COLUMBIA RIVER BASIN

2021 LONG-TERM WATER SUPPLY & DEMAND FORECAST

Executive Summary

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Department of Ecology, State of Washington
Washington State University
The University of Utah
Aspect Consulting
State of Washington Water Research Center

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EXECUTIVE SUMMARY

Meeting Eastern Washington's Water Needs

The Columbia River Basin is the fourth largest watershed in North America in terms of average annual flows, and encompasses nearly 70% of Washington State, mainly east of the Cascade crest. The river is intensively managed to meet a range of competing instream and out-of-stream water demands. Water must also be managed to fulfill the needs of important fish species and meet tribal treaty commitments. Reliable access to water is essential for current and future economic activity and environmental benefits, as well as cultural enhancement across eastern Washington and beyond.

The water supply delivery systems in the Columbia River Basin were built to reliably deliver water under 20th century conditions. As the climate changes, regional population grows, and agriculture responds to these and other trends, the timing and quantity of water supplies and demands are shifting. Washingtonians continue to adapt, changing the ways we use water and how we manage water resources to fulfill our needs.

The primary purpose of the 2021 Long-Term Water Supply and Demand Forecast is to provide a system-wide, quantitative assessment of how future environmental and economic conditions and human responses are likely to influence water supplies and demands over the next 20 years. In this way, the 2021 Forecast provides the foundation for understanding how vulnerabilities might change in the future, informing Washingtonians' efforts to enhance the resilience of the Columbia River system and of our communities.

Overview of Forecast Methods

In collaboration with the Washington Department of Ecology's Office of Columbia River, Washington State University (WSU) and its partners (University of Utah and Aspect Consulting) applied a range of methods to quantify expected changes in water supplies and demands by 2040 (Table ES-1). We used integrated hydrological, crop production, and river operations computer models to evaluate expected changes in surface water supply and agricultural water demand, given a range of possible climate change, crop production, and water capacity futures. We estimated expected changes in residential water demand based on population growth projections and explored potential changes in hydropower production based on that industry's projections of electricity needs. Additionally, we synthesized an independent study on climate change impacts on low flows to explore changes that could affect important fish species. We also evaluated trends in groundwater levels in different aquifer layers across eastern Washington. The results are provided for four different geographic scopes (Figure ES-1, Table ES-1), fulfilling the following specific objectives:

- **Columbia River Basin:** Estimate climate-driven 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 demands for each of eastern Washington's 34 Water Resource Inventory Areas (WRIAs).
- **Washington's Aquifers:** Evaluate groundwater trends in four different aquifer layers within the Columbia Plateau Regional Aquifer System (CPRAS) plus aquifers outside CPRAS, for each of 16 groundwater subareas in eastern Washington.
- **Washington's Columbia River Mainstem:** Estimate changes in supplies in the context of the Mainstem's legal, regulatory, and management schemes.

The Washington State Legislature has mandated that the 20-year forecast be updated every five years[1]. Since 2011, when the team first used computer-based models, we have incorporated substantial improvements to the Forecast as climate science, modeling methods and the conditions across the Columbia River Basin have evolved. New or improved aspects unique to this 2021 Forecast include:

- *Better inclusion of plausible changes in temperature and precipitation extremes,* with the inclusion of an expanded set of 34 climate change scenarios.

1 RCW 90.90 https://app.leg.wa.gov/rcw/default.aspx?cite=90.90

			Methods	Geographic Scopes
SUPPLIES		Surface water	Integrated modeling of historical (1986-2015) and multiple future scenarios (2026-2055). Climate change impacts also modeled through 2070 (2056-2085)	• Columbia River Basin (including focus on eastern Washington) • Washington's Watersheds • Columbia River Mainstem
SUPPLIES		Groundwater	Trends analysis using existing well depth data	• Washington's Aquifers
DEMANDS	Out of Stream	Agricultural	Integrated modeling of historical (1986-2015) and multiple future scenarios (2026-2055). Climate change impacts also modeled through 2070 (2056-2085)	• Columbia River Basin (including focus on eastern Washington) • Washington's Watersheds
DEMANDS	Out of Stream	Residential	Data-based estimates of per capita use and population growth projections Only municipal and self-supplied domestic uses	• Eastern Washington • Washington's Watersheds
DEMANDS	Instream	Flows for Fish	Independent simulation modeling study (Mauger et al. 2021[a])	• Washington's Watersheds
DEMANDS	Instream	Flows for Fish	Compared integrated modeling results to flow regulations	• Columbia River Mainstem
DEMANDS	Instream	Hydropower	Review existing data and information from power entities	• Columbia River Basin

[a] Mauger, G.S., M. Liu, J.C. Adam, J. Won, G. Wilhere, J. Atha, L. Helbrecht, and T. Quinn. 2021. New Culvert Projections for Washington State: Improved Modeling, Probabilistic Projections, and an Updated Web Tool. Report prepared for the Northwest Climate Adaptation Science Center. Climate Impacts Group, University of Washington.

