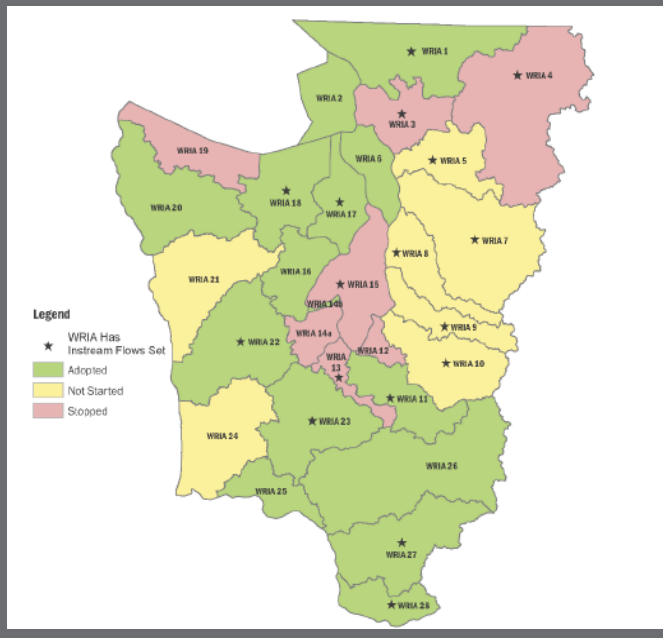
Washington State Legislative Report

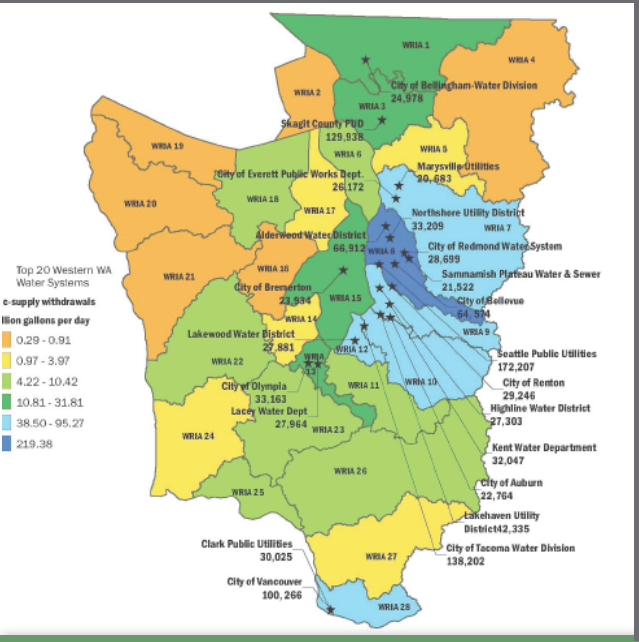
DRAFT

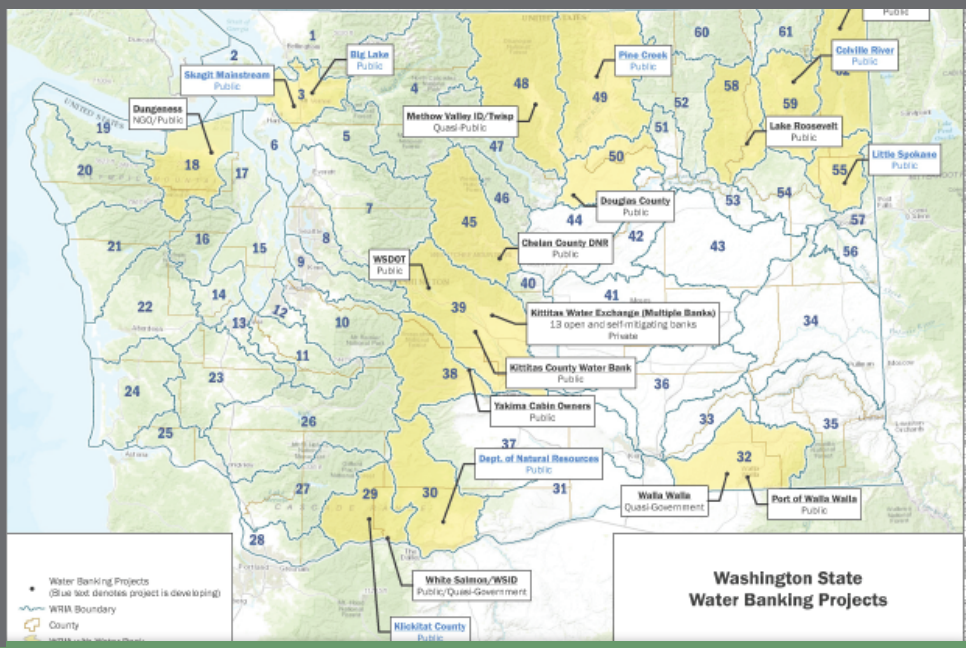
Columbia River Basin
Long-Term Water Supply and Demand Forecast

