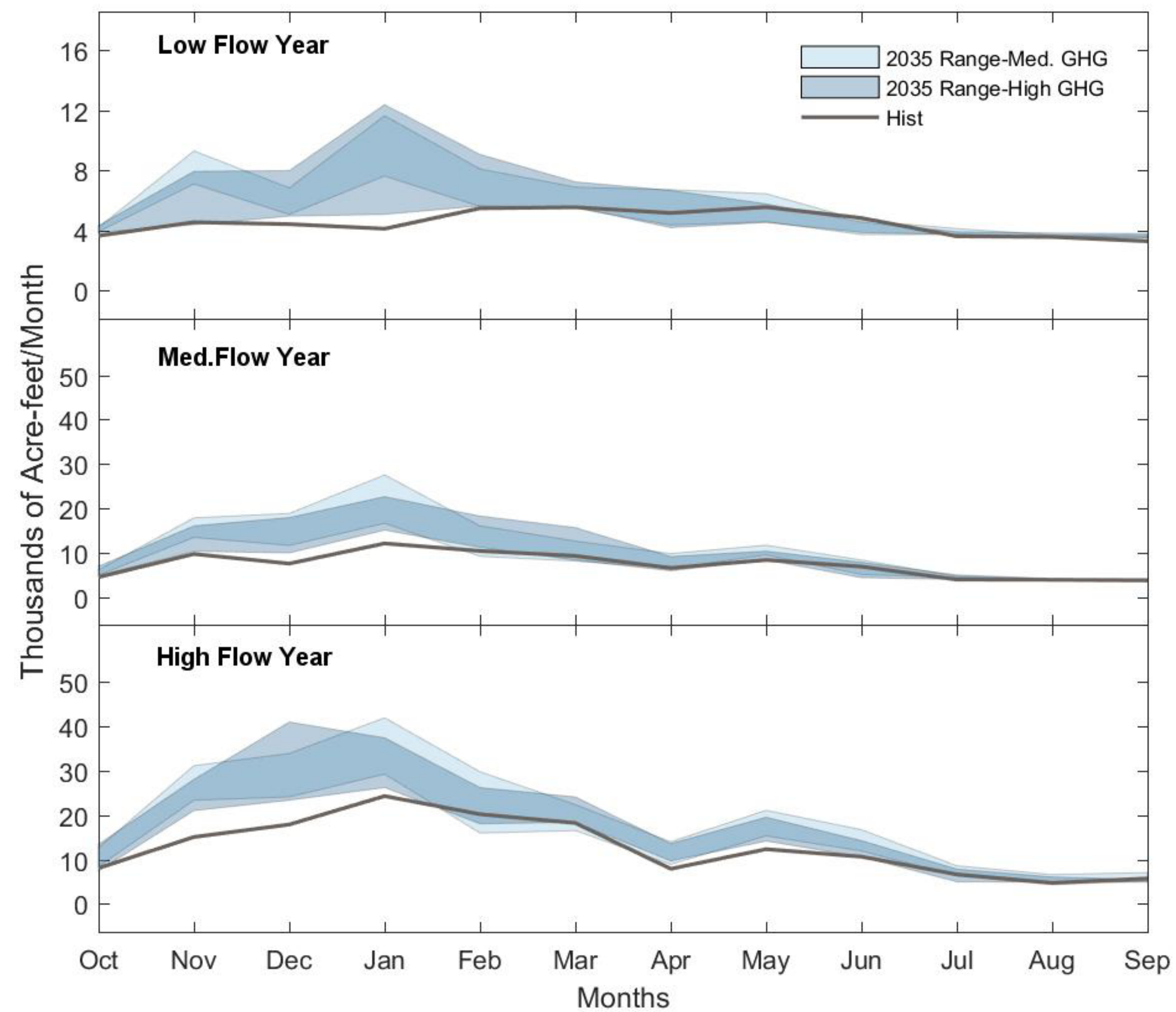
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Hawkes Creek (incomplete)
Watershed Planning	Phase 2 (Assessment)
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	Bull Trout
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

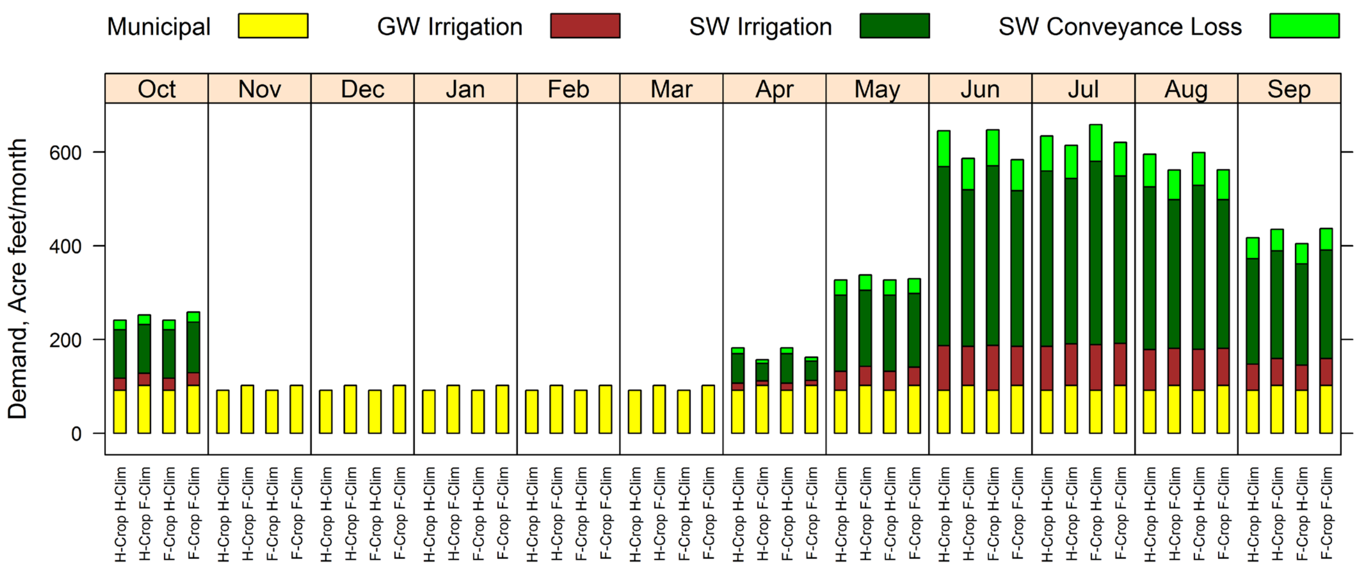
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND



Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

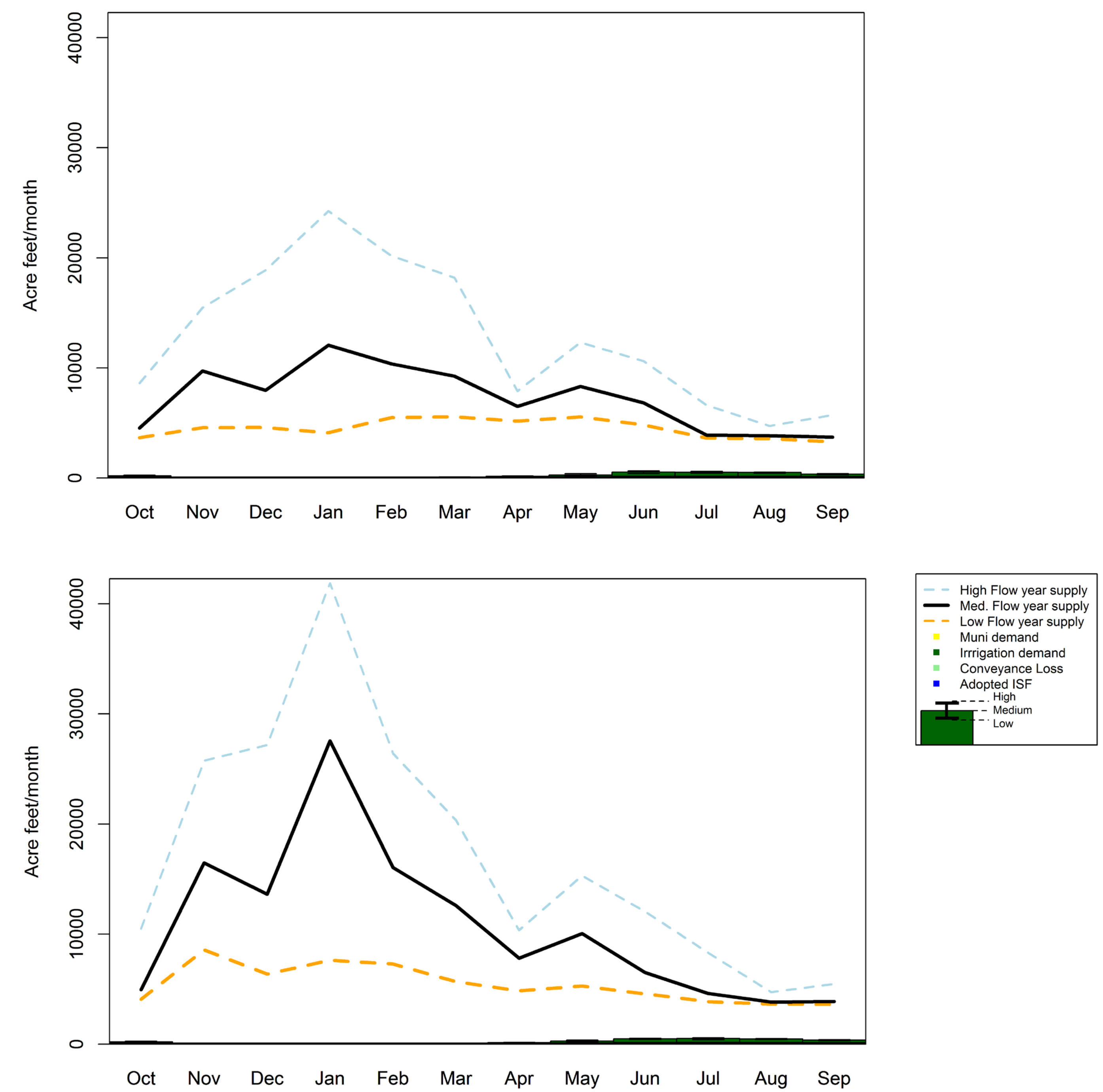
PLACEHOLDER

Awaiting Results

DRAFT

SUPPLY & DEMAND

WRIA 53
Lower Lake Roosevelt



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

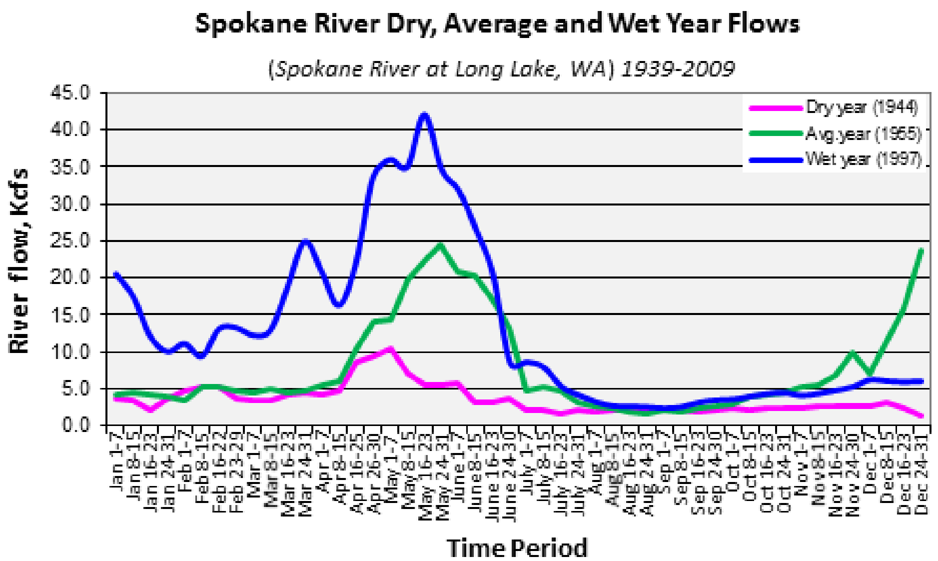
- The tributary surface water supply forecast for Lower Spokane is characterized mostly by increases from October through January for all percentile years, with increases in May and June for the 80th percentile supply year.
- Irrigation demands are somewhat balanced with municipal demands in this watershed, and are relatively modest overall.
- Assuming no change in irrigated acreage, irrigation demand is projected to increase in May and decrease in June, July and August. Climate change have the most influence in both decreasing and increasing demands.
- Municipal demand is forecasted to increase by 14% by 2035.

PLACEHOLDER

Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

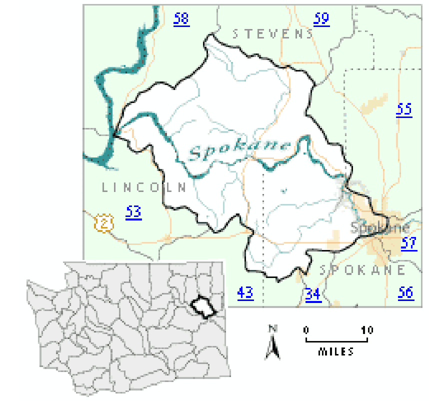
MANAGEMENT CONTEXT	
Adjudicated Areas	Chamokane Creek (federally administered)
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	YES (Chapter 173-557 WAC)
Fish Listed Under the Endangered Species Act[1]	Bull Trout spawning and rearing unknown
Groundwater Management Area	NO (For additional information on groundwater decline areas within this WRIA, see Module xx.)

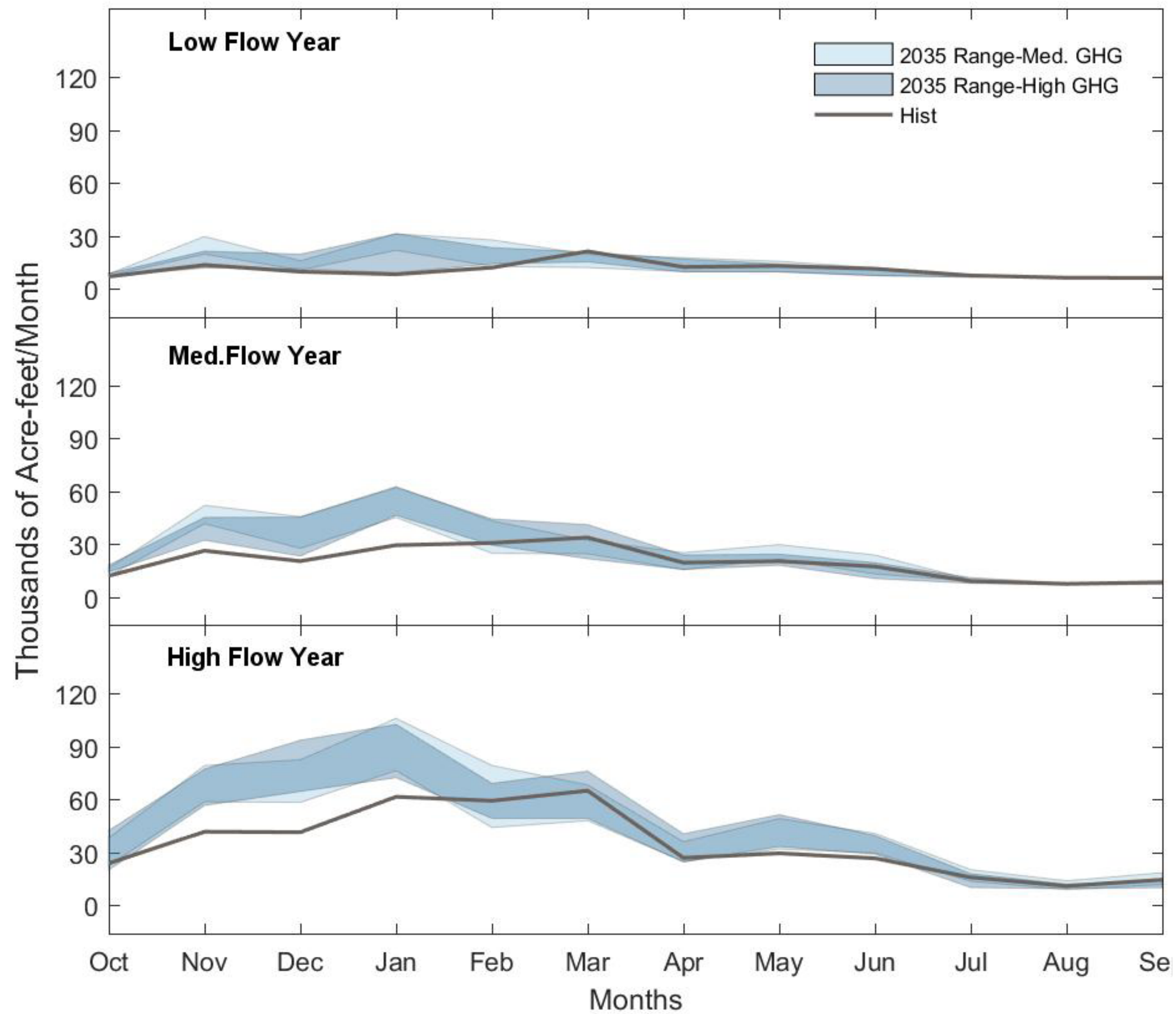
[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