Table ES-1. *Summary of the components of the 2021 Forecast, the methods used to estimate changes by 2040, and the geographic scopes for which results are presented and discussed.*

- *Deeper exploration of climate change impacts on water supply and demand,* by adding a longer term, 50-year outlook through 2070.
- *Deeper analysis of trends in groundwater levels that highlight future vulnerabilities in groundwater supply,* due to an expanded analysis of available depth to water data from existing wells.
- *More detailed analysis of seasonal residential water demand,* with use of monthly data from municipal water providers' water system plans.
- *More accurate and credible estimates of surface water supply and agricultural water demand,* resulting from updated and improved data and model calibration.
- *More detailed simulations of crop water requirements and irrigation needs,* thanks to improvements in the integrated hydrology and crop production computer model.
- *Finer scale estimates of interruptions to water users and their impacts on curtailment, crop yields, and instream flow deficits,* by incorporating more detailed water rights information in curtailment modeling, and exploring additional model outputs.
- *Data-driven evaluation of the potential impacts of double cropping on agricultural water demand,* through new analyses of remotely sensed data and of double cropping in warmer agricultural counties across the western states.
- *A new evaluation of projected changes in low flows that could lead to vulnerabilities for fish species,* thanks to an independent study on climate change impacts on low flows in Washington State.
- *More detailed exploration of factors that could significantly affect the demands for electricity from hydropower,* including transition to electric vehicles, expansion of data centers and future policies and renewable energy targets in Washington State.

These enhancements help the Forecast hone in on the vulnerabilities arising from expected future changes in water supply and demand, and improve our confidence in the results.

Future Vulnerabilities Associated with Changes in Water Supplies and Demands

The 2021 Forecast focused on identifying the vulnerabilities that eastern Washington may face as the climate changes, population grows, and agriculture, hydropower, and other demands for water change.

The availability of water to meet all instream and out-of-stream demands is vulnerable to expected changes in climate and population growth in eastern Washington, even though the amounts of annual surface water supplies and agricultural water demands in the region are expected to be relatively stable. Our key findings highlight the four main types of changes that are leading to vulnerabilities across eastern Washington.

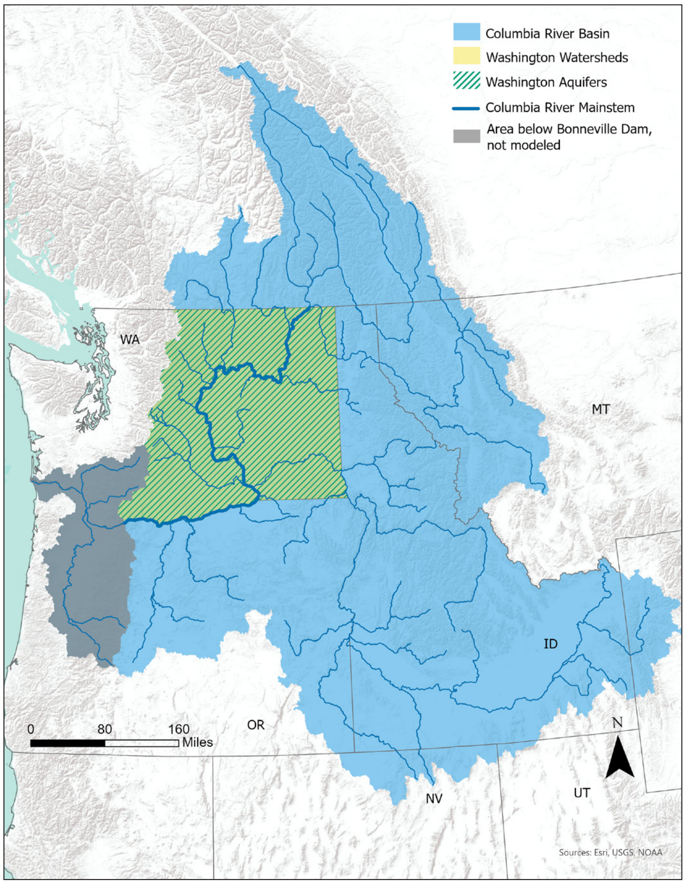

Figure ES-1. Long-term water supplies and demands were forecast through 2040 and beyond, and results are provided for four different geographic scopes: Columbia River Basin, Washington's Watersheds, Washington's Aquifers, and the Columbia River Mainstem.

KEY FINDING 1

The timing of surface water supplies is shifting earlier in the season, especially in the snowmelt-dominated Cascades watersheds. In general, annual supplies are, at most, forecast to increase slightly. Driven by the increasing temperatures and more frequent climatic extremes expected by 2040, however, the early (wet) periods are getting wetter and the late (dry) periods are getting drier, which may have important implications for meeting demands. In some watersheds, these changes are also reflected between years, where supplies in dry years are decreasing and supplies in wet years are increasing.