Western Washington Supply and Demand Forecasting

WRIA	Water Resources Rules	Basin	Int
WRIA 1	Chapter 173-501 WAC	Nooksack River	
WRIA 3	Chapter 173-503 WAC	Lower Skagit	
WRIA 4	Chapter 173-503 WAC	Upper Skagit	
WRIA 5	Chapter 173-505 WAC	Stillaguamish River	
WRIA 7	Chapter 173-507 WAC	Snohomish River	
WRIA 8	Chapter 173-508 WAC	Cedar-Sammamish	
WRIA 9	Chapter 173-509 WAC	Duwamish-Green River	
WRIA 10	Chapter 173-510 WAC	Puyallup River	
WRIA 11	Chapter 173-511 WAC	Nisqually River	
WRIA 12	Chapter 173-512 WAC	Chambers-Clover Creek	
WRIA 13	Chapter 173-513 WAC	Deschutes River	
WRIA 14	Chapter 173-514 WAC	Kennedy-Goldsbourgh	
WRIA 15	Chapter 173-515 WAC	Kitsap	
WRIA 17	Chapter 173-517 WAC	Quilcene-Snow	
WRIA 18	Chapter 173-518 WAC	Elwha-Dungeness	







November 2016

Table of Contents

List of Figures

Executive Summary

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 the Office of Columbia River (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 for 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 need to be augmented for Western Washington WRIAs, because of the existence of:
    - Some 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 significant proportion of water withdrawals in some WRIAs,
    - Non-trivial small farm acreage missing in the WSDA land cover data used in the agricultural forecast, and
    - Livestock consumptive use, not accounted for in this framework, which is a large fraction of agricultural water demands in certain WRIAs.
- Western Washington has far fewer interruptible water rights than Eastern Washington, primarily because Eastern Washington has several basins (e.g. Yakima, Walla Walla) where hundreds of 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 because data on this type of curtailment is more available (as opposed to information from specific stream patrolmen and water masters for which comprehensive accounting does not yet exist).
- For WRIAs with storage-regulated supplies, the Eastern Washington approach of relying on simple reservoir models that simulate the reservoir operation rules should be applicable.
- A robust stakeholder input process should be included if a 2021 integrated planning effort is launched, including public meetings, meetings with key planning jurisdictions, meetings with key stakeholder groups, and surveys of interested parties with specialized knowledge in Western Washington supply and demand issues. 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.

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 necessary to ensure results are accurate at the scale of Washington's watersheds. An integrated State-wide planning effort would:

1. Provide a foundation for long-term management of Washington's water supply to address increases in water demand associated with growth, anticipated stresses on water supply due to climate change, and prioritization of funding for water management projects.
2. Allow for more robust water supply infrastructure planning by the Legislature.
3. Fill in data gaps in local jurisdictions that did not plan under watershed planning.
4. Allow for integrated solutions and cross-coordination amongst regional partners, and among other states with statewide water plans.