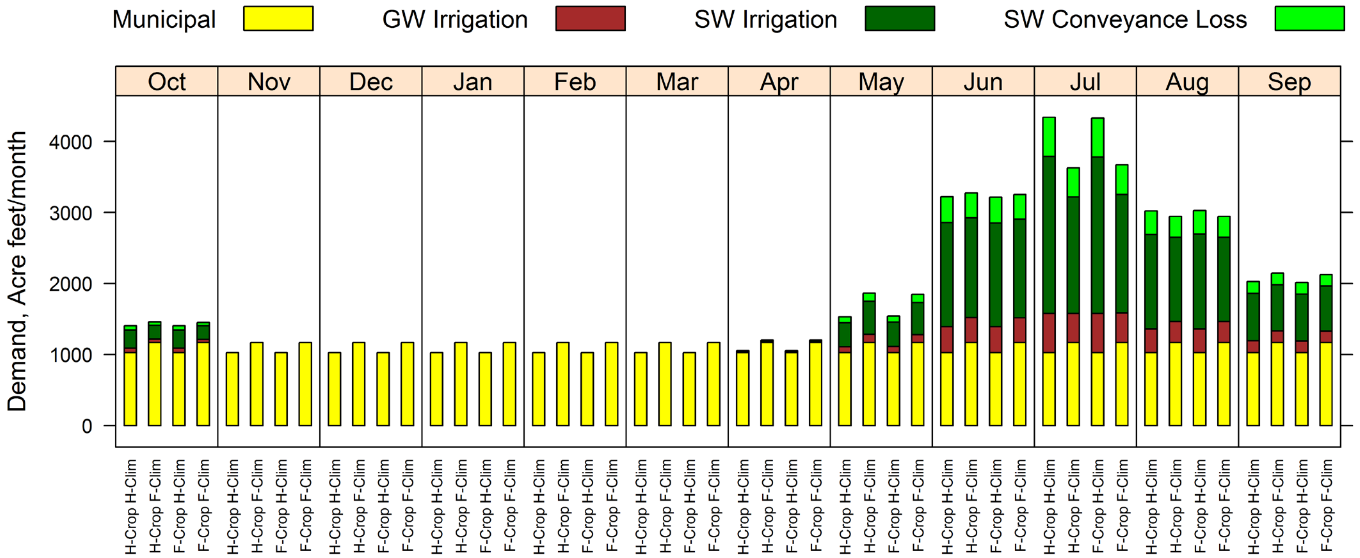
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND



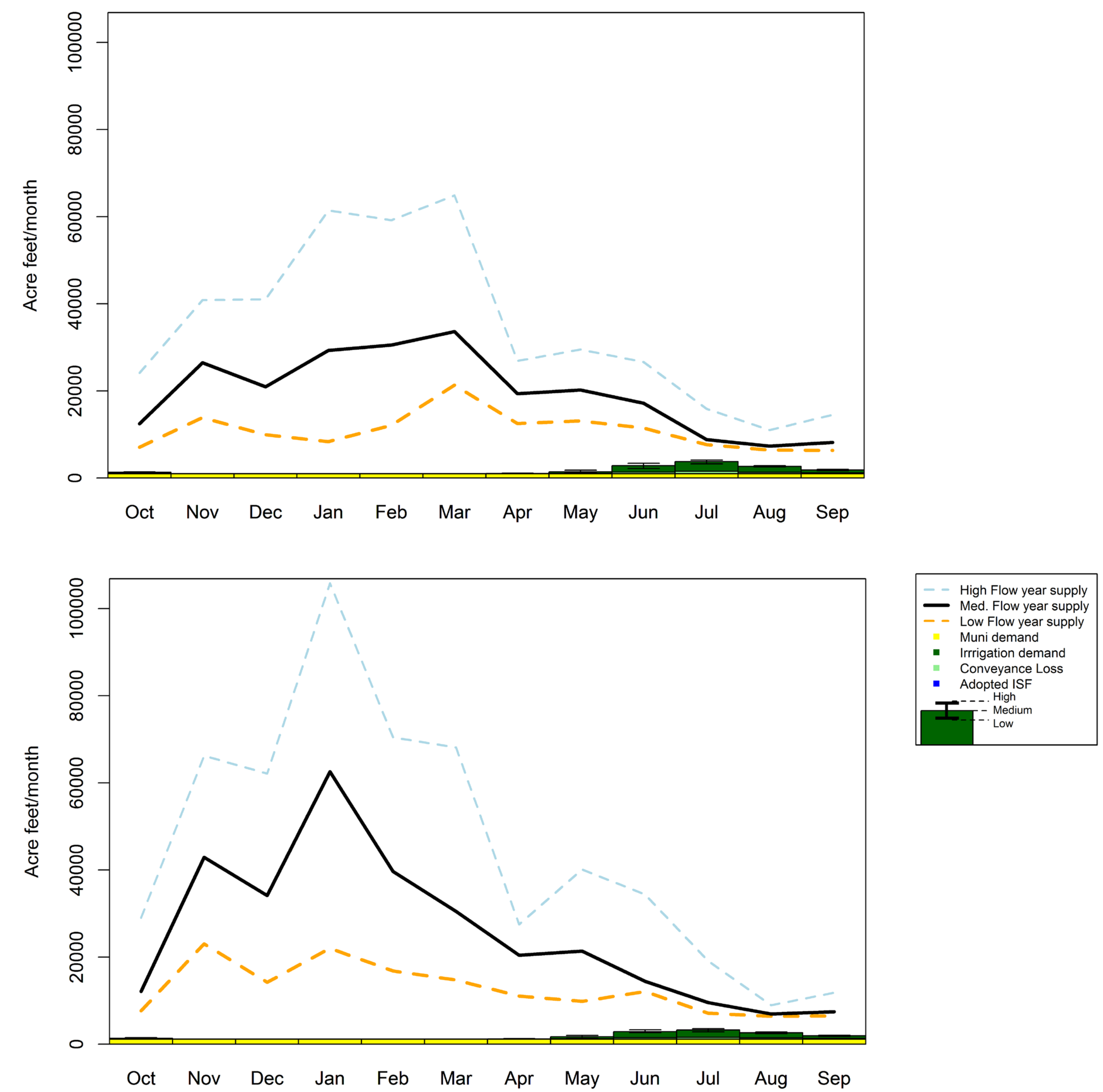
Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) “H-Crop H-Clim”, b)”H-Crop F-Clim”, c)“F-Crop H-Clim”, and d) ”F-Crop F-Clim” where “H-Crop” represents historic crop mix; “F-Crop” as future crop mix under medium economic scenario,”H-Clim” as historic climate and “F-Clim” values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the “top of crop” and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

DRAFT
WRIA 54

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

Lower Spokane

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Little Spokane is unclear as a combination of increases and decreases in supply (depending on climate scenario) occur from January through July.
- Instream flow requirements are the largest water demands in Little Spokane. Municipal demands are larger than in many other watersheds of eastern Washington, exceeding irrigation demand.
- Assuming no change in irrigated acreage, irrigation demands are projected to increase for all months except July, which is projected to decrease. However, in June and August climate and crop mix changes result in opposite signs of demand change (increases for climate change and mostly decreases for crop mixes).
- Municipal demand is projected to increase by 18% by 2035.

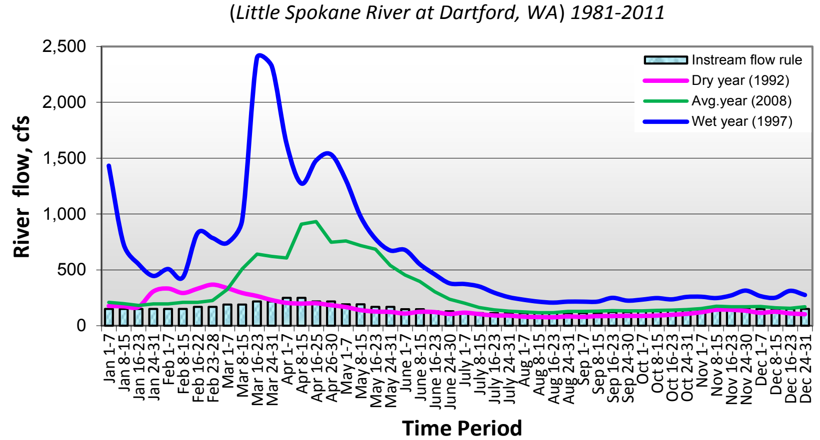
PLACEHOLDER

Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Deadman Creek
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	Yes (Chapter 173-555 WAC). 196 interruptible water rights curtailed periodically. Weekly frequency of interruption from 1984-2014 averaged 2 years from December to June (94% reliable), and ranged from 6 to 20 years from July to November (33% to 80% reliable).
Fish Listed Under the Endangered Species Act[1]	Bull Trout spawning and rearing unknown
Groundwater Management Area	NO

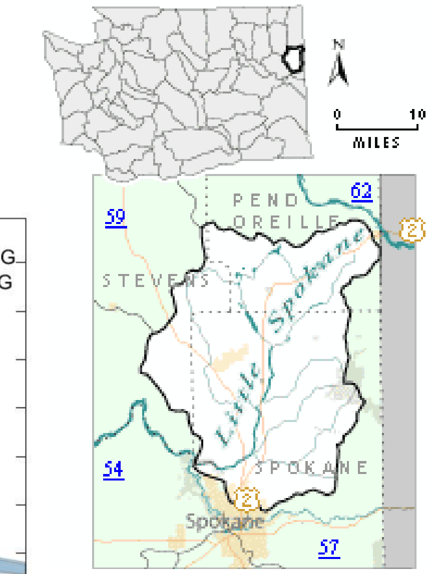
[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

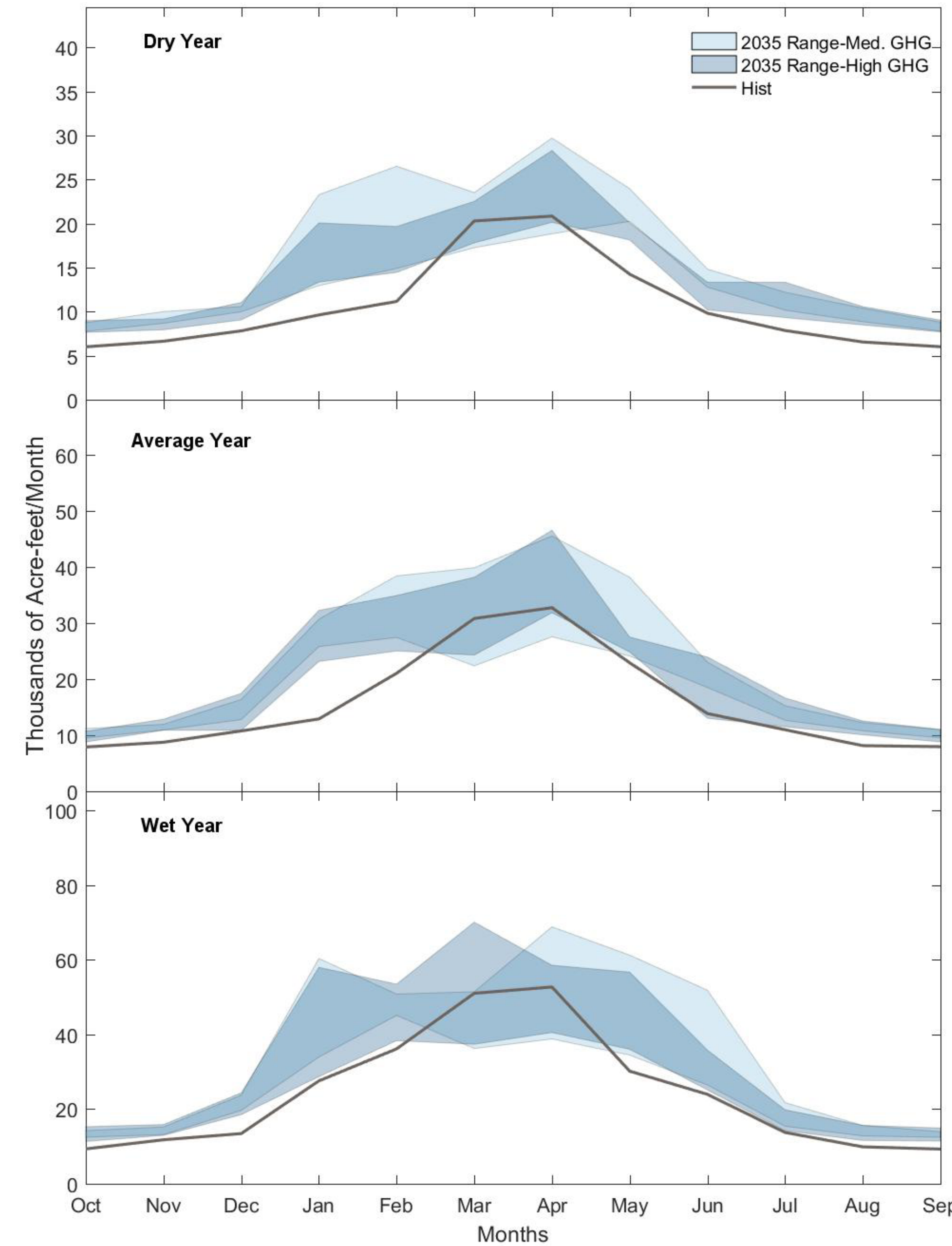
Comparison of Dry, Average and Wet Year Flows to Instream Flow Rule
(*Little Spokane River at Dartford, WA*) 1981-2011



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

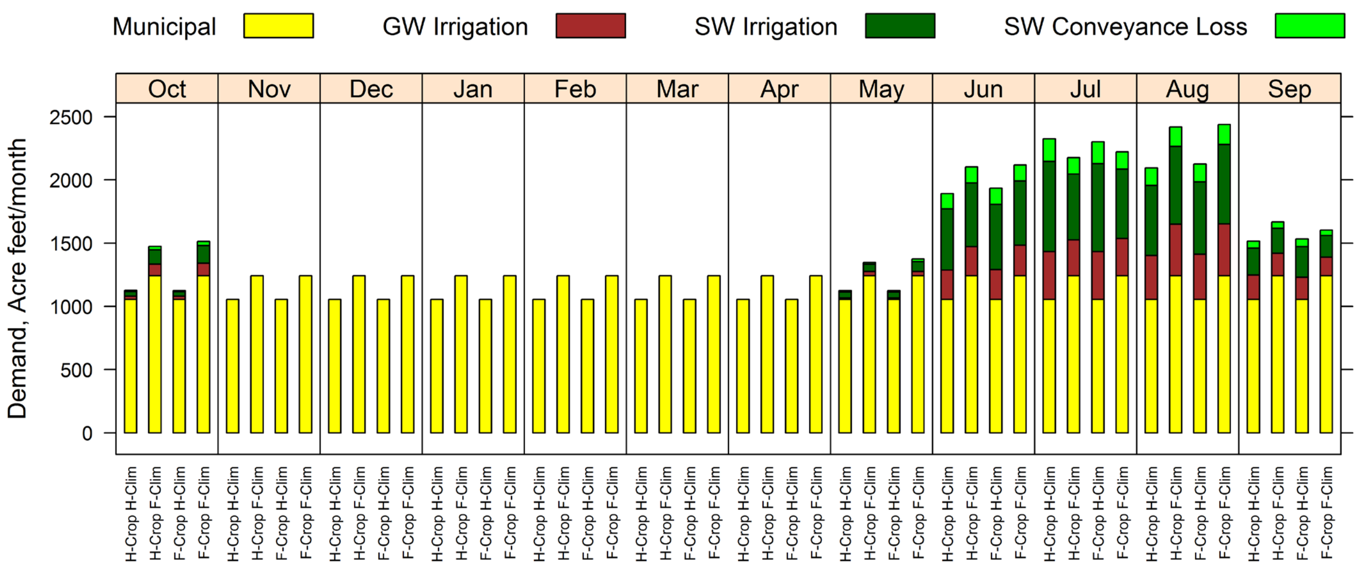
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

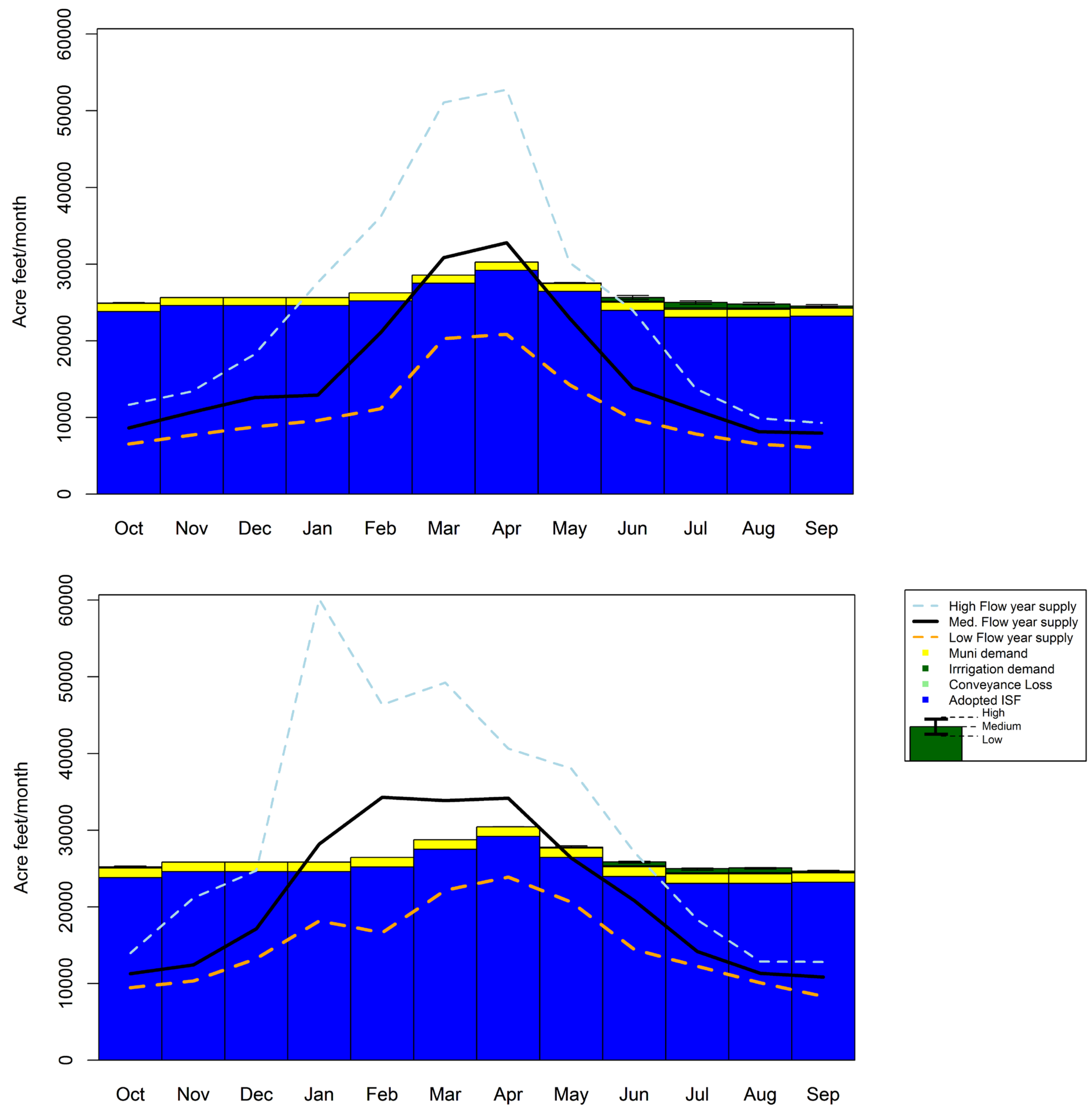


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Hangman is less certain as it is characterized by a combination of increases of increases and decreases during the months of January through July, depending on climate scenario.
- Unlike many other watersheds in eastern Washington, municipal demands are larger than irrigation demands in Hangman watershed.
- Assuming no change in irrigated acreage, irrigation demand is projected to increase for all months during the irrigation season. This is response to climate change while crop mix changes are resulting in some increased demand in July and August demands.
- Municipal demand is forecasted to grow 26% by 2035.