Vulnerabilities in future water supplies arise from:

- A shift in the timing of water supply, with the center of timing of water supplies shifting on average 22 (±2) days earlier by 2040, and likely increasing the possibility for water supplies and demands to be out of sync.
- Shifts in availability within a water year, with historically wet months (November through May) experiencing a 14.9% (± 2.5%) increase in water supply, and historically dry months (June through October) experiencing a-28.5% (± 2.6%) decrease in water supply by 2040 (Table ES-2).

KEY FINDING 2

Future changes in population and in agriculture in eastern Washington could lead to increases in instream and out-of-stream demands for water. Though climate change alone could result in slight declines in agricultural water demand, population growth, trends in demands for electricity, and planned water development projects could lead to an overall increase in demands for water.

Vulnerabilities, driven by climate-driven changes in water supply are exacerbated by expected changes in water demands. As with supply-driven vulnerabilities, annual agricultural water demand masks the areas of concern, as it is expected to decline slightly (-1.7% ± 0.7%) by 2040 (Table ES-3). However, this pattern is not uniform across eastern Washington, as some watersheds are expecting significant increase in agricultural water demand by 2040 (see Key Finding 4). In addition, the Office of Columbia River (OCR) estimates that 250,000 ac-ft of water may become available by 2040 for out-of-stream uses, as a result of planned water supply projects. If this full amount is used for irrigation, this would lead to an average increase in agricultural water demand by 2040 of 7.5 (± 0.7%) (Table ES-3).

SUPPLY – WASHINGTON PORTION OF THE COLUMBIA RIVER BASIN			
	Historical (million ac-ft)	2040 Forecast (million ac-ft)	% change by 2040
Median year (50th percentile)	16.3	16.7 (± 0.32)	2.0% (± 2.0%)
Wet Season (November - May)	11.5	**13.2 (± 0.29)**	**14.9% (± 2.5%)**
Dry Season (June - October)	4.8	**3.5 (± 0.13)**	**-28.5% (± 2.6%)**

Table ES-2. *Modeled water supply in the historical (1986-2015) and forecast (2040) periods for the Washington portion of the Columbia River Basin, distinguishing between the dry and wet season. The median (50th percentile) supply estimates are included as reference. Throughout, values between parentheses represent confidence intervals around the average of future values, obtained under different climate scenarios. The percent change reflects the difference from the historical to the forecast (2040) values, and is accompanied by confidence intervals associated with climate uncertainty. Changes highlighted in orange and blue are decreases and increases in supply (expected to be associated with decreasing and increasing water availability), respectively, which are statistically different to zero. Values in black show metrics that are expected to remain mostly stable into the future.*

Expected increases in residential water demand by 2040 are also significant (24% on average across eastern Washington; Table ES-3). While residential water demand overall is a relatively small portion of out-of-stream demands, the expected increase will likely exacerbate the supply-driven vulnerabilities in specific areas, as these demand increases are also variable across the region (see Key Finding 4). Though significant uncertainty remains around which factors will actually drive future demand for electricity, it is clear that demand for hydroelectric power is likely to increase, with estimates ranging from 5% to 34% by 2040. This will place further pressure on limited supplies, as does the continued restoration efforts at the federal, state and local level to ensure instream water demands (such as instream flows) are met as well.

Convergence of decreasing water supplies with increasing agricultural and residential water demands are expected to occur fairly consistently during July and August along the Columbia River Mainstem. This convergence is reflected in the expected increase in frequency of instream flow deficits—that is, the frequency with which flows are expected to be insufficient to meet regulatory instream flow requirements—which at some locations could increase over 35% by 2040.

The water demands described so far do not address areas of currently unmet water requirements suggested by other studies, and declining groundwater (see Key Finding 3) poses additional risks to other water uses. These demands at risk of not being met can reach 13.4 million ac-ft per year for the Columbia River Mainstem during an extreme drought year, and an additional 1.4 to 2.3 million ac-ft per year for fully meeting tributary instream flows, interruptible and proratable water rights, and replacing declining groundwater supplies across eastern Washington (see details in the *Vulnerabilities Across the Columbia River Basin* section of the Legislative Report). The combination of these existing unmet demands with expected changes in water supplies and demands in the future, heighten the need to work collaboratively to address vulnerabilities across eastern Washington and beyond.

KEY FINDING 3

Groundwater levels are declining in most aquifer layers and groundwater subareas across eastern Washington. As with surface water supplies and demands, these declines are not uniform across the region, yet in some subareas and in some aquifers reach as much as-7.0 (± 0.4) ft per year. These declines will likely limit the options to meet demands by moving from surface water to groundwater sources. It may also increase the need to replace current groundwater sources with surface water in the future.