DRAFT

Overview of Western Washington Water Supply and Demand Issues

Washington State has increasing demands on water resources that are not limited to the Columbia River Basin. For this reason, preliminary planning efforts to extend long-term water forecasting work to Western Washington have been initiated as part of preparing the 2016 Columbia River Basin long-term supply and demand forecast. This report outlines the overall approach and available resources to be considered in extending the next update to the forecast, scheduled for 2021, to Western Washington.

Planning for extension of the forecast to Western Washington would be advantageous because it would:

- Provide a foundation for long-term management of Washington's water supply to address increases in water demand associated with growth, anticipated stresses on water supply due to climate change, and prioritization of funding for water management projects.
- Support evaluation of statewide water supply and demand trends;
- Fill in planning gaps in watershed planning jurisdictions that did not participate or did not adopt a watershed plan; and
- Allow budgetary planning for water supply projects that considers statewide supply issues and priority needs.
- Support potential collaboration with other states that have state water plans, such as Oregon, Idaho, and 33 states that either have adopted state water plans or have state water plans in progress;

Regulatory, Legal, Policy Framework

The following sections provide a summary of the key regulatory, legal, and policy issues that would need to be considered in moving towards a statewide planning effort.

Statutory Authorities for Planning and Forecasting

Sufficient planning authority exists in Washington to support development of a State Water Plan by the Department of Ecology. Some of the key planning authorities that would be used to support such development include:

- The Legislature gave Ecology broad planning authority to accomplish its environmental mission in RCW 90.54.010(1)(e): "The long-term needs of the state require ongoing assessment of water availability, use, and demand. A thorough inventory of available resources is essential to water resource management. Current state water resource data and data management is inadequate to meet changing needs and respond to competing water demands. Therefore, a state water resource data program is needed to support an effective water resource management program. Efforts should be made to coordinate and consolidate into one resource data system all relevant information developed by the department of ecology and other agencies relating to the use, protection, and management of the state's water resources."
- Under Chapter 90.82 RCW Watershed Planning Act, the Legislature provided comprehensive supply and demand authority. "The legislature finds that the local development of watershed plans for managing water resources and for protecting existing water rights is vital to both state and local interests."

Instream Flow Rules

Instream flow rules have been established in many watersheds in subsections of Title 173 of the Washington Administrative Code (WAC), to support the mandate outlined in RCW 90.54.005 of providing sufficient water and habitat for fish. Establishment of instream flows also set priority dates for flows corresponding to the dates of each rule. As a result, new surface water rights approved in these basins are interruptible when instream flows are not met, unless approved mitigation has been established. In most areas, groundwater and surface water are considered by Ecology to be hydraulically connected, and newer post-rule unmitigated groundwater rights are also interruptible. As a result, it has become increasingly difficult to obtain new reliable water rights and corresponding water supplies.

In the OCR forecasts, WSU worked with Ecology's database to forecast how well instream flows are likely to be met in the future, and the effect of interruption on out-of-stream uses. This included:

- Comparing instream flow rule flows to different water year scenarios (e.g. dry, average, wet).
- Forecasting current and future shortfalls in meeting instream flows on a weekly basis.
- Forecasting the current and future risk of interruption to junior water users. A summary of interruptible water users by Western Washington watershed is provided in Table 1 below.

These same curtailment methodologies are applicable to Western Washington.