PLACEHOLDER

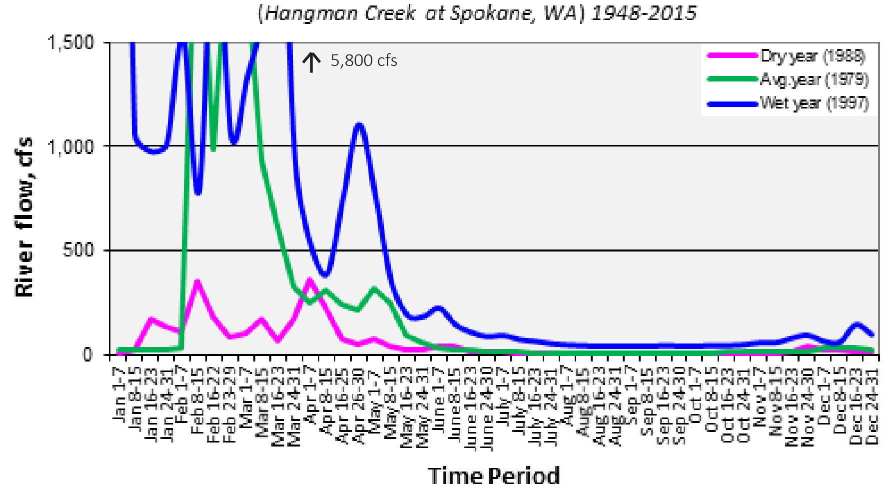
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Crystal Springs
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	No ESA-listed fish spawn or rear in WRIA waters
Groundwater Management Area	NO (For additional information on groundwater decline areas within this WRIA, see Module xx.)

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

Hangman Creek Dry, Average, Wet Year Flows

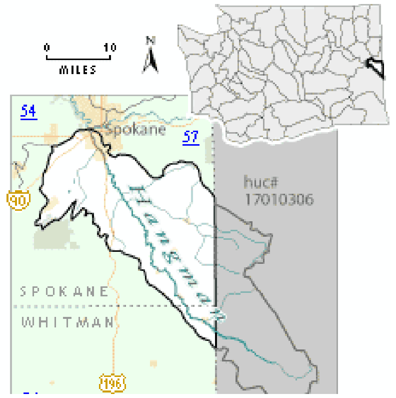
(Hangman Creek at Spokane, WA) 1948-2015

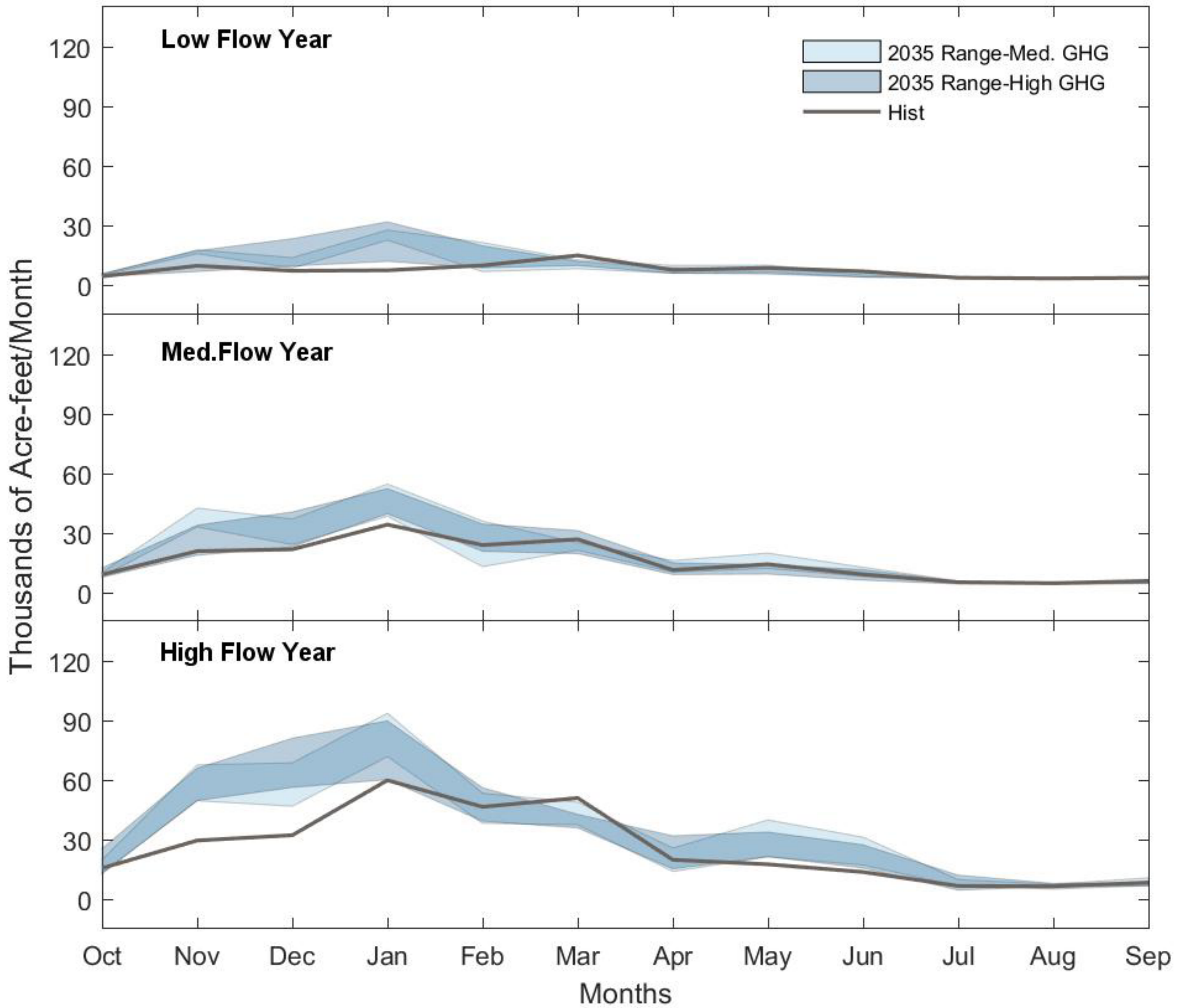


Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

DRAFT
WRIA 56
Hangman

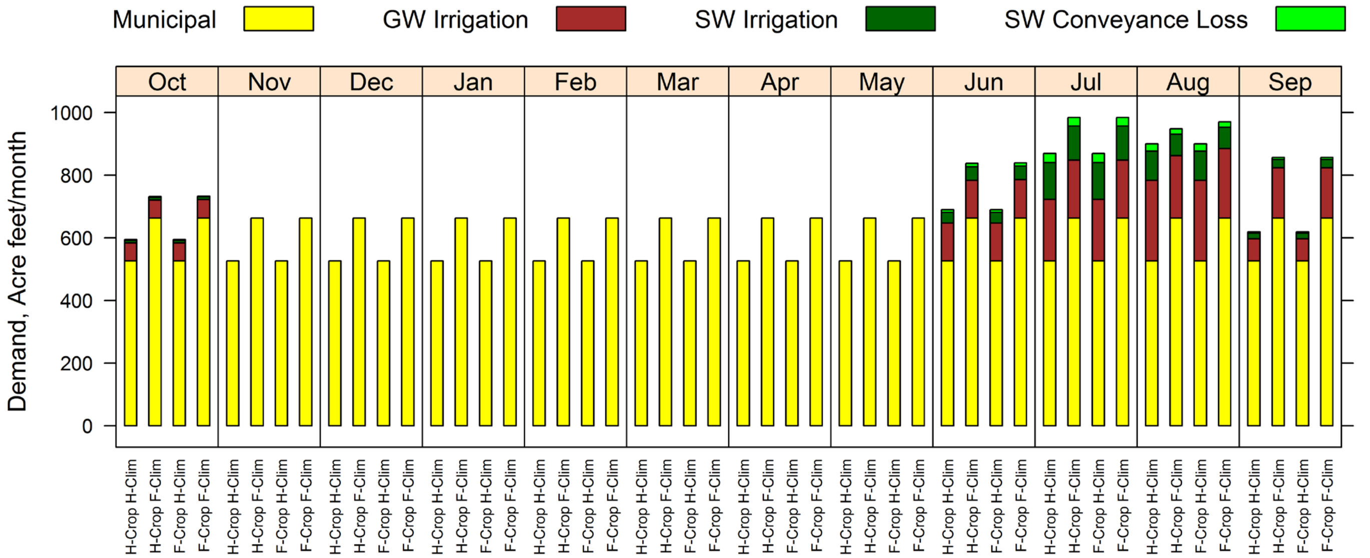
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

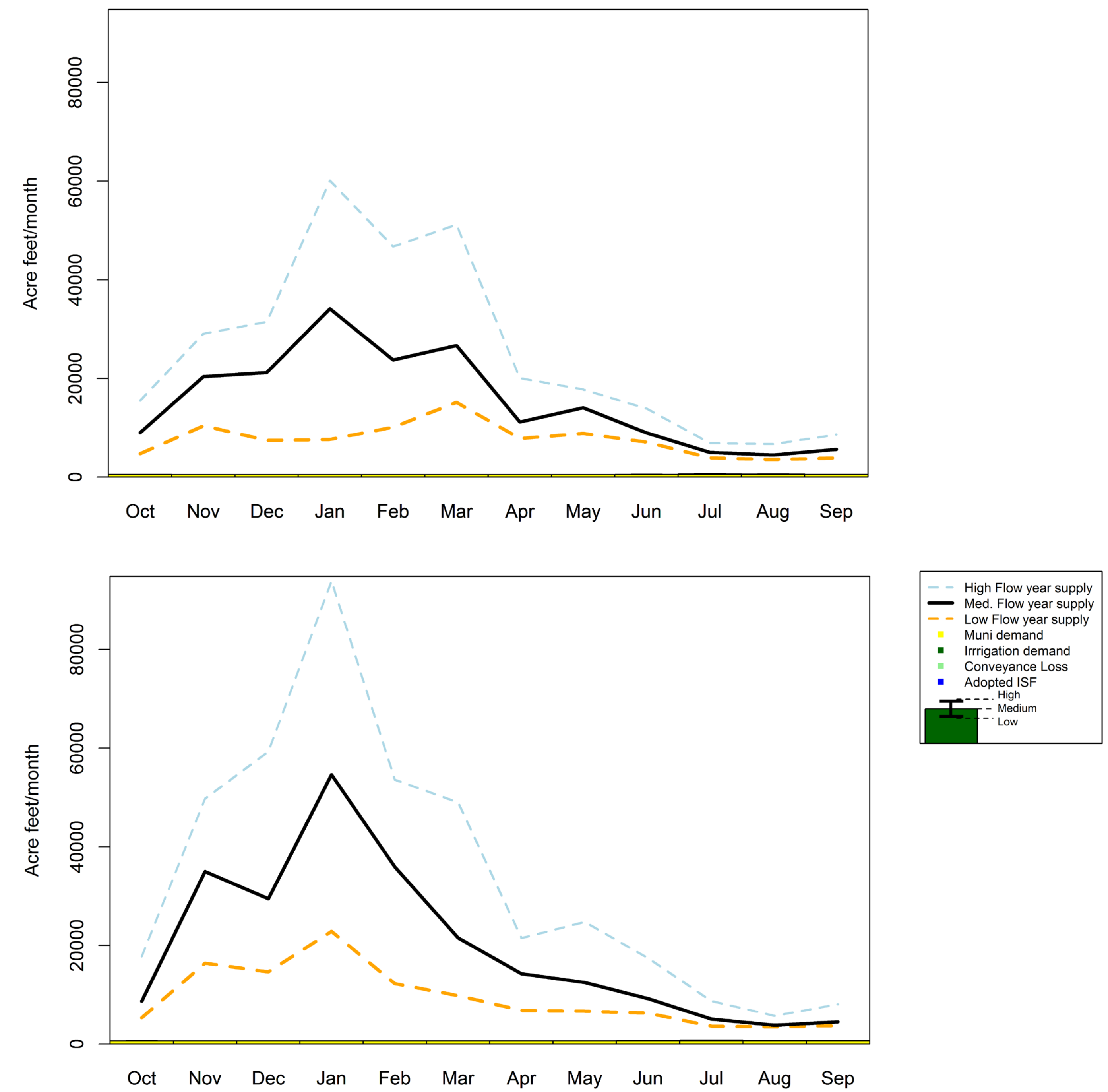


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Middle Spokane is characterized by significant increases from October through February, with a mix of increases and decreases in March and mostly decreases in April. June through August supplies are mixed with mostly increases for the 80th percentile supply year and decreases for the 20th percentile supply year.
- Municipal demands are the largest source of water demand in this watershed, and are also one of the largest among all of the WRIAs in eastern Washington.
- Assuming no change in irrigated acreage, irrigation demands are projected to increase for all months. This is response to climate change while crop mix changes (in isolation) are resulting in mostly unchanged demands.
- Municipal demand is projected to increase by 8% by 2035.

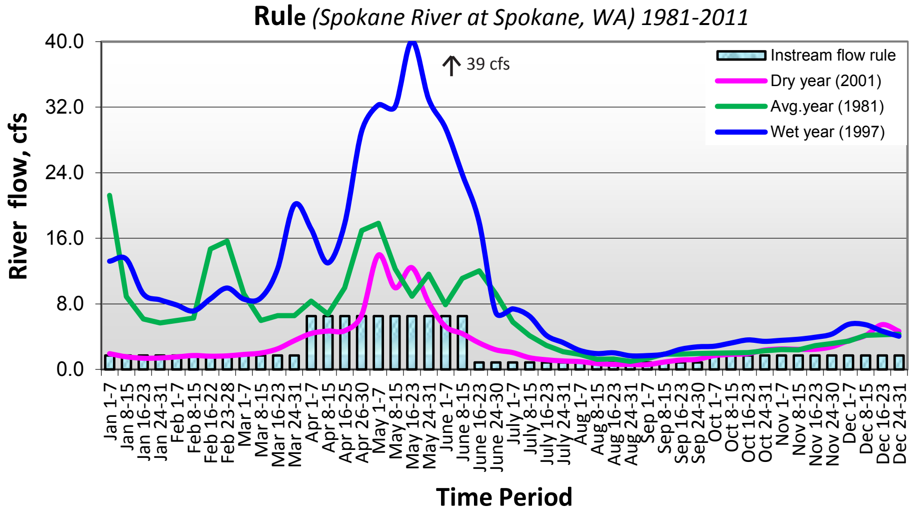
PLACEHOLDER

Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Walla Walla River
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	Yes (Chapter 173-557 WAC). No interruptible rights have been issued to date that are subject to instream flow curtailment.
Fish Listed Under the Endangered Species Act[1]	Bull Trout spawning and rearing unknown
Groundwater Management Area	NO

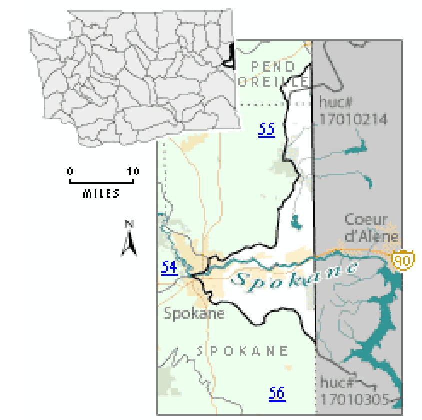
[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

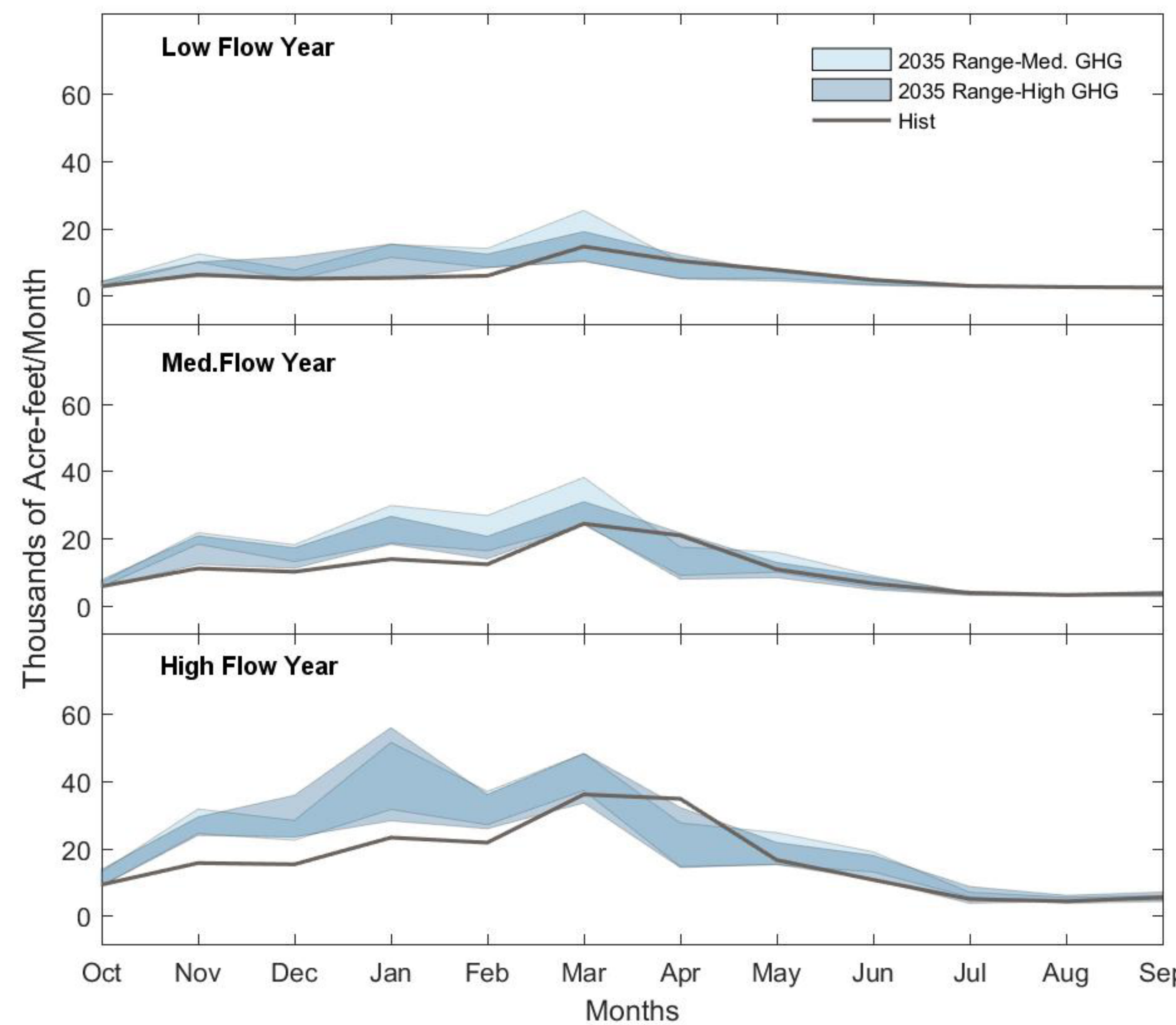
Comparison of Dry, Average and Wet Year Flows to Instream Flow Rule *(Spokane River at Spokane, WA) 1981-2011*