Many groundwater subareas are vulnerable due to declining trends in groundwater levels and the shallowness of the available saturated thickness (the depth to water in a groundwater well, relative to the depth at which water is withdrawn) (Figure ES-2). Each of those subareas will face unique challenges due to the particular combination of changes in groundwater supply and water demands that it is expected to experience, at which locations, and by when. For example, the Okanogan and the Walla Walla groundwater subareas are expected to see significant

OUT-OF-STREAM DEMANDS – WASHINGTON PORTION OF THE COLUMBIA RIVER BASIN			
	Historical (million ac-ft)	2040 Forecast (million ac-ft)	% change by 2040
Median agricultural water demand	3.01	2.96 (± 0.021)	-1.7% (± 0.6%)
Residential water demand	0.19	0.23	22%
Median agricultural water demand + residential water demand	3.20	3.19 (± 0.021)	-0.3% (± 0.7%)
Median agricultural water demand + residential water demand + planned water supply projects	3.20	3.44 (± 0.021)	7.5% (± 0.7%)

Table ES-3. *Expected changes in out-of-stream water demands by 2040 in the Washington portion of the Columbia River Basin. The "median agricultural water demand" estimate considers median climate change impacts, and is assumes that the extent of agricultural acreage remains constant between the historical (1986-2015) and forecast (2040) time periods. The "median agricultural water demand + residential water demand" scenario adds the expected increases in residential water demand. The "median agricultural water demand + residential water demand + planned water supply projects" scenario adds the 250,000 ac-ft of additional water that could be available for out-of-stream uses by 2040 through water development projects. Values between parentheses represent confidence intervals around the average of future values, due to the range of demand values obtained under 34 different climate scenarios. These confidence intervals were maintained in all three scenarios, since we were unable to quantify the uncertainty in the estimate of residential demand or available water. The percent change reflects the difference from the historical to the forecast values, and is accompanied by confidence intervals associated with climate uncertainty. Changes highlighted in blue and orange are decreases and increases in demand, respectively, which are statistically different to zero. Values in black show metrics that are expected to remain mostly stable into the future.*

reductions in available saturated thickness within 10 years. The Okanogan subarea is also expected to experience significant increases in agricultural water demand (see Key Finding 4). On the other hand, Rock-Glade is expected to see decreases in agricultural water demand, but is expected to experience some of the largest increases in residential consumptive water use in some places (see Key Finding 4), while potentially seeing opposing trends in wells accessing the Wanapum and Saddle Mountain layers (negative and positive, respectively). Similarly, the Odessa and Yakima subareas likely will not see increases in agricultural water demand, but are expected to see some of the largest increases in summer residential consumptive use (see Key Finding 4).

These fairly consistent groundwater declines coincide with vulnerabilities expected due to changes in surface water supplies (see Key Finding 1). This convergence suggests that finding opportunities to prepare for and mitigate the impacts of future changes in water supplies needs to explore options other than finding alternative sources.

KEY FINDING 4

Local increases in out-of-stream demands are expected, converging with local decreases in water supply, such as in the Yakima River Basin. The combination of lower supplies at critical times and locally increasing demands leads to increasing frequency of instream flow deficits and resulting prorationing or curtailments.

The types of vulnerabilities that our region is expected to face due to changes in water supply in the future (see Key Findings 1 and 3) are generally common across all of eastern Washington. However, the degree to which these changes are expected, and the convergence of expected changes in supply and in the different out-of-stream demands for water vary significantly across watersheds.

The Yakima River Basin is an important example of such convergence. The upper watersheds (WRIAs 38 and 39) are expected to experience increases in agricultural water demand (Figure ES-3), while at the same time expecting decreasing water supplies in low supply years (Figure ES-4). The independent study we summarized also highlighted The Cascades WRIAs due to expected decreases in low flows as snowmelt shifts earlier in the year and spring temperatures increase.