Table 1. Western WA Interruptible Water Rights by WRIAs

WRIA	Water Resources Rules	Basin	Interruptible Water Rights
WRIA 1	Chapter 173-501 WAC	Nooksack River	118
WRIA 3	Chapter 173-503 WAC	Lower Skagit	54
WRIA 4	Chapter 173-503 WAC	Upper Skagit	10
WRIA 5	Chapter 173-505 WAC	Stillaguamish River	27
WRIA 7	Chapter 173-507 WAC	Snohomish River	100
WRIA 8	Chapter 173-508 WAC	Cedar-Sammamish	94
WRIA 9	Chapter 173-509 WAC	Duwamish-Green River	42
WRIA 10	Chapter 173-510 WAC	Puyallup River	67
WRIA 11	Chapter 173-511 WAC	Nisqually River	36
WRIA 12	Chapter 173-512 WAC	Chambers-Clover Creek	9
WRIA 13	Chapter 173-513 WAC	Deschutes River	63
WRIA 14	Chapter 173-514 WAC	Kennedy-Goldsbourgh	29
WRIA 15	Chapter 173-515 WAC	Kitsap	95
WRIA 17	Chapter 173-517 WAC	Quilcene-Snow	25
WRIA 18	Chapter 173-518 WAC	Elwha-Dungeness	26
WRIA 22	Chapter 173-522 WAC	Lower Chehalis River	78
WRIA 23	Chapter 173-522 WAC	Upper Chehalis River	338
WRIA 25	Chapter 173-525 WAC	Grays-Elochoman	4
WRIA 26	Chapter 173-526 WAC	Cowlitz	75
WRIA 27	Chapter 173-527 WAC	Lewis	34
WRIA 28	Chapter 173-528 WAC	Salmon-Washougal	49
Total			1373

Seawater Intrusion

Seawater intrusion is the movement of seawater into fresh water aquifers caused by natural processes or human activities, including pumping of groundwater. Intrusion of seawater into fresh water aquifers results in elevated chloride and sodium levels that in sufficient concentrations can render water non-potable. A general rule of thumb is that approximately 100 milligrams per liter (mg/L) of chloride is indicative of seawater intrusion, and concentrations over 250 mg/L chloride (EPA's secondary maximum contaminant level and DOH's drinking water limit) result in significant taste effects. All coastal areas in Washington State have the potential for seawater intrusion, and numerous cases of seawater intrusion have been documented, particularly in island communities. For example, Whidbey, Lopez, Marrowstone, Guemes Islands all have areas where seawater intrusion has been documented.

While Ecology does not have a formal seawater intrusion policy, several coastal counties have adopted policies on seawater intrusion. Examples include:

- Skagit County has an Interim Seawater Intrusion Policy that was adopted in 1994 and is currently being updated. The updated policy requires wells located at a distance of less than ½ mile from the coast to limit pumping rates to one, two, or three gallons per minute maximum, depending on measured chloride levels.
- Jefferson County has established seawater intrusion protection zones (SIPZs), which are defined as all land within ¼ mile of marine shorelines and additional areas within 1000 feet of a groundwater source with a history of chloride analyses above 100 mg/L have designations of 'at risk' or 'high risk', depending on chloride concentrations. County requirements include monitoring of chloride levels and groundwater pumping rates, and in high risk cases, a hydrogeologic assessment. Island County has implemented a similar approach based on risk levels and chloride concentrations.

Extension of water supply forecasting to Western Washington will need to consider limitations on local water supplies caused by seawater intrusion risks and prevention.

Tidal Effects

All of the coastal counties in Western Washington have surface water bodies that are subject to tidal influences. For example, tidal influences on the Green-Duwamish river system extend approximately 11 miles upstream from river mouth, while the Columbia River has tidal effects that extend beyond the City of Vancouver, more than 100 miles upstream.

Water availability can be influenced by tidal effects on surface water systems. In watersheds where instream flow rules that limit water availability are in place, restrictions on water available may only be in place upstream from the influence of the mean annual high tide occurrence at low instream flow levels. For example, the instream flow rule for the Green-Duwamish River basin (WAC 173-509) specifically limits rule restrictions to upstream of approximately River Mile 11, the limit of tidal effects. Other instream flow rules, such as the Elwha-Dungeness River rule (WAC 173-518) restrict flows from the river mouth, regardless of tidal influence. Given the variability among instream flow rules in this regard, extension of the forecast to Western Washington will need to consider water availability in tidally-influenced areas on a case-by-case basis.