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

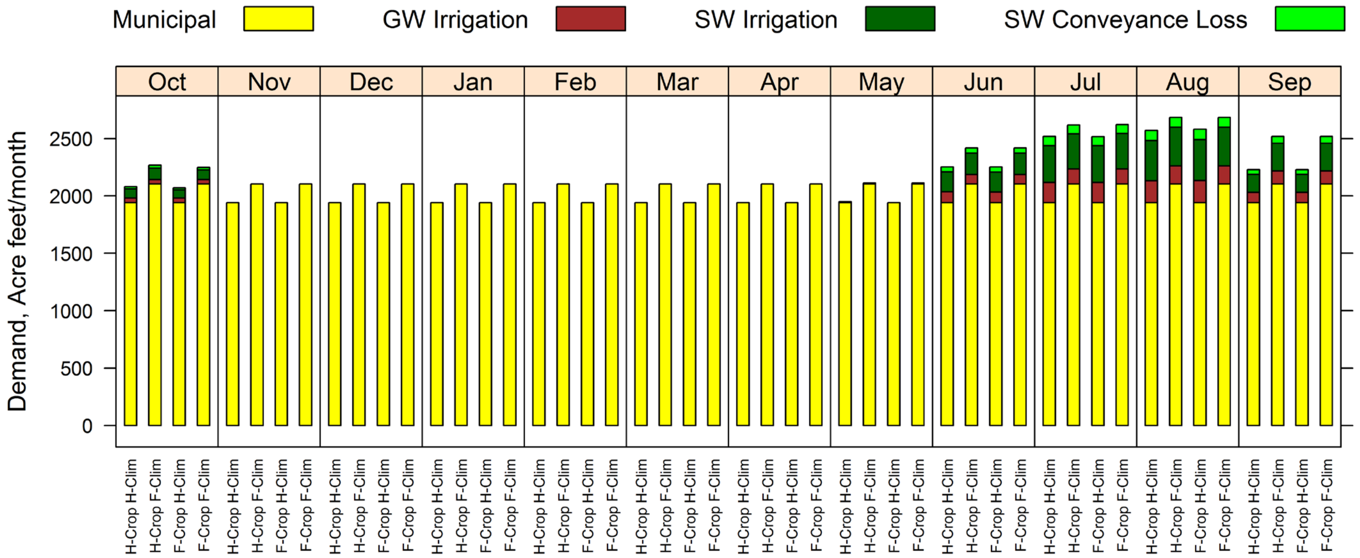
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

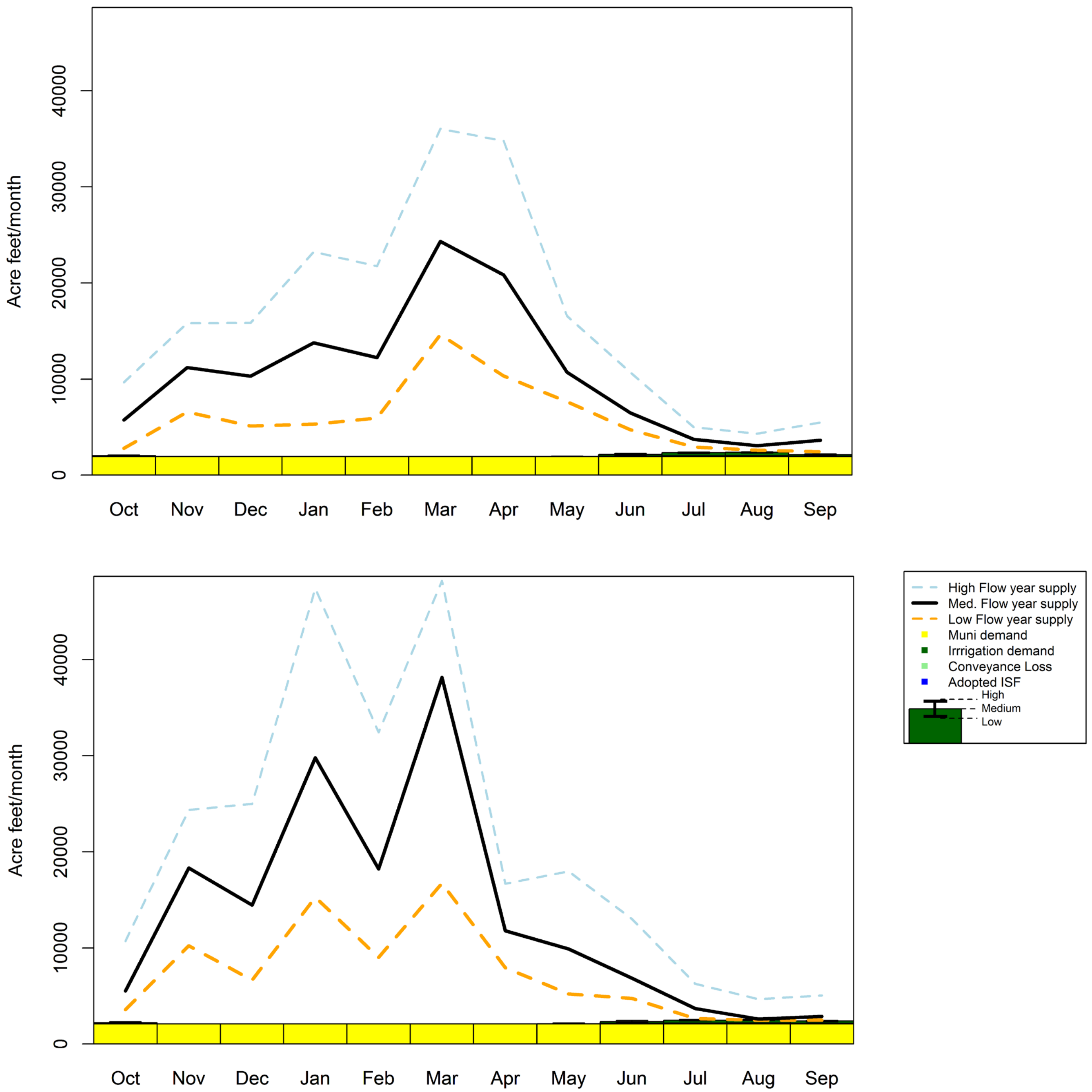


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

Middle Spokane

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Middle Lake Roosevelt is characterized By mostly increases from November through February and decreases from March through July, although the 80th percentile supply years show a combination of increases and decreases in March and June.
- Irrigation is a larger source of demand than municipal demand, though both demands are modest in comparison to other watersheds within eastern Washington.
- Assuming no change in irrigated acreage, irrigation demands are projected to increase for all months except May (which will decrease). This is in response to climate change as crop mix changes (in isolation) are resulting in increased demands in June, September, and October. Decreased demand in May is in response to crop mix changes.

PLACEHOLDER

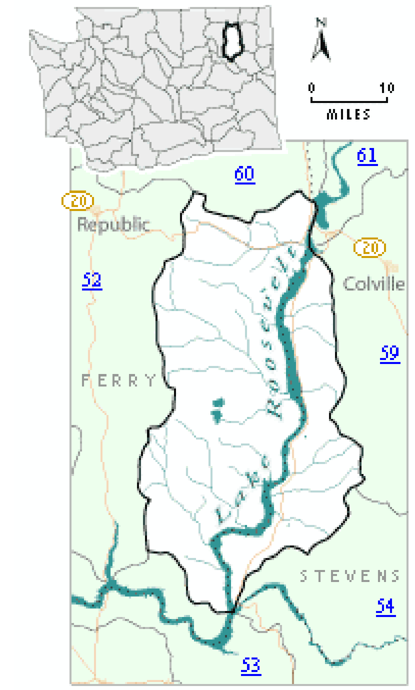
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

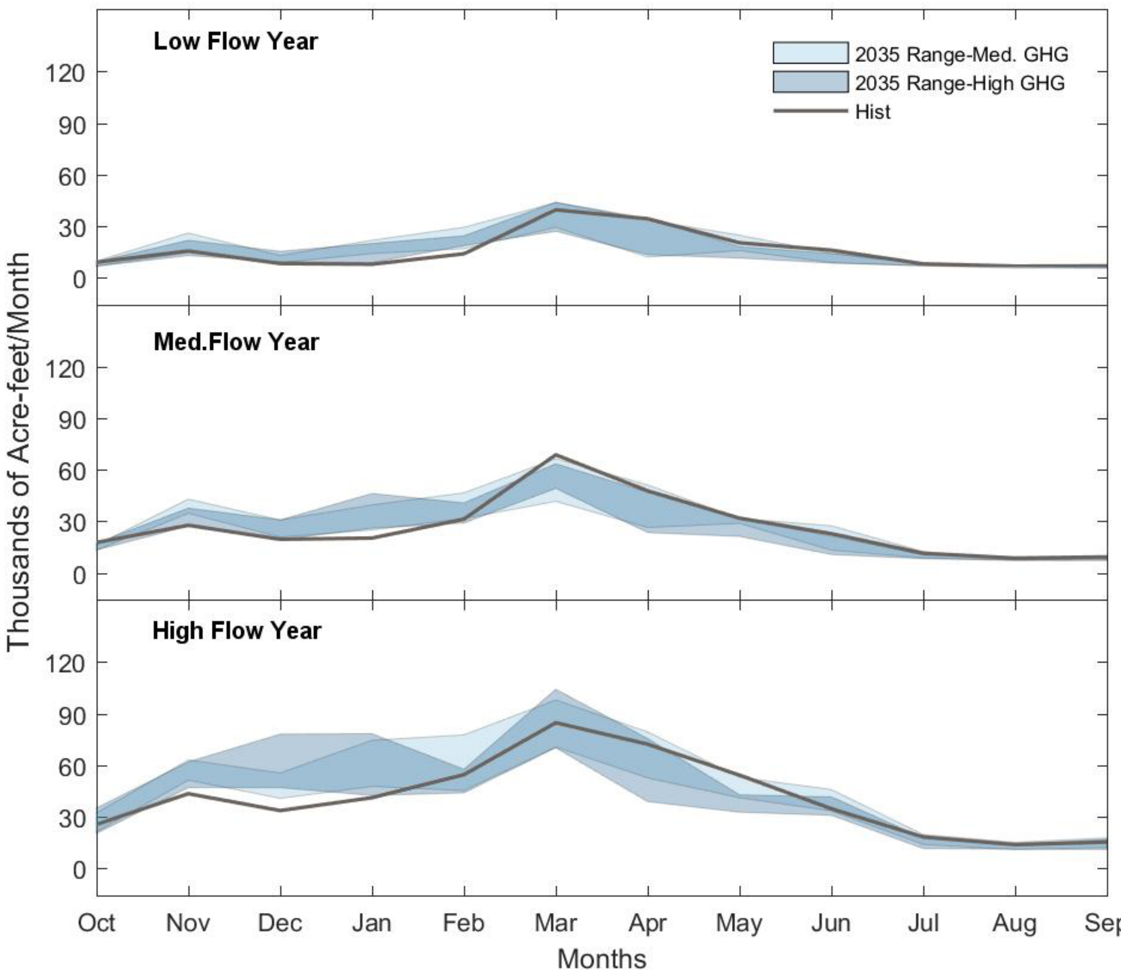
MANAGEMENT CONTEXT	
Adjudicated Areas	Quillisascut Creek, Cheweka Creek, Jennings Creek, Magee Creek , Stranger Creek, Harvey Creek, Alder Creek , O-Ra-Pak-En Creek, Corus Creek, Hunter Creek (incomplete)
Watershed Planning	NO
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	Bull Trout spawning and rearing unknown
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

DRAFT
WRIA 58
Middle Lake Roosevelt

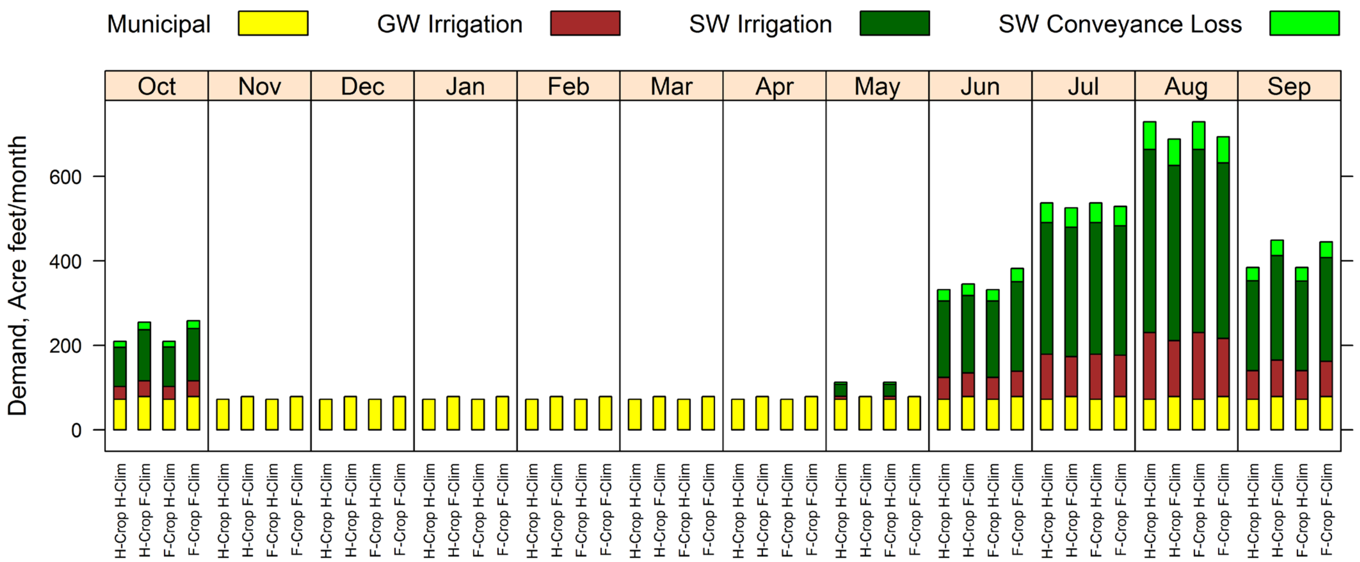
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the “2035 Range-Med. GHG” and the “2035 Range-Med. High” values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND



Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) "H-Crop H-Clim", b)"H-Crop F-Clim", c)"F-Crop H-Clim", and d) "F-Crop F-Clim" where "H-Crop" represents historic crop mix; "F-Crop" as future crop mix under medium economic scenario,"H-Clim" as historic climate and "F-Clim" values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the "top of crop" and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