TIME TO AN EXPECTED 25% DECLINE IN AVAILABLE SATURATED THICKNESS IN AT LEAST ONE AQUIFER LAYER

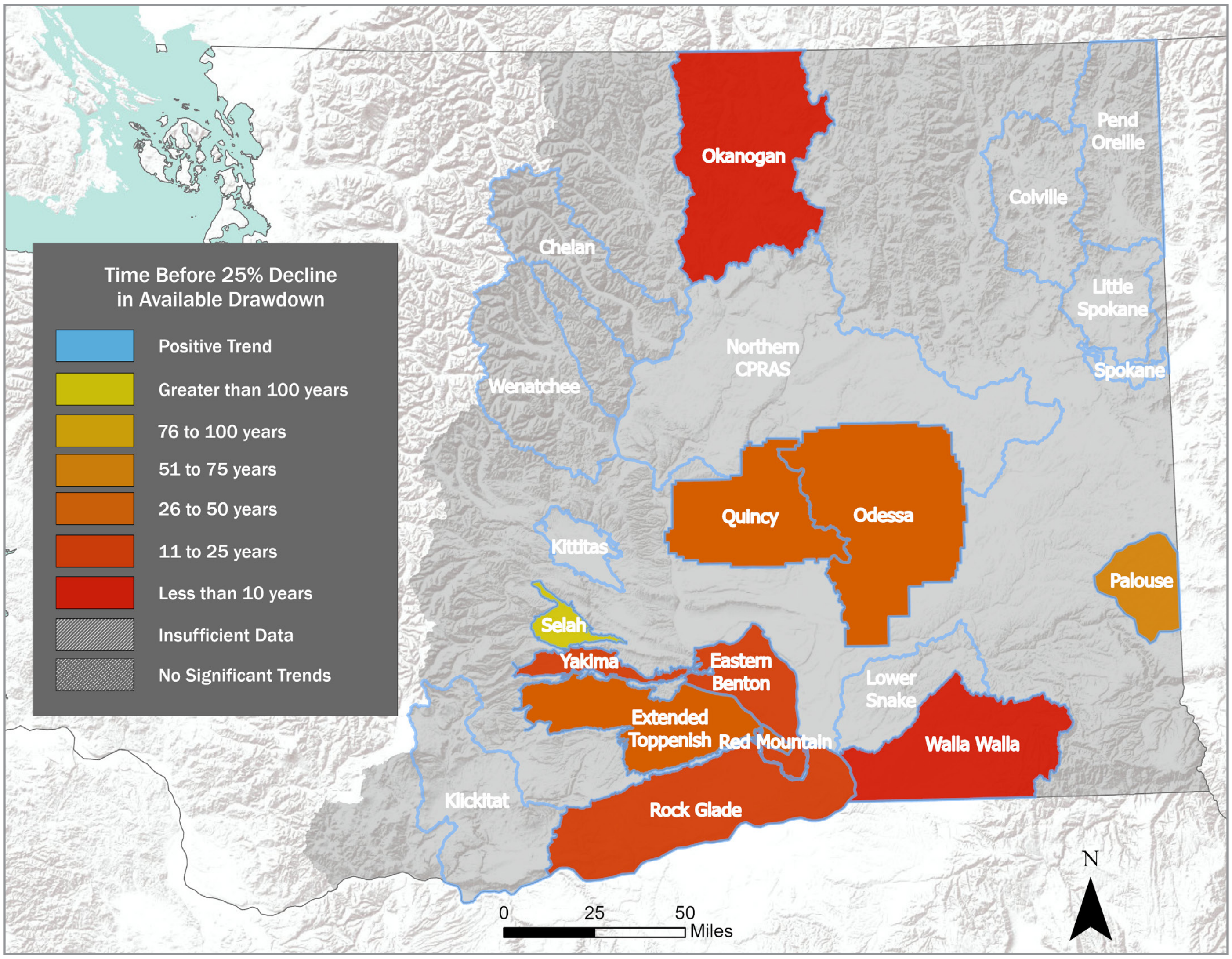

Figure ES-2. Time (in years) until the average available saturated thickness has declined by 25% in at least one aquifer layer in each groundwater subarea. These times are based on declines in available saturated thickness in different aquifer layers, as we show the most vulnerable aquifer layer for each subarea; that is, the time until 25% decline in available saturated thickness may reflect the vulnerability related to declines in the Grande Ronde layer for some subareas, for the Wanapum layer for other subareas, and the Overburden layer for other subareas (for more details see the Forecast Results for Aquifer Layers *section).*

The patterns of expected increases in residential water demand are different to those of agricultural water demand. For example, the Lower Yakima watershed (WRIA 37) is considered vulnerable because of the overlap between expected increases in summer residential water demand (Figure ES-5) coinciding with steep decreases in supply in the summer months (Figure ES-6). Though overall residential water demand in eastern Washington is only about a quarter the magnitude of agricultural water demand, these results warrant serious attention. Increases in summer residential demand of over 20% are expected to occur in WRIAs showing declining summer supplies and that include municipalities using surface water sources (such as WRIA 37). Similarly, WRIAs with the largest expected increases in summer demand lie over aquifer layers with declining groundwater levels (see Key Finding 3), while also including municipalities using groundwater sources.

We conclude that numerous WRIAs in eastern Washington are vulnerable to expected changes in the timing and variability of water supply combined with changes in some type of out-of-stream water demand. Each WRIA has a unique combination of challenges to adapt to in the future, depending in part on the specific balance of changes in supply and demand that lead it to be vulnerable.