Rainwater Collection

Rainwater collection by individual property owners provides a contribution to water availability in Western Washington. In certain areas, such as the San Juan Islands, rainwater harvesting is fairly commonplace.

In 2009, Ecology clarified its policy on rainwater collection, through the document 'Water Resources Program Policy Regarding Collection of Rainwater for Beneficial Use' (POL 1017). This policy includes the following language stating the purpose of the policy is to:

- "Clarify that a water right is not required for on-site storage and use of rooftop or guzzler collected rainwater."
- "Identify the Department of Ecology's intent to regulate the storage and use of rooftop of guzzler collected rainwater if and when the cumulative impact of such rainwater harvesting is likely to negatively affect instream values or existing water rights."

Based on this policy, the on-site storage and beneficial use of rooftop or guzzler collected rainwater is not subject to the permit process of RCW 90.03 (the state water code).

As part of extending the forecast to Western Washington, existing and potential use of rainwater will need to be considered as a component of water availability.

Legal Decisions Affecting Water Resources

Several recent legal decisions, pending cases, and policy initiatives are affecting or will potentially affect the availability of water supplies in Western Washington. In several basins statewide (e.g., Skagit, Dungeness, Kittitas, Yakima, Nooksack), regulatory uncertainty over legal water availability has created economic conditions that are politically challenging for counties. Specific examples include the following:

- In 2001, junior surface water users in the Yakima Basin, including 1,000 cabin owners and the City of Roslyn, were given a court-ordered water use curtailment. The curtailment resulted in a drop in property values, inability to obtain bank loans for refinancing, a less attractive market for cabin sales, and insurance challenges.
- In 2006, new groundwater use was restricted in the Upper Kittitas basin resulting in work stoppages on active homebuilding projects, and the inability to access bank loans.
- In 2013, a Washington State Supreme Court Decision (Swinomish Indian Tribal Community v. Ecology) invalidated a portion of an instream flow rule based on Overriding Considerations of the Public Interest (OCPI) that allowed exempt well development in Skagit and Snohomish Counties. As a result, approximately 500 existing homeowners and many undeveloped property owners are now faced with property devaluation, and the inability to access bank loans for refinancing and home sales.
- In 2015, the State Supreme Court cancelled the city of Yelm's water right permit. In reversing Ecology's approval of the Yelm's permit, the Court ruled that Ecology had also erroneously used the OCPI determination and violated existing instream flows. Ecology had conditioned approval on an "out-of-kind" mitigation package, based on a combination of retiring existing water rights, habitat protection, and stream restoration, to offset the water use from the permit. This decision suggests that any mitigation scenario that is not 'water for water' will no longer obtain approval from Ecology.

Case law on groundwater exempt use, impairment of instream flows, conjunctive management of surface and groundwater, county building permit and Growth Management Act (GMA) responsibilities, OCPI standards continue to be clarified by the court system. A key pending case under review by the state Supreme Court is:

- Whatcom County v. Hirst. The pending decision on this case could have significant ramifications for use of exempt wells and rural water supply in Western Washington. The lower court decision essentially directed local governments to follow Ecology's interpretation of instream flow rules. According to the decision, if Ecology interprets a particular instream flow rule to provide a specific exemption for domestic exempt wells, then a county can rely on that interpretation in making water availability determinations related to land use decisions. This is considered the case even if there are unmet senior instream flows. The current decision also acknowledges that each instream flow rule must be interpreted individually.

Rural Water Supply Workshops

Ecology is leading a series of Rural Water Supply workshops with stakeholders, with a mission to find solutions to rural water supply limitations. Balancing instream and out of stream water uses has been a significant challenge for Ecology, especially in recent years. One goal of this process is to determine whether legislative action is appropriate in the future to address the limitations imposed by the courts on OCPI interpretations. Without new tools, future rural development in many basins could be significantly restricted by adoption of an instream flow rule. If this path is taken, it may take multiple legislative sessions for an agreement to be reached.