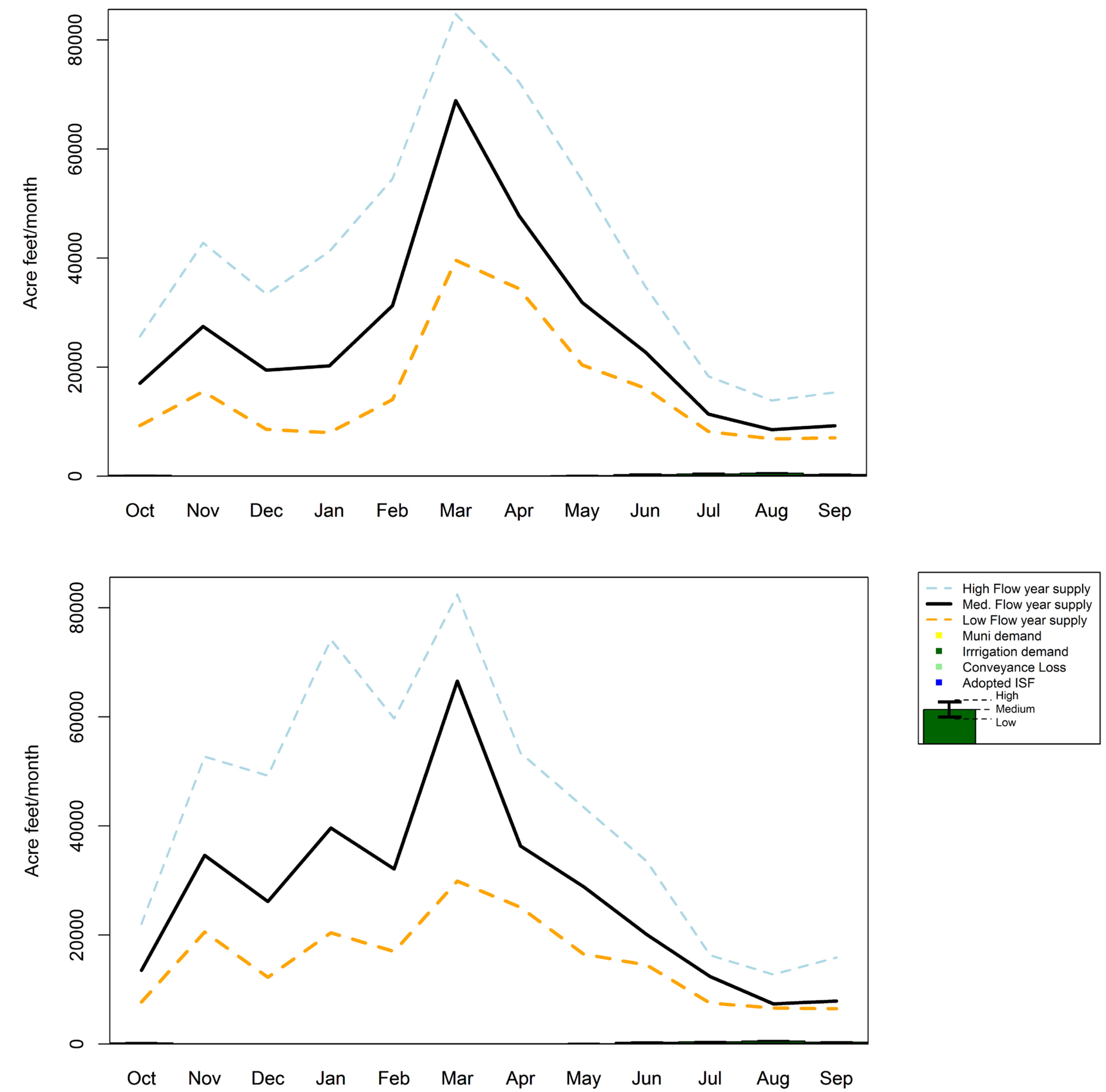
Awaiting Results

DRAFT

WRIA 58

SUPPLY & DEMAND

Middle Lake Roosevelt



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

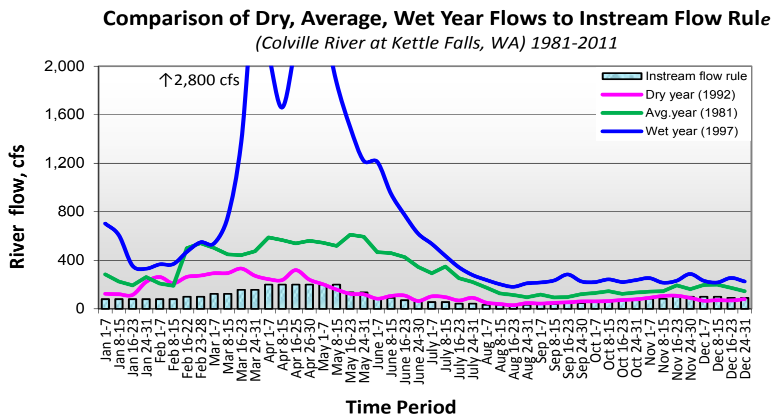
- The tributary surface water supply forecast for Colville is characterized mostly by increases in all months, with substantial increases from February through June.
- The primary demands are instream flow requirements and irrigation, with municipal demands that are fairly small.
- Assuming no change in irrigated acreage, irrigation demand is unclear as climate and crop mix changes are results in demand changes of opposite sign, with climate change resulting in increased demands for all months and crop mix changes resulting in decreased demand in all months.
- Municipal demands are forecasted to grow by roughly 6% by 2035, though the resulting demand will still be modest in comparison to other WRIAs of eastern Washington.

PLACEHOLDER

Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

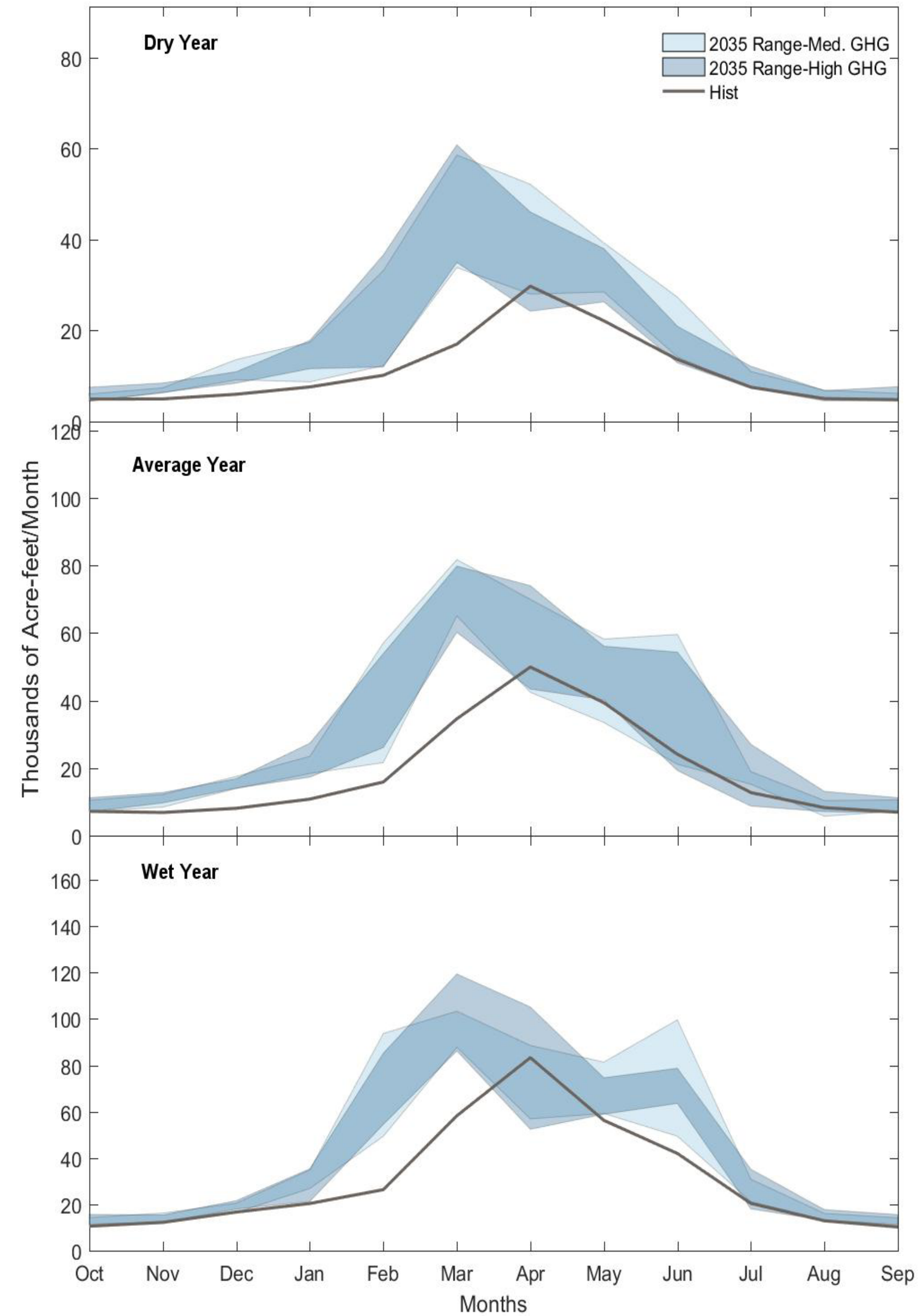
MANAGEMENT CONTEXT	
Adjudicated Areas	Sherwood Creek, Deer Creek, Chewelah Creek, Hoffman Creek, Pingston Creek, Bull Dog Creek, Thomason Creek, Narcisse Creek, Grouse Creek, Jumpoff Joe Creek, Jumpoff Joe Lake
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	Yes (Chapter 173-559 WAC). 85 interruptible water rights curtailed periodically. Weekly frequency of interruption from 1984-2014 ranged from 0 to 5 years from January to October (83% to 100% reliable), and from 5 to 9 years in November and December (70% to 83% reliable).
Fish Listed Under the Endangered Species Act[1]	Bull Trout spawning and rearing unknown
Groundwater Management Area	NO

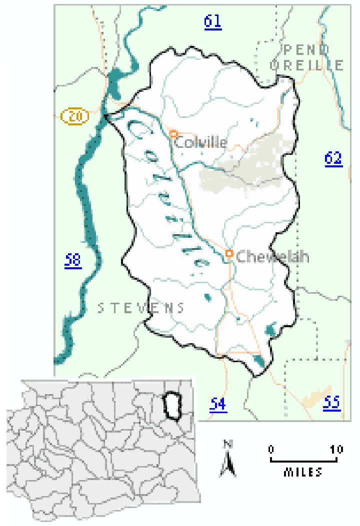
[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

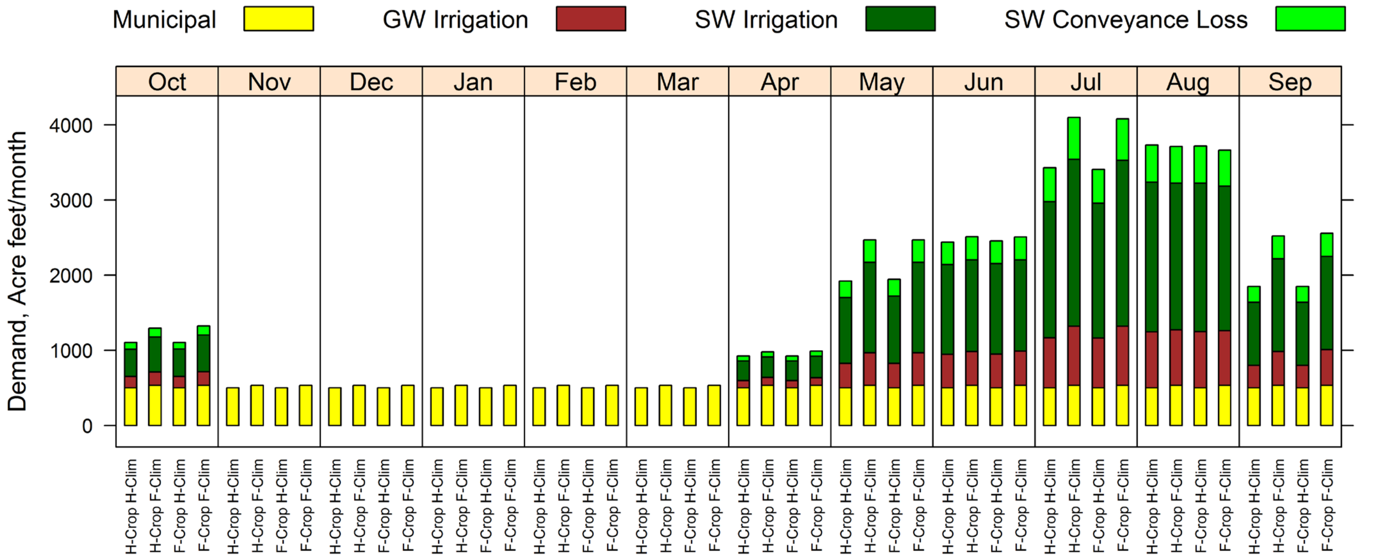
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND

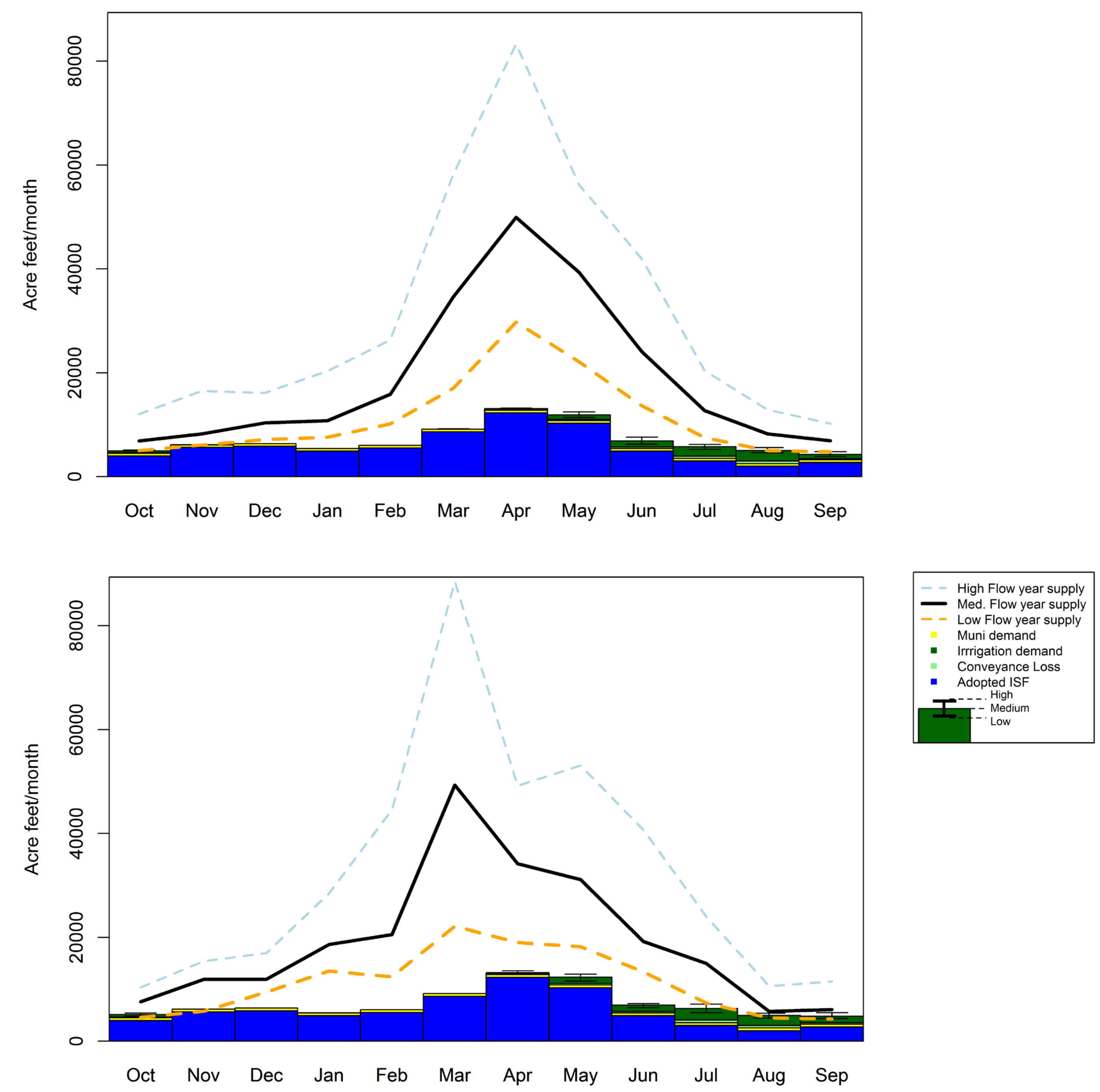


Modeled historical (1981-2011) and forecast (2035) agricultural, municipal, and instream flow water demands within the WRIA. Water demand was forecast under four scenarios combination of: a) “H-Crop H-Clim”, b)”H-Crop F-Clim”, c)“F-Crop H-Clim”, and d) ”F-Crop F-Clim” where “H-Crop” represents historic crop mix; “F-Crop” as future crop mix under medium economic scenario,”H-Clim” as historic climate and “F-Clim” values represent demand forecast under IPCC Representative Concentration Pathway (RCP) 4.5 centering 2035. Each bar represents median (50th percentile) demand condition. Ground water (GW, brown) and surface water (SW, dark green) irrigation demands are shown at the “top of crop” and include water that will actually be used by plants, as well as on-field losses based on irrigation type. Conveyance losses (light green) are estimated separately. Consumptive municipal demands (yellow) include self-supplied domestic use, but exclude self-supplied industrial use.

PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Kettle is characterized by mostly increases from November through February and mostly decreases from April through August, with mixed effects in June for the 80th percentile supply year.
- Both irrigation and municipal/domestic demands are quite small.
- Assuming no change in irrigated acreage, irrigation demands are Projected to increase in August and October and decrease in June, July, and September. These changes are due to mixed responses to climate and crop mix changes.
- Municipal demand is forecasted to grow roughly 9% by 2035, though total municipal demand will still be modest.