EXPECTED CHANGES IN AGRICULTURAL WATER DEMAND AND ANNUAL SURFACE WATER SUPPLY IN LOW FLOW YEARS

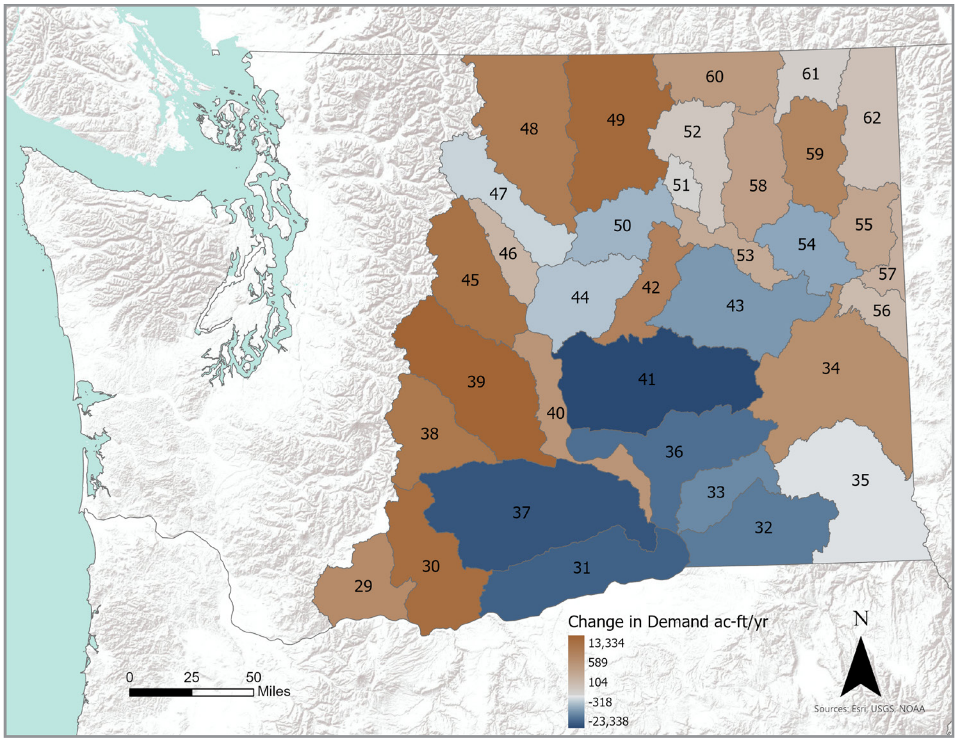

Figure ES-3. *Expected change in agricultural water demand between the historical (1986-2015) and forecast (2040) time periods, summarized by WRIA. Changes in demand are expressed in acre-feet per year.*

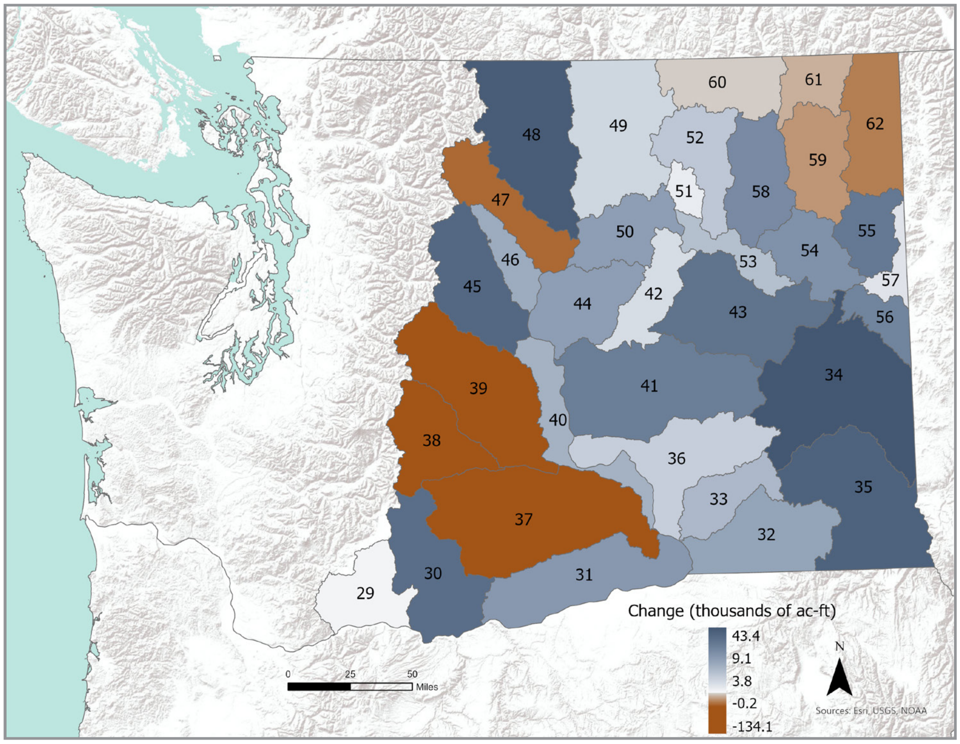

Figure ES-4. *Changes in annual water supply expected during low flow years (20th percentile) by 2040, in thousands of acre-feet. WRIAs are colored based on the magnitude of change in annual water supply between historical (1986-2015) and forecast (2026-2055) time periods. Future supplies were represented by the median of 34 climate change scenarios. Note that one value is given for WRIAs 37, 38 and 39, and one value is given for WRIAs 44 and 50, reflecting the sum of changes in those groups of WRIAs.*