Ecology facilitated a number of meetings starting in 2014 and completed a report at the end of that year, with additional meetings being held on an ongoing basis.

Water Availability Guidance for Counties

Ecology has also been working collaboratively with county representatives and interested stakeholders to update the 1993 Guidelines on determining water availability for new buildings. This ad hoc workgroup is developing guidance to assist counties in GMA requirements related to protection of water resources. Goals of this process include developing:

- Clear, specific guidance regarding legal water availability for local governments to use when making land use decisions is important to Ecology.
- A guidance tool that both local government and Ecology staff can use to aid this decision-making process is necessary to fulfill the obligations of state and local government.

Updating water availability guidance is linked with Ecology's development of a rural water strategy.

Key stakeholders

Key stakeholders that should be considered during extension of the supply and demand forecast to Western Washington include, state, county, and local regulatory and planning agencies, municipal and domestic water purveyors, agricultural groups and irrigation districts, hydropower operators. In addition to these, there are several regional stakeholder forums where water issues are regularly discussed.

The Washington State Department of Health (DOH) tracks water use from water purveyors and is a source of current and projected demand information from Water System Plans filed by purveyors. Water purveyors are periodically updating water demand projections as part of water system planning. Stakeholders with sources of information on water use and demand include:

- Cities
- Counties (comprehensive plans)
- DOH water use tracking
- Office of Financial Management (for supporting population estimates)
- United States Geological Survey (USGS) water projections

Agriculture is significant in Western Washington. According to the Washington State Department of Agriculture, there are 16,345 working farms with a wide variety of crops/animals in Western Washington. Agricultural stakeholders include:

- Washington State Water Resources Association (WSWRA)
- Washington State Farm Bureau (WSFB)
- Washington State Department of Agriculture (WSDA)
- United States Department of Agriculture (USDA)
- Office of Farmland Preservation (OFP)

Western Washington contains 25 hydroelectric sources (dams/plants). These hydroelectric sources are managed by various public utility districts and the Northwest Power and Conservation Council, which should be consulted to help inform forecasts of hydropower demand.

The Washington State Department of Fish and Wildlife (WDFW) helped coordinate the instream flow portion of the OCR Supply and Demand Forecast, and produced an Instream Atlas for key Columbia River tributaries. WDFW was consulted to help inform the basis for projections of instream flow demand, and the effects of potential supply changes on instream flows over time.

Several other regional stakeholder groups have an interest or can potentially provide information to support water supply and demand forecasting:

- Puget Sound Partnership – This is a state agency that focuses on efforts to restore and protect Puget Sound. It has an Action Agenda that identifies key ongoing programs, local priority actions, and other actions to be implemented on a biannual basis.

- Water Resource Advisory Council (WRAC) – This is an Ecology convened public forum for the exchange of information on water resources management in Washington. Topics include proposed rules, policies, legislation, legal constraints, budgetary issues, and drought responses.
- Climate Impacts Group (CIG) – This University of Washington based study group supports the development of climate resilience by advancing understanding and awareness of climate risks.
- Washington Water Utilities Council (WWUC) – A committee that monitors legislation that affects water utilities in Washington in an effort to ensure adequate high-quality potable water can be provided at the lowest reasonable cost.
- Chehalis Basin Work Group – Under the direction of the Governor in 2014, the Chehalis Basin Work Group developed a recommended suite of actions that would reduce flood damages in the near term, restore habitat for aquatic species, and consider long-term, large-scale flood damage reduction actions. The recommended suite of actions is known as the Chehalis Basin Strategy. The Strategy is a comprehensive and integrated approach to implementing flood damage reduction and aquatic species restoration actions in the Chehalis Basin.
- Watershed Planning Units – Local watershed plans are the expression of the public interest under RCW 90.82. Active planning units have detailed supply and demand information that would be useful for the forecast.