PLACEHOLDER

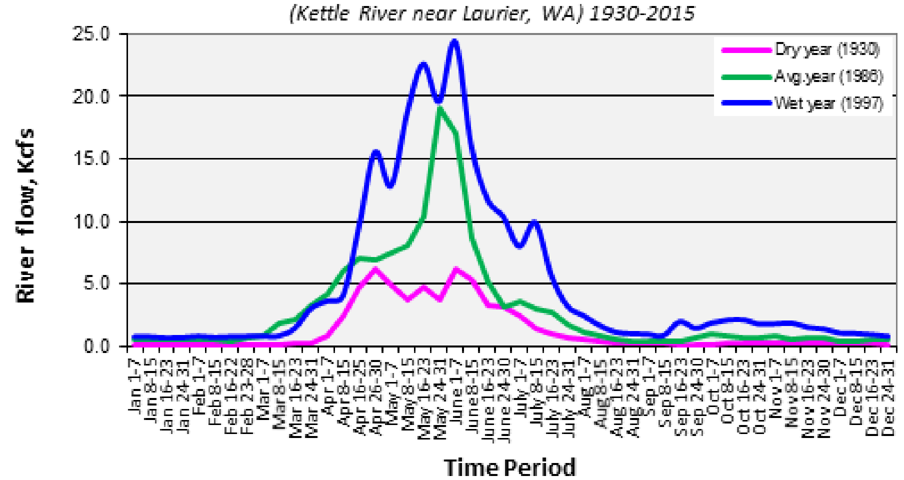
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Twin Creek
Watershed Planning	NO (planning terminated at the end of phase 2)
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	Bull Trout spawning and rearing unknown
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

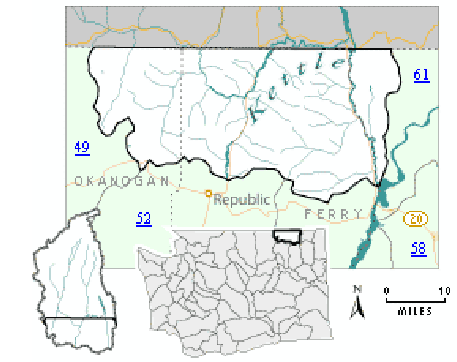
Kettle River Dry, Average, Wet Year Flows

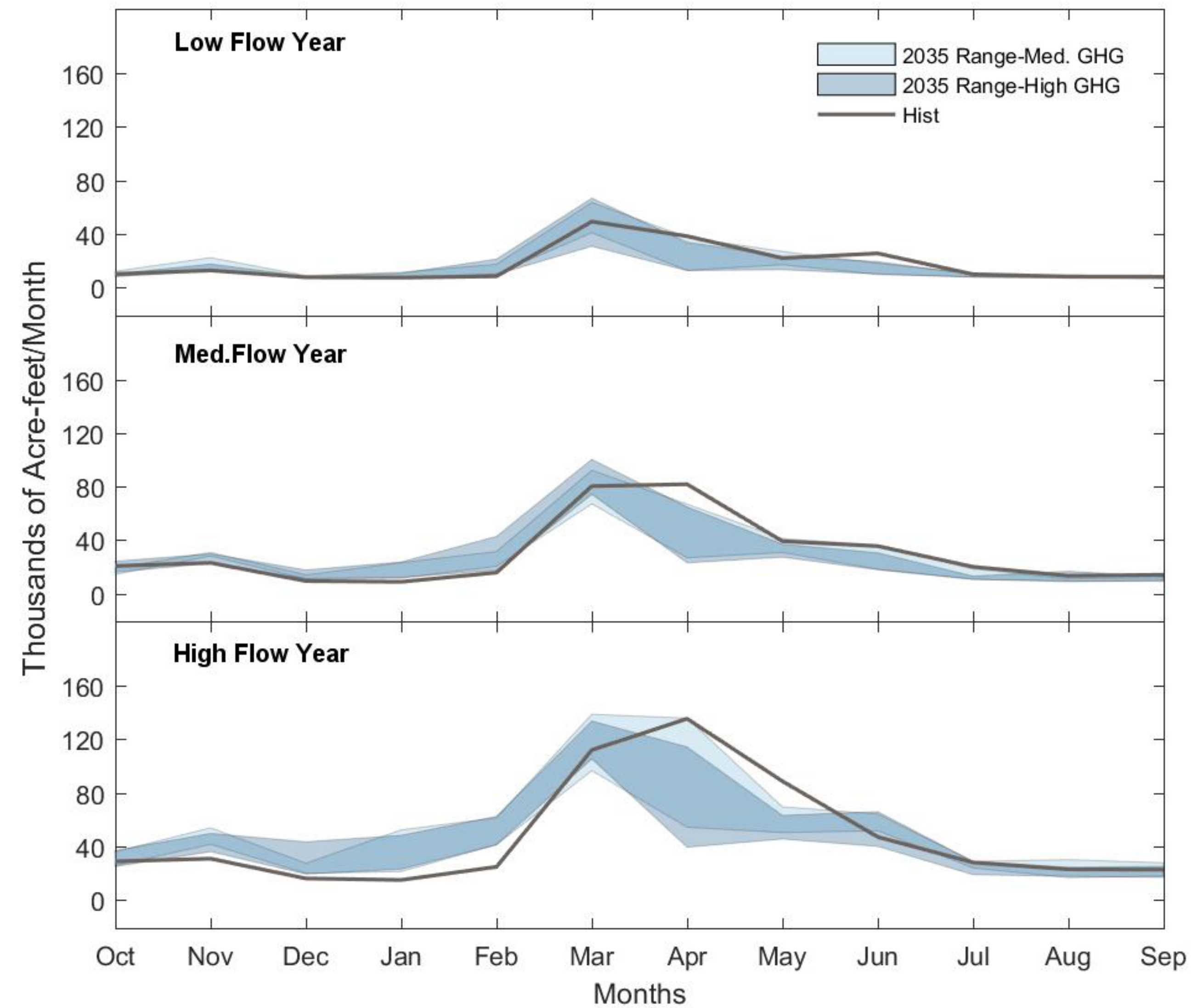
(Kettle River near Laurier, WA) 1930-2015



Historical flows plots: Actual historical flows measured at an existing stream gauge (data obtained from the U.S. Geological Survey [link: http://waterdata.usgs.gov/wa/nwis]). The stream gauge selected was the one furthest downstream within the WRIA. Flows are shown for the year with the lowest annual flow on record (Dry year), the year with the highest annual flow on record (Wet year), and the year with annual flow closest to average flow for that gauge. Average flow was calculated as the mean of the central 60% of years on record, ranked by their annual flows, which were assumed to represent "average" years. Only years with sufficient weekly data points to provide a complete flow curve were selected. WRIAs with adopted instream flow rules show those flow requirements as well, for comparison purposes.

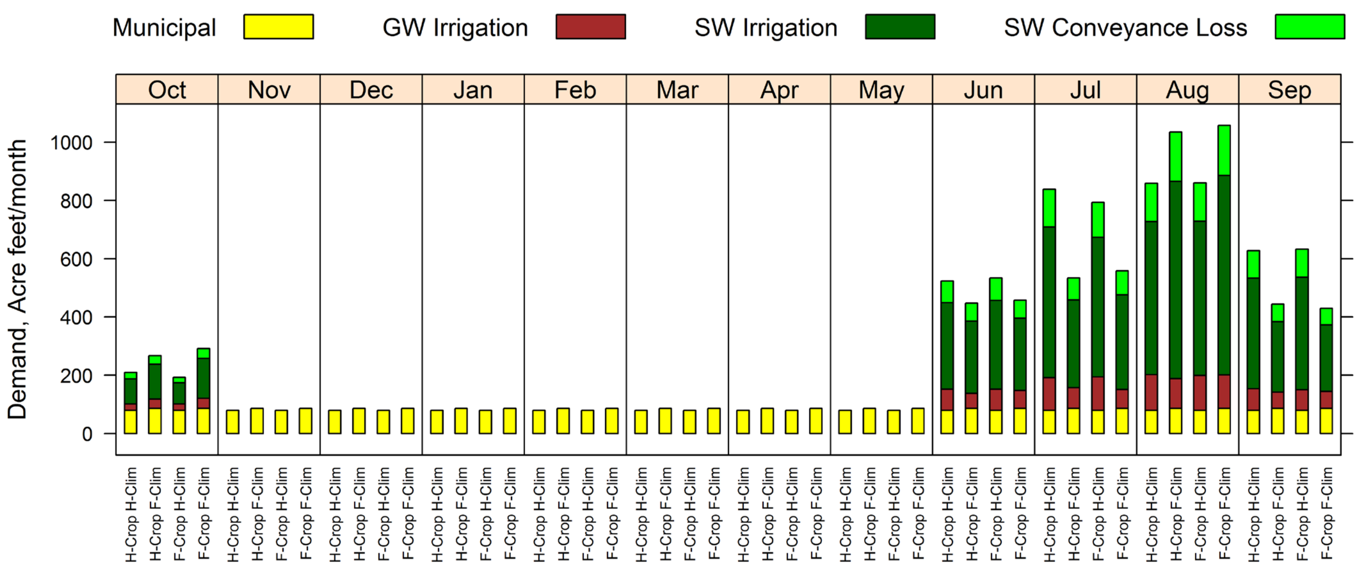
SUPPLY





Modeled historical (1981-2011) and forecast (2035) surface water supply generated within the WRIA for low (20th percentile, top), median (middle), and high (80th percentile, bottom) supply conditions. Water supply was forecast under two emissions scenarios: the "2035 Range-Med. GHG" and the "2035 Range-Med. High" values represent supply forecast under IPCC Representative Concentration Pathways (RCP) 4.5 and 8.5, respectively. The spread of each 2035 supply is due to the range of climate change scenarios considered. Supplies are reported prior to accounting for demands, and thus should not be compared to observed flows.

DEMAND



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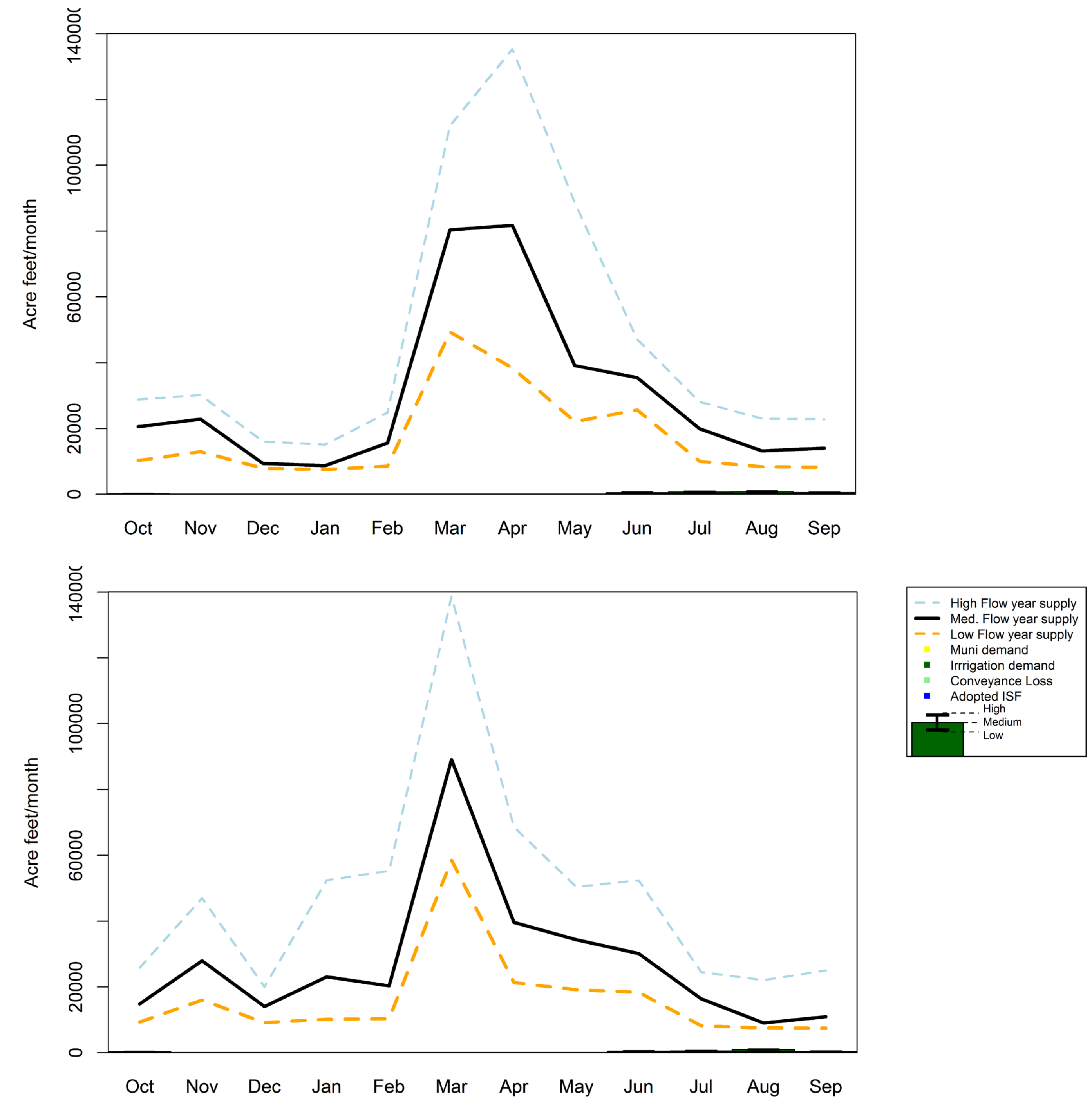
PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



Comparison of surface water supply, surface water agricultural and municipal demands for historical (1981-2011; top panel) and forecast (2035; bottom panel), using the middle value of the range of climate change scenarios considered. High (80th percentile), median, and low (20th percentile) supply conditions are shown as different curves. The 80th, 50th, and 20th percentile demand conditions are also shown for agricultural demand using error bars. These results do not consider water curtailment.

MANAGEMENT CONTEXT

- The tributary surface water supply forecast for Upper Lake Roosevelt is characterized by mostly increases from November through March and decreases from April through August, with mixed effects in June for the 80th percentile supply year.
- Both municipal/domestic and irrigation demands are fairly small.
- Assuming no change in irrigated acreage, irrigation demands are projected to decrease in all months except October, during which it is projected to increase. The effects from changes in climate are mixed with increase in June, September, and October and decrease in rest of the irrigation season. Crop mix changes almost always contributed to decrease in demand.
- Municipal demand is forecasted to grow roughly 8% by 2035, though total municipal demand will still be modest.

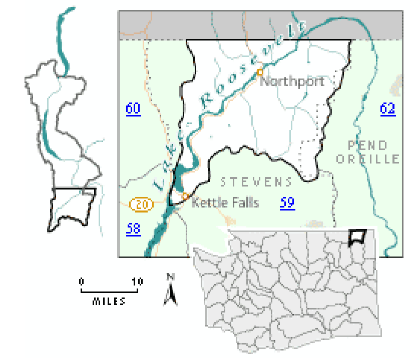
PLACEHOLDER

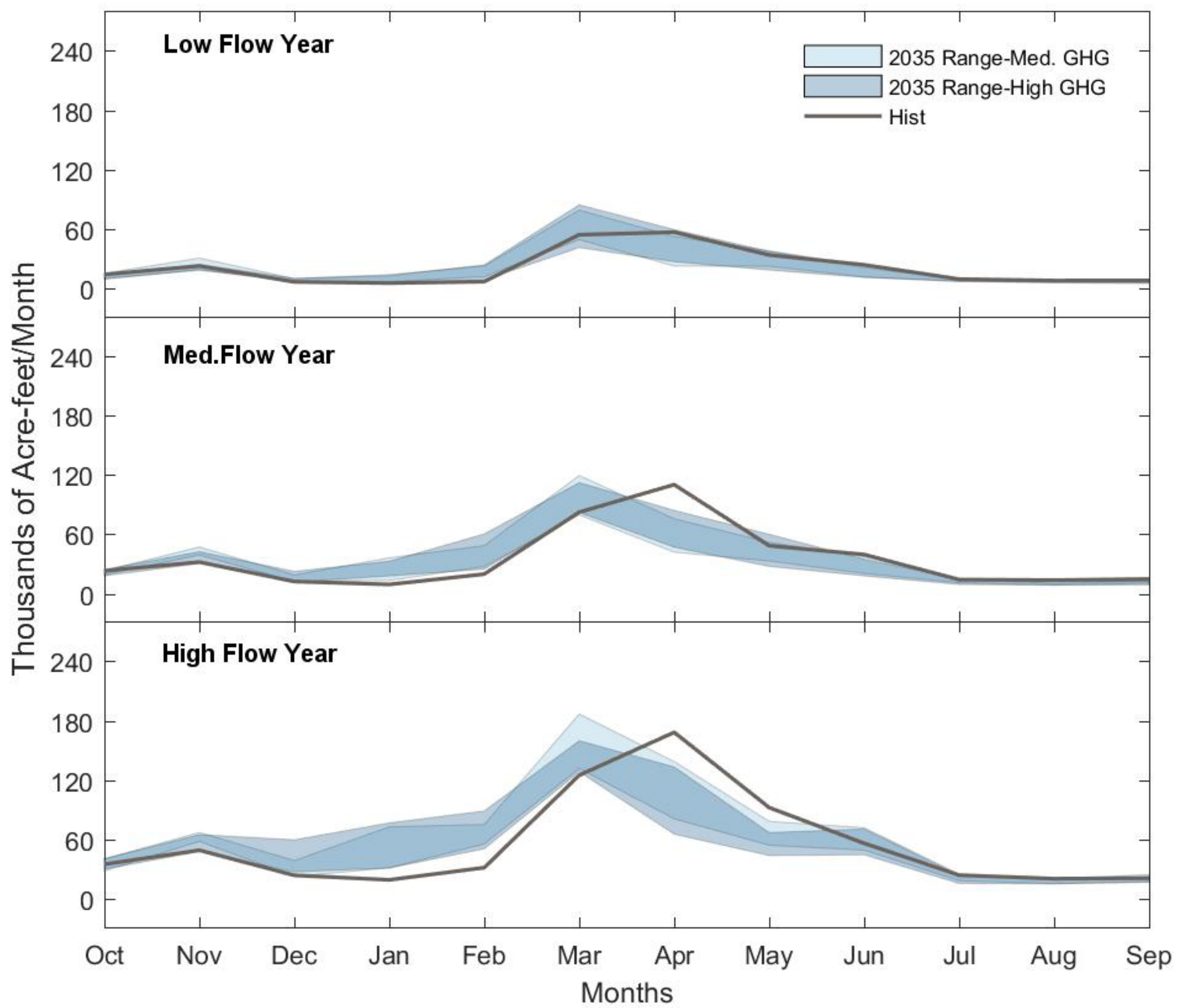
Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	NONE
Watershed Planning	NO
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	Bull Trout spawning and rearing unknown
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.