EXPECTED CHANGES IN RESIDENTIAL CONSUMPTIVE USE AND SURFACE WATER SUPPLY DURING SUMMER MONTHS

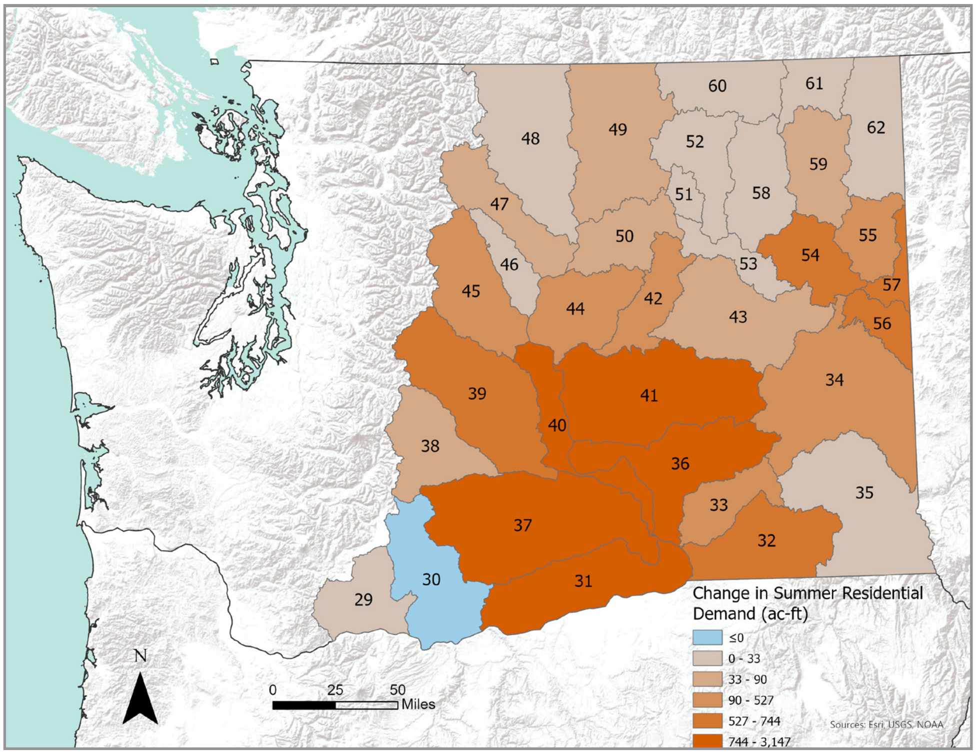

__Figure ES-5__. Change in residential consumptive water use during summer months (June, July and August) from 2020 to 2040, expressed in ac-ft, summarized by WRIA.

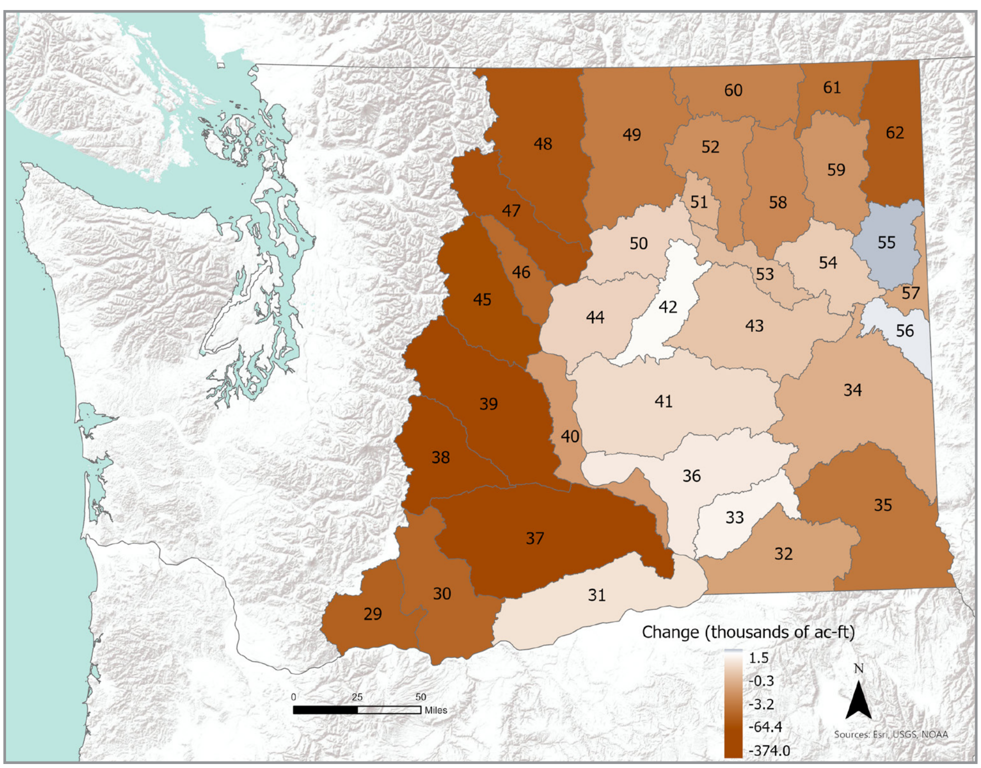

__Figure ES-6__. Change in surface water supply during summer months (June, July and August) from historical (1986-2015) to forecast (2040) periods, by WRIA. Changes in demand are expressed in thousands of acre-feet per year. One value is given for WRIAs 37, 38, and 39, reflecting the sum of changes in those WRIAs. Likewise, one value is given for WRIAs 44 and 50, reflecting the sum of changes in those WRIAs.

Other Findings

The 2021 Forecast explored a variety of additional factors contributing to changes in water supplies and water demands, a range of possible alternative futures, and the possible implications of these changes. A series of other important findings also arose from these explorations, including the following:

- Annual supply across eastern Washington is expected to increase slightly through 2040, from 16.3 million ac-ft per year to 16.7 million ac-ft per year. This slight increase in supply (2.0% ± 2.0%) is the net effect of an 14.9% (± 2.5%) increase in the early (wet) season supply, and a-28.5% (± 2.6%) decrease in the (dry) late season supply.
- An average decrease of-1.7% (± 0.7%) in agricultural water demand is expected in eastern Washington by 2040. This is the net effect of an 9.4% (± 1.9%) increase in the early irrigation season demands, and a-9.8% (± 1.2%) decrease in the late season. The two future changes in agricultural production we explored—earlier planting dates and changes in crop mix—had counteracting effects, having little overall impact on agricultural water demands.
- Current estimates suggest double cropping occurs on approximately 121,000 acres, or 6% of total irrigated acres in eastern Washington. More than half of these acres are in Grant and Franklin Counties. Our analysis of potential double cropping suggests that increases in summer temperatures will outweigh any benefits from longer growing seasons, and further double cropping in eastern Washington is likely to be negligible.
- The shift in timing of water supplies could range from as much as 23 days earlier by 2040 in the central and southern Cascades WRIAs, to as little as 2 days in the Lower Snake (WRIA 33). This range is closely linked to the proportion of a WRIA's supply that comes from snowmelt, which is much higher in the Cascades WRIAs.
- Cascades WRIAs are expecting the greatest decreases in minimum flows, quantified using a common low-flow metric representing the minimum flow that has a 10% chance of occurring any given year (called 7Q10). Minimum flows in the Cascades WRIAs could be reduced by as much as-15.6 cfs. The lower elevation areas in the heart of central Washington, on the other hand, are expecting slight increases (approximately 1 cfs) by 2040.
- The patterns of change in the frequency of curtailments expected by 2040 vary from WRIA to WRIA. However, there is a trend towards increasing frequency of curtailment by 2040, during the summer months (June, July, and August) across all WRIAs with adopted instream flow rules, with curtailments expected as many as 14 additional years (out of 30) in some weeks and under some climate change scenarios. For example, curtailment frequency in the Wenatchee watershed (WRIA 45) during August is expected to increase from 10 years out of 30 historically to 23 years out of 30 by 2040.
- Reduced irrigation due to curtailment generally caused reductions in yields of forage and high value perennial crops. The magnitude of the yield reduction for crops experiencing curtailment was generally greater under future (2040) conditions than under historical (1986-2015) conditions. The forecast reductions in yield were on the order of 20-25% larger than under historical conditions, though in the Yakima (WRIAs 37, 38, 39) loss in yields could triple.
- Instream flow deficits along the Columbia River Mainstem could occur as many as 10 additional years (out of 30) by 2040, mainly in July and August. In late July, instream flow deficits could increase in frequency from 16 out of 30 years historically to 24 out of 30 years, while in August they could increase from 23 out of 30 years to 30 years out of 30 for most control points along the Columbia River Mainstem. In the spring, on the other hand, water supply is expected to increase, improving the ability of flows to meet instream flow requirements, and reductions in the expected frequency of instream flow deficits. However, these reductions in frequency are relatively minor.

The 2021 Forecast also provides detailed information on the expected changes in water supplies and demands for each WRIA and aquifer layer in eastern Washington. This information can more specifically and directly inform local, watershed, or county level water management decisions.

Conclusion

Where vulnerabilities due to changes in surface water supply exist, expected increases in demands will tend to make them more acute. This is particularly likely in places that may already be experiencing declining groundwater levels. Given the patterns of water demand changes across eastern Washington, numerous watersheds are expected to experience either an increase in agricultural water demand or an increase in residential water demand. Therefore, each watershed will have a rather unique combination of challenges to adapt to. These vulnerabilities will express themselves more obviously during low flow years. The expected increases in frequency of instream flow deficits and curtailment during July and August are a reflection of the impacts of these changes on water supplies and demands.

This 2021 Forecast confirms the findings of the 2016 Forecast and improves our understanding of expected changes in future surface and groundwater supplies and instream and out-of-stream demands. Our results have re-affirmed the importance of understanding the impacts of climate change on the timing and location of water supplies, and how these supply changes interact with changes in agricultural and residential water demands. The generally declining groundwater trends also re-affirm the need to pursue further integration of groundwater into future Forecasts, to better understand these interactions.

In this way, the Forecast results can support insights and understanding relevant to water management that will help Washingtonians prepare for changes in water availability expected in the future. We envision groups with diverse perspectives using the Forecast to understand what vulnerabilities are most acute, and which actions are most likely to make a difference to sustainably meeting the region's water demands, helping us maintain and enhance eastern Washington's economic, environmental, and cultural prosperity for the next 20 years and beyond.

Columbia River at Wanapum Pool