Although many of these organizations exist in the Eastern Washington community, the Office of Columbia River found it useful to form a Policy Advisory Group (PAG) that helped inform specific policy issues basin-wide, include the Forecast Effort (Figure 1). Ecology could consider whether a broad Statewide interest PAG might be appropriate.

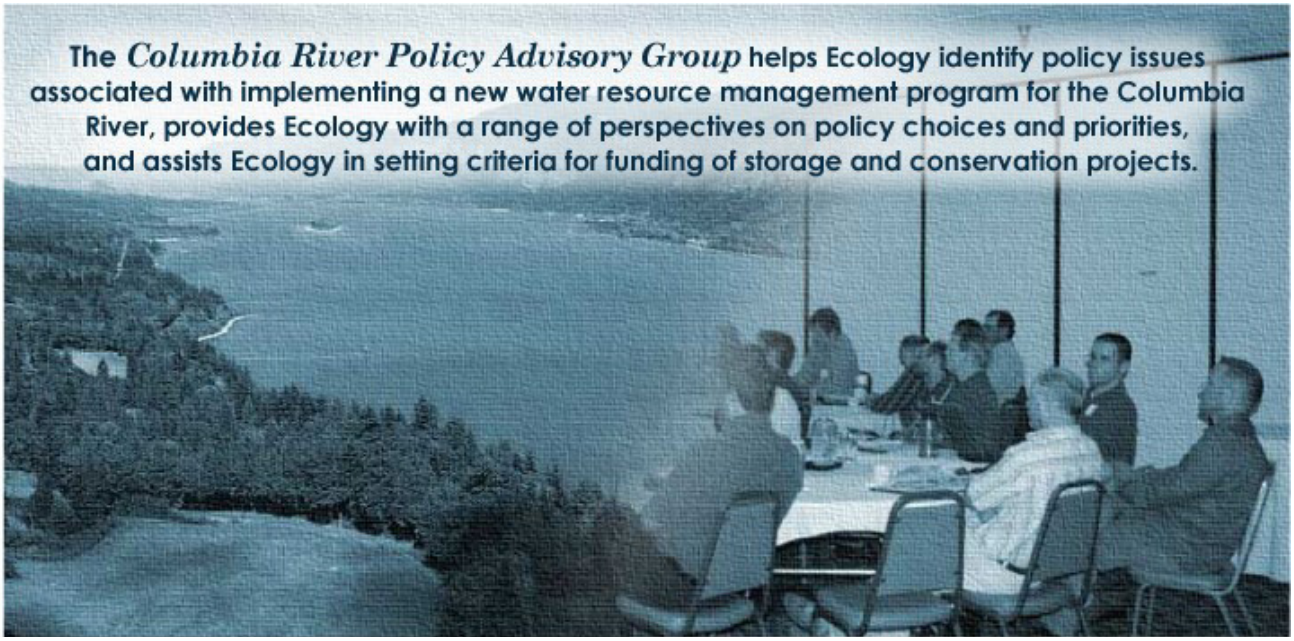


Figure 1. Columbia River Policy Advisory Group

Key Published Documents and Supporting Data

In order to move towards a state water planning effort, we considered the availability of key published documents and supporting data that were foundational to the eastern Washington forecast, and their availability in western Washington. The following sections summarize key data sources and planning efforts that are available.

Watershed plans (WRIA)

There are 28 Water Resource Inventory Areas (WRIAs) in Western Washington under the Watershed Management Act (RCW 90.82/ESHB 2514), which are illustrated in Figure 2. Of the 28 watersheds, 15 have plans that have been adopted, seven have plans that have been started but not finished, and seven have not conducted planning. Instream flow rules are in place for 18 of the watersheds. Each adopted watershed plan required robust public participation. The plans outline the planning process, review technical assessment and findings, analyze alternatives, recommend an implementation program, and provide access to further pertinent documentation.

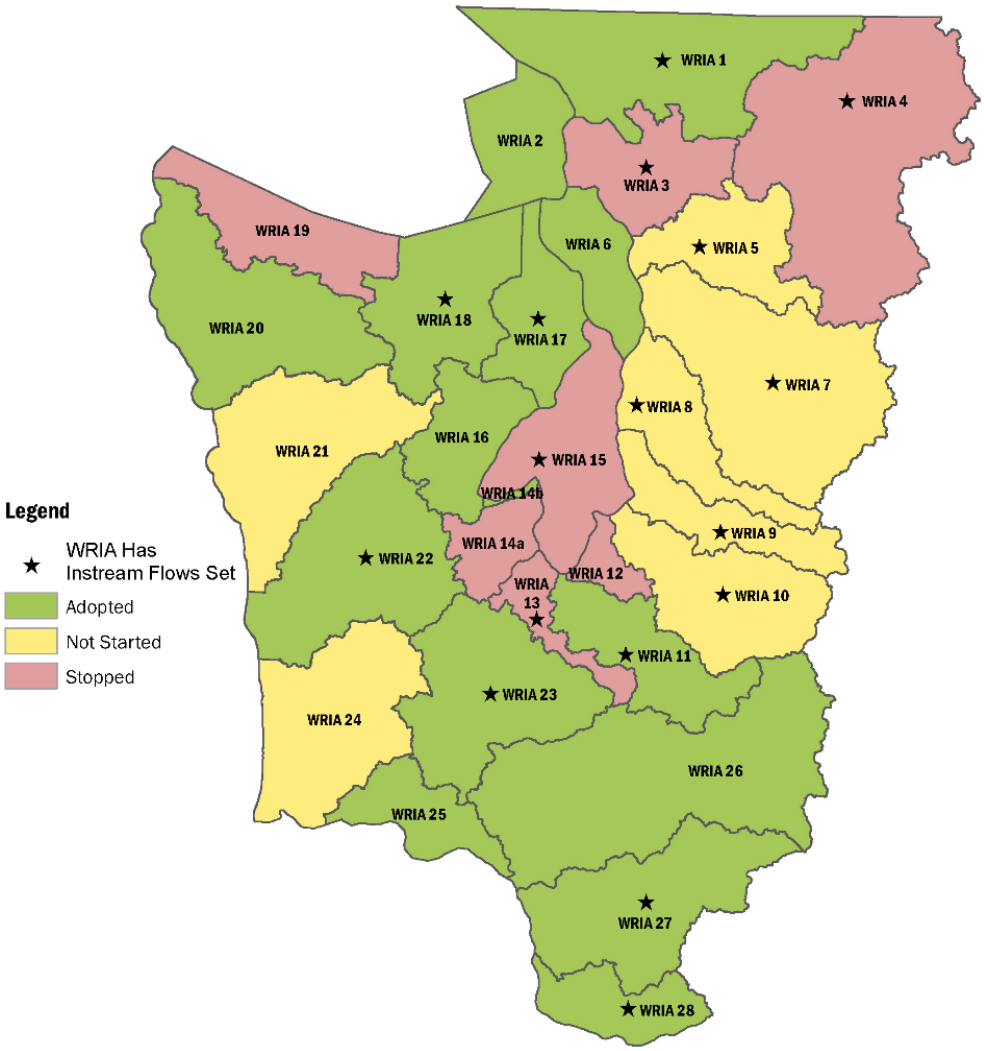


Figure 2. Western Washington WRIAs and Watershed Planning Status

Comprehensive Water System Plans

Water system plans are required to be submitted to DOH for Group A systems and periodically updated. These planning documents provide key information on both water supply and current and future water demand.

Group A water systems have 15 or more service connections or regularly serve 25 or more people 60 or more days per year. State law requires all Group A public water systems to apply for an annual operating permit. (See Chapter 246-294 WAC.)

Group B public water systems serve fewer than 15 connections and fewer than 25 people per day. The Office of Drinking Water and local health jurisdictions regulate Group B systems in our state. (See Chapter 246-297 WAC.)

Figure 3 summarizes the number and types of water systems in Western Washington