SUPPLY





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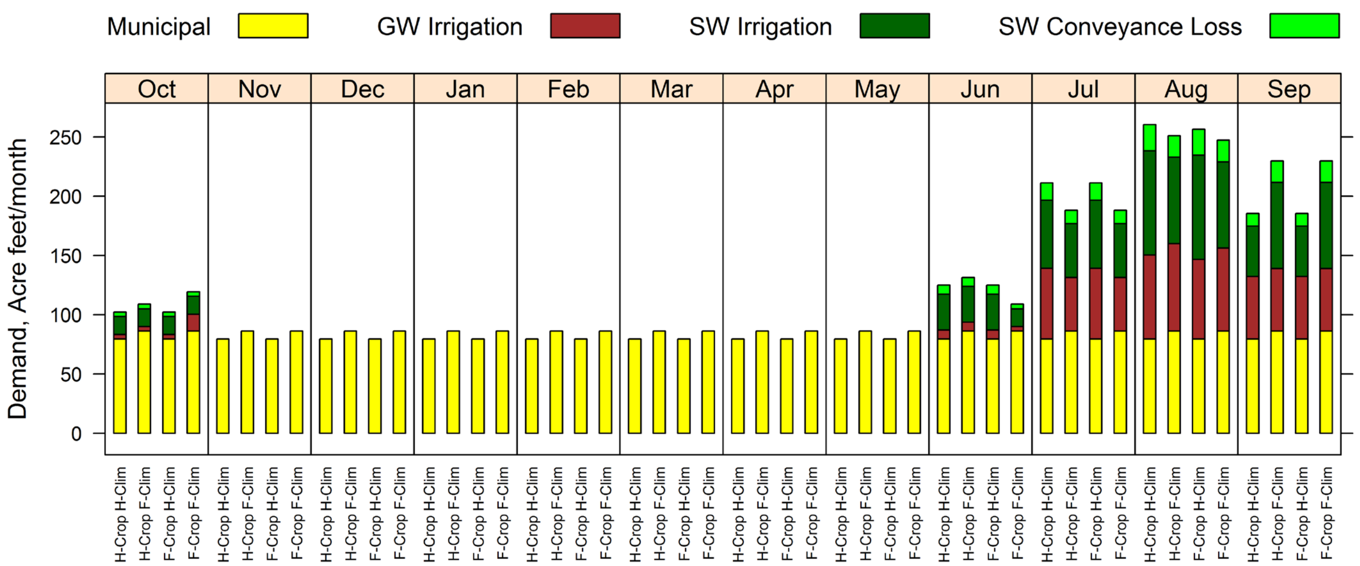
DEMAND



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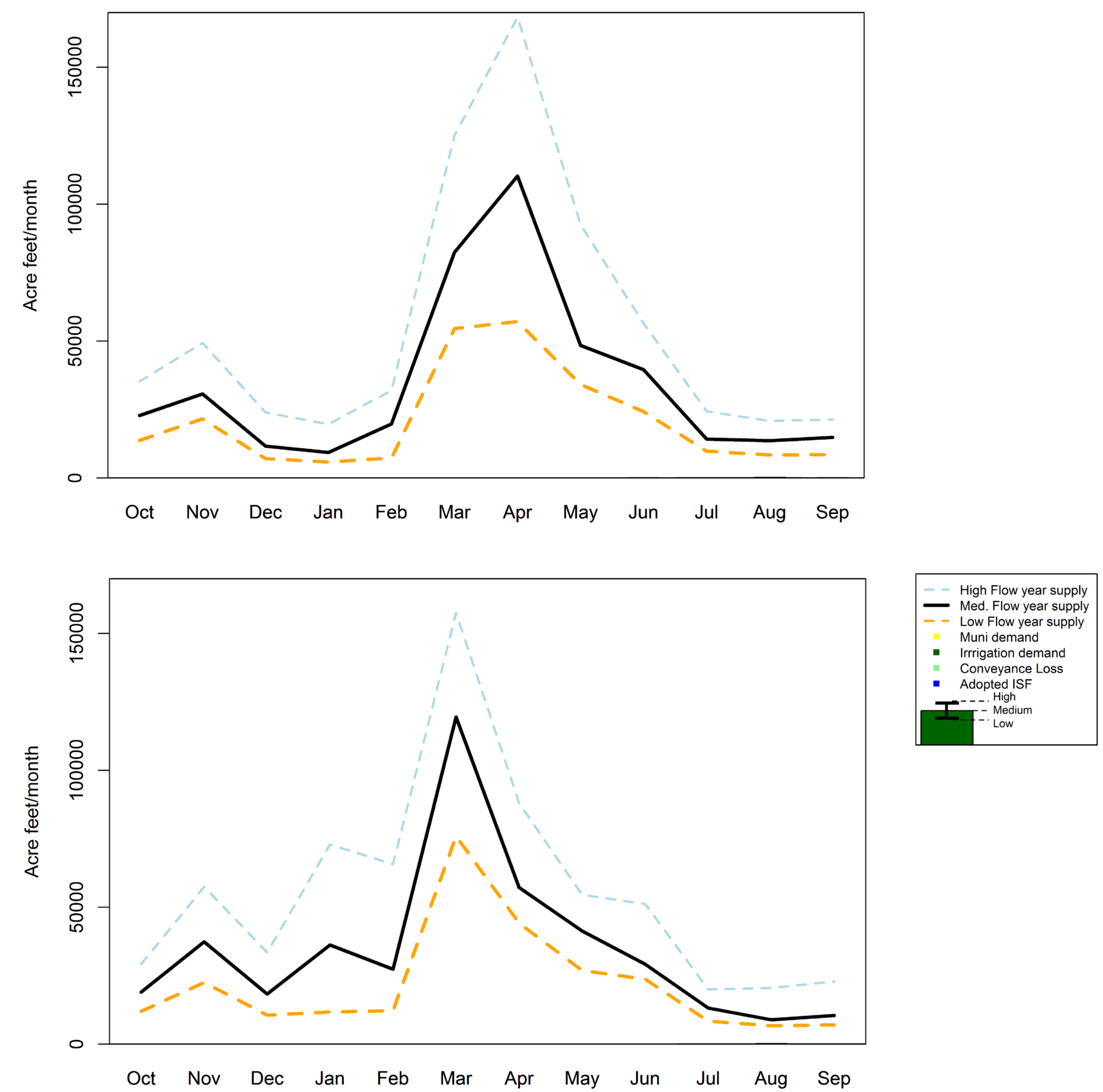
PLACEHOLDER

Awaiting Results

SUPPLY & DEMAND



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MANAGEMENT CONTEXT

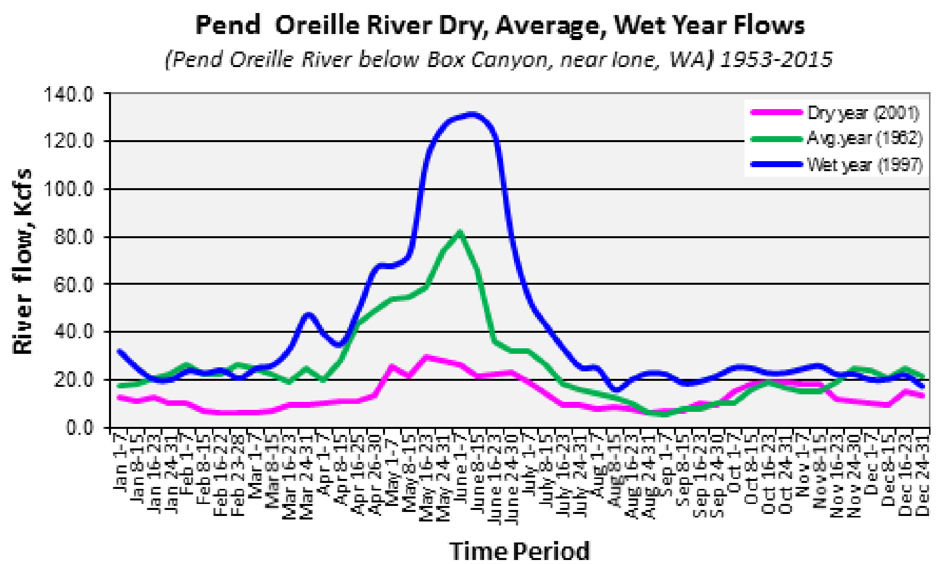
- The tributary surface water supply forecast for Pend Oreille is characterized by mostly increases from November through March and decreases from May through August.
- Municipal demand is the primary source of demand, though small in comparison to watersheds with larger population centers.
- Assuming no change in irrigated acreage, irrigation demands are projected to increase in May, June, August, and October and decrease in July and September. While climate change (in isolation) is resulting in a a mix of increases and decreases in demand, crop mix changes are not showing any impact.
- Municipal demand is forecasted to grow 9% by 2035.
- If additional water capacity is provided, agricultural irrigation water demand is not anticipated to increase.

PLACEHOLDER

Further bullets will be added once water capacity scenarios and curtailment modeling are complete.

MANAGEMENT CONTEXT	
Adjudicated Areas	Renshaw Creek, Little Calispell Creek, Marshall Lake and Creek
Watershed Planning	Phase 4 (Implementation)
Adopted Instream Flow Rules	NO
Fish Listed Under the Endangered Species Act[1]	Bull Trout
Groundwater Management Area	NO

[1]All species that spawn or rear in WRIA waters are identified. Species that migrate through WRIA waters are not individually identified, but migratory corridors for listed fish species that spawn and rear upstream are noted.



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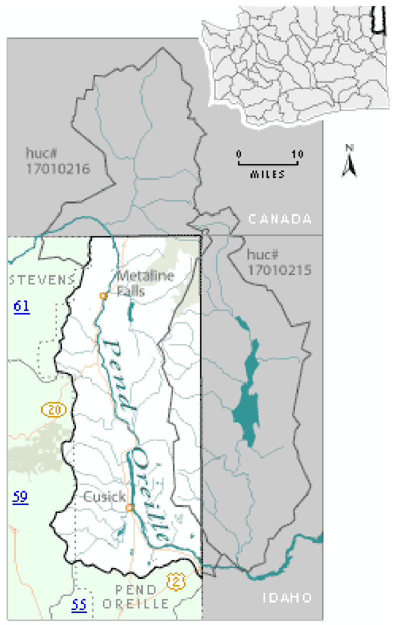
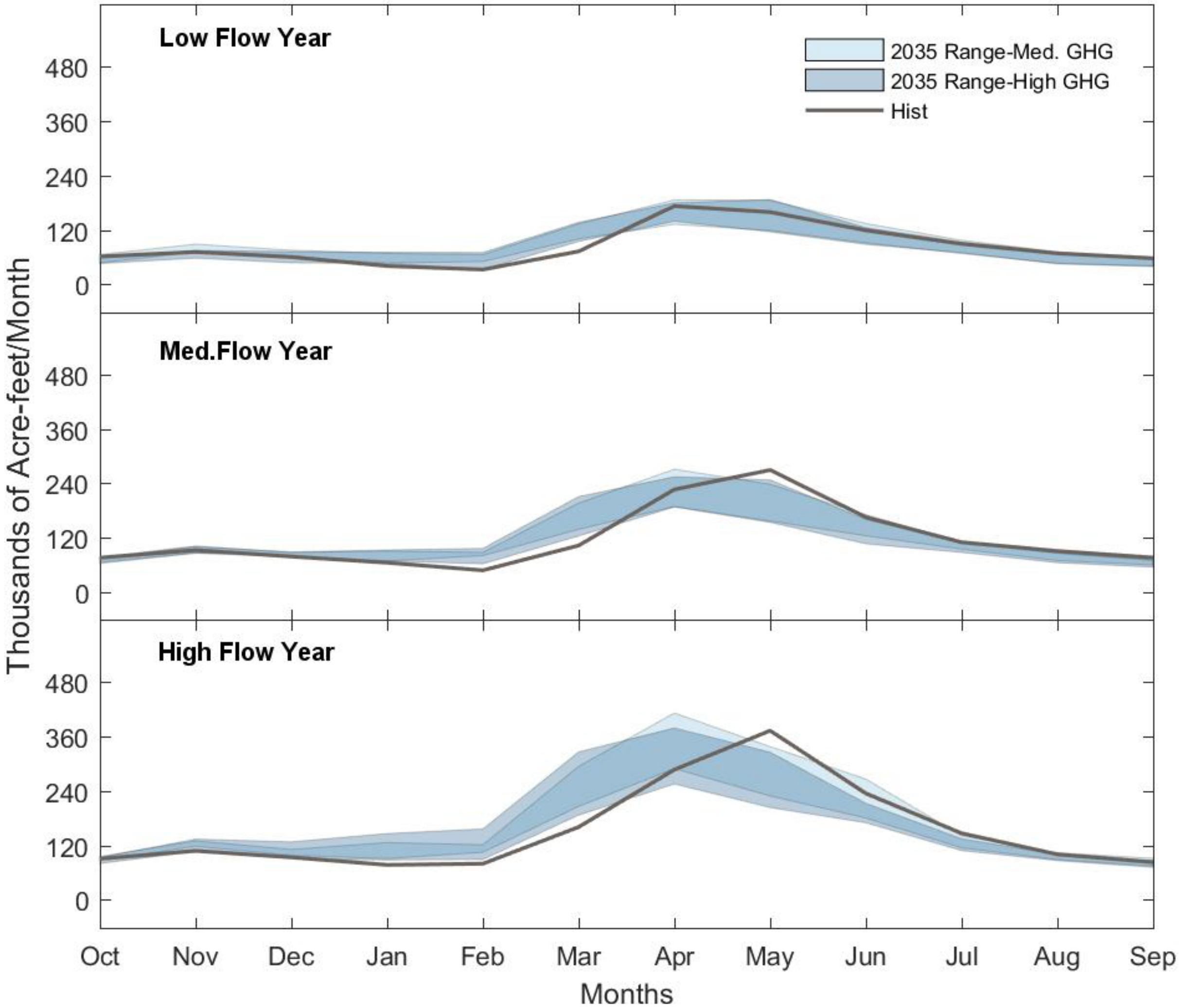
SUPPLY





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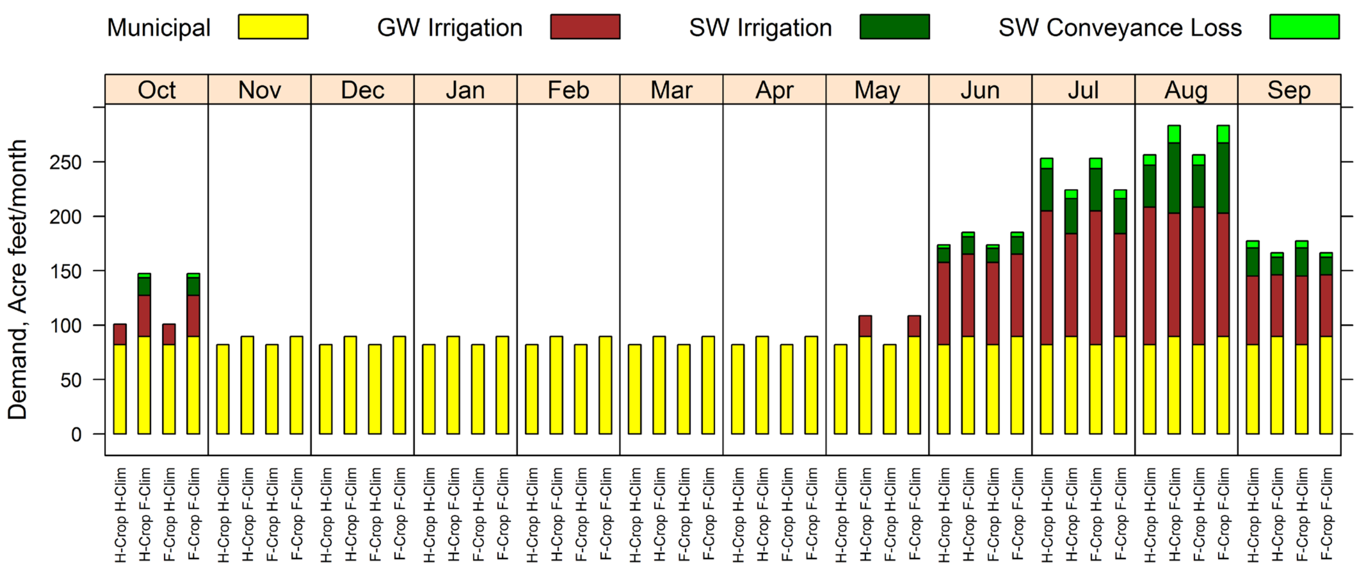

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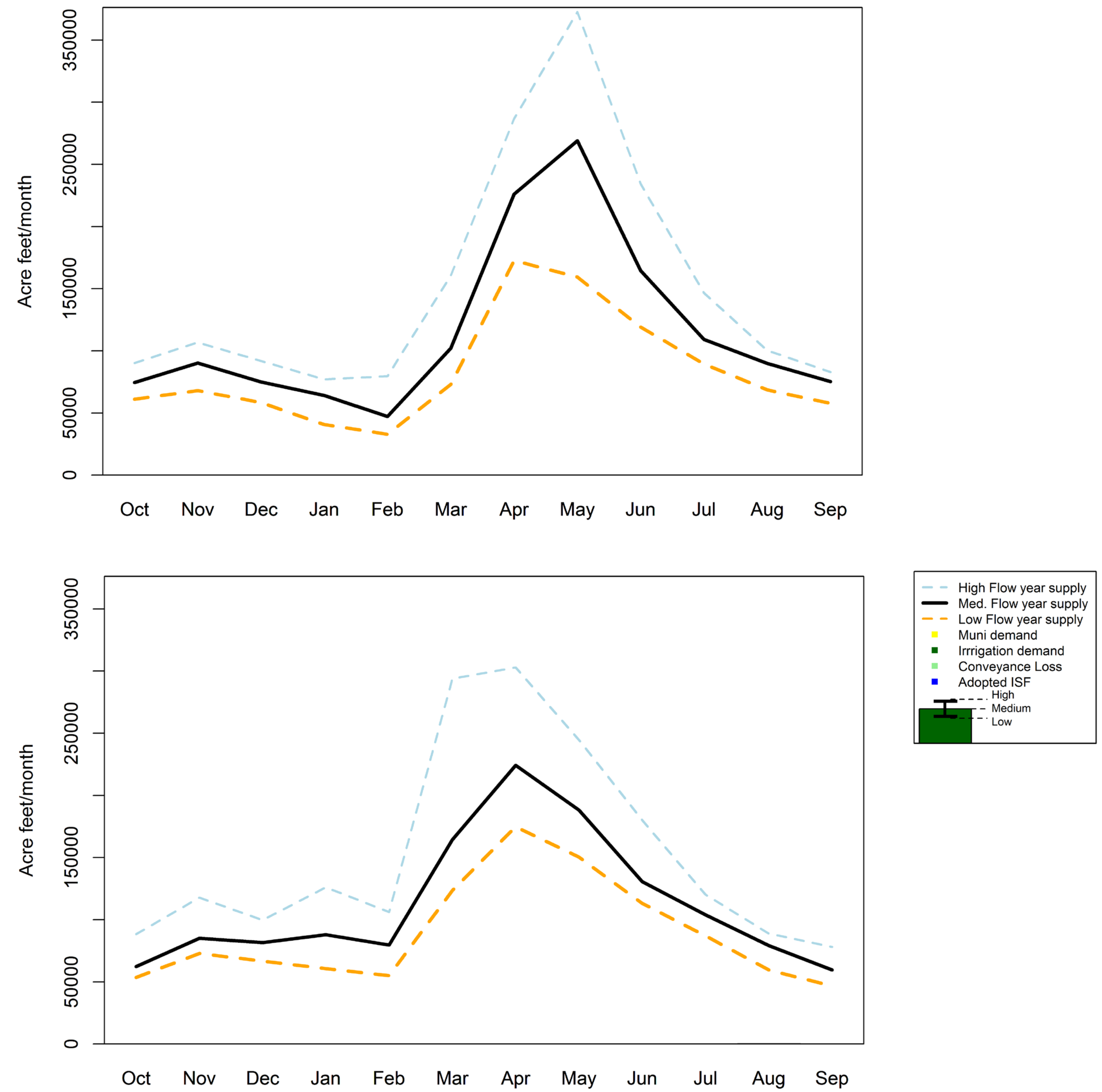
PLACEHOLDER

Awaiting Results



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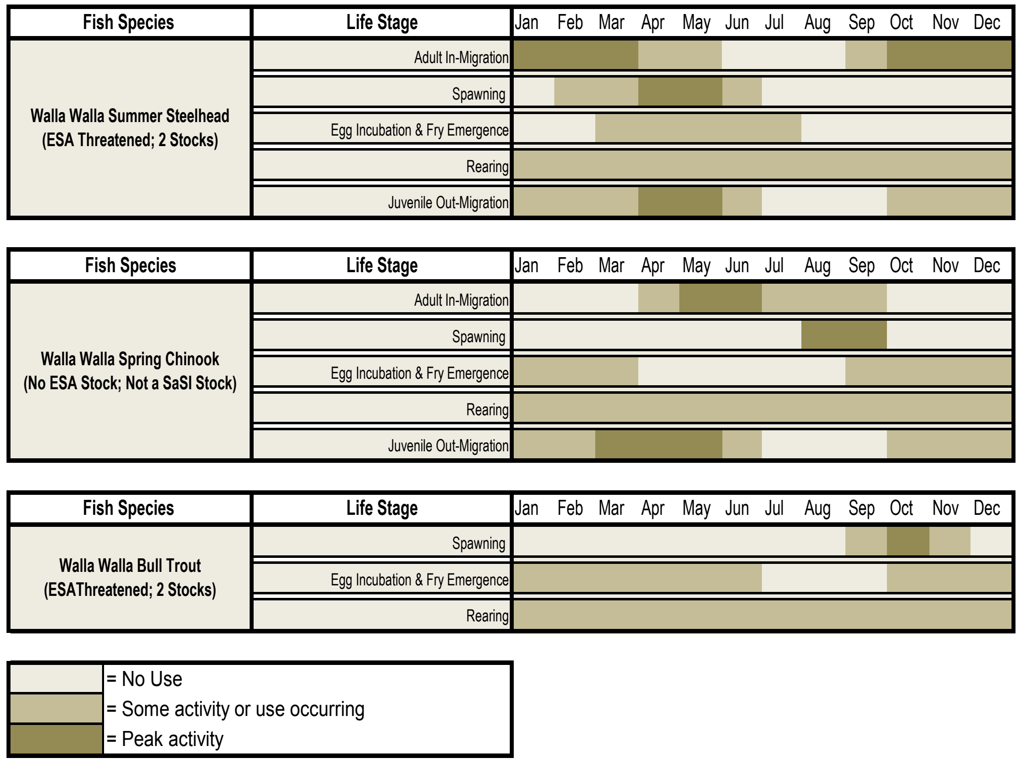
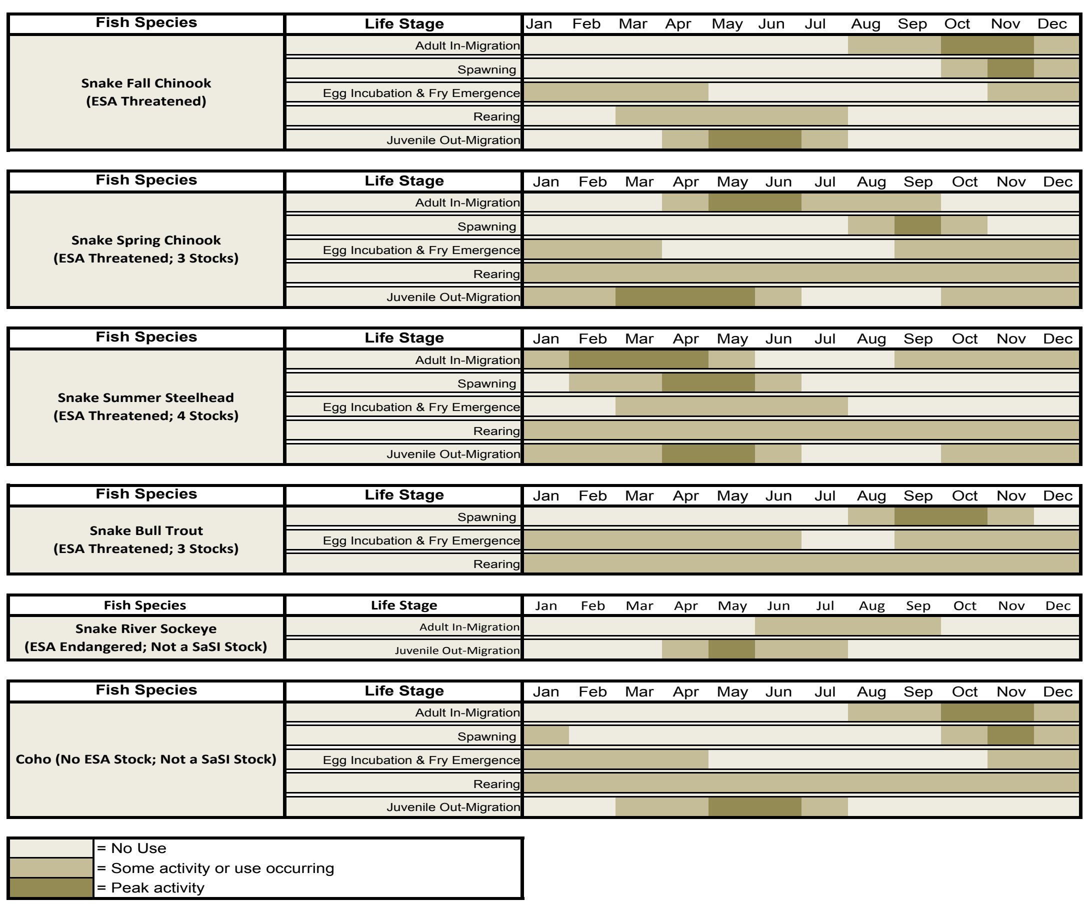
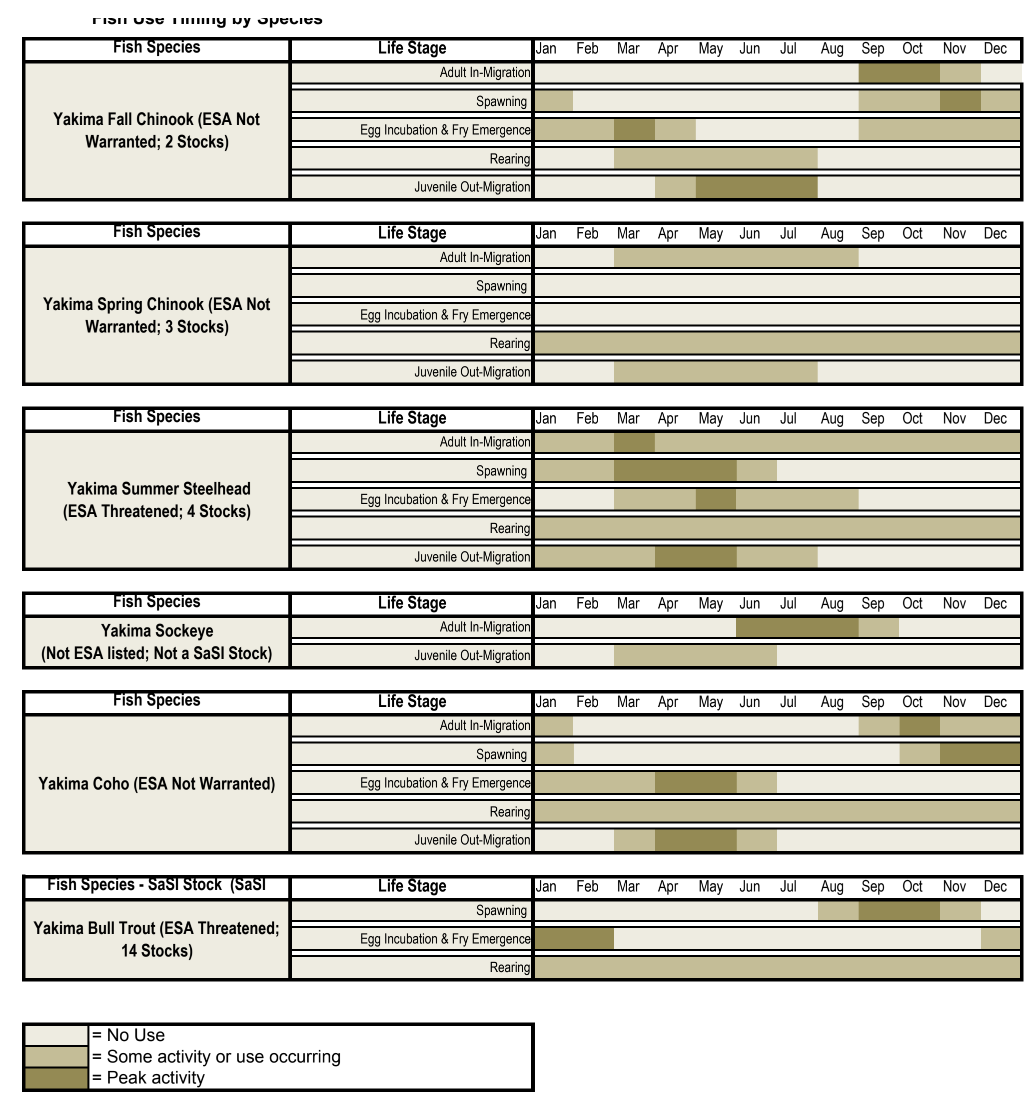
WRIA 32



WRIA 35



WRIA 37



Fish use charts for WRIAs 38 and 39 are available in the 2016 Columbia River Instream Atlas (Ecology Publication in preparation).

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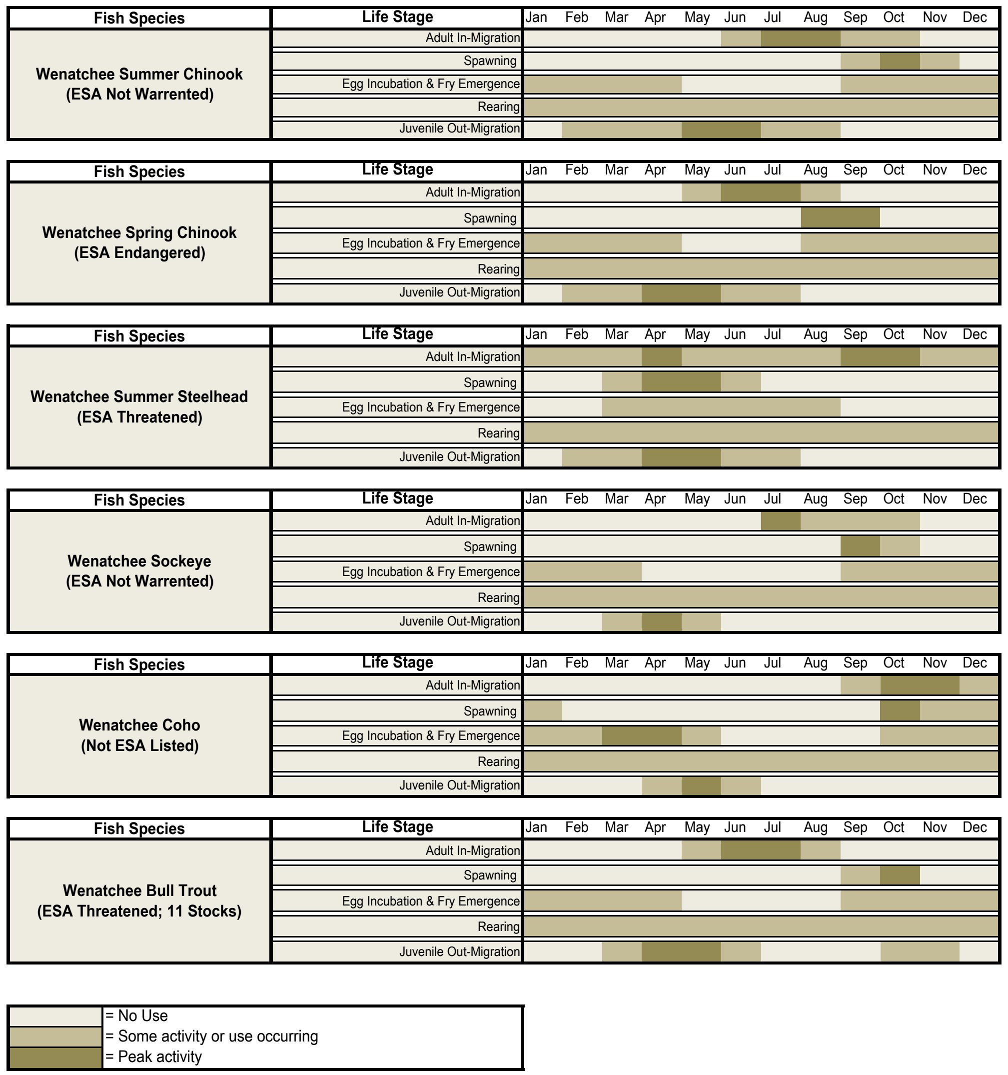
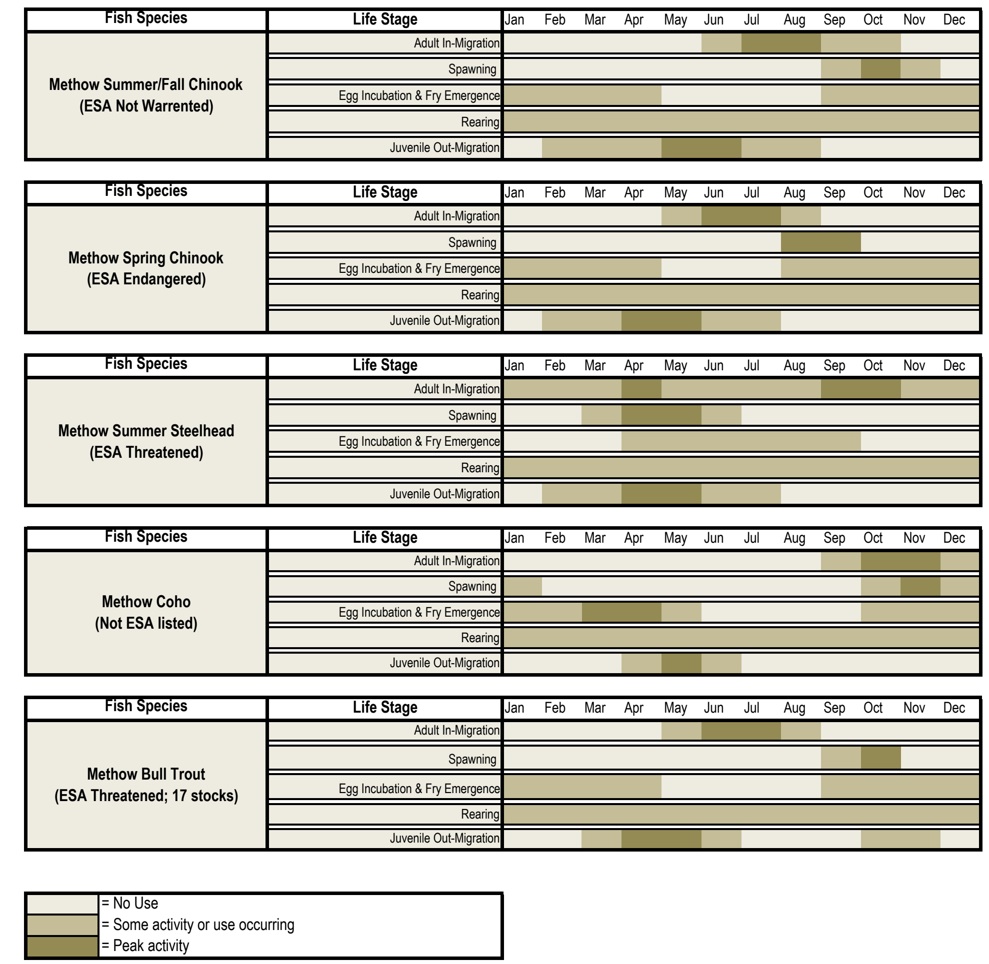
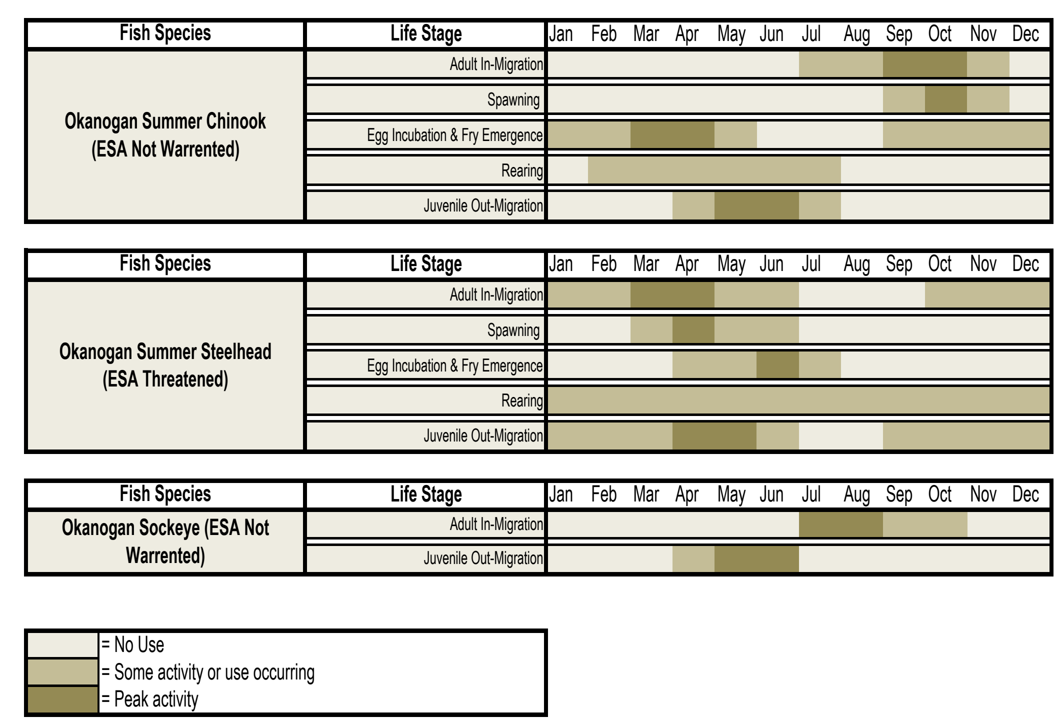
WRIA 45



WRIA 48



WRIA 49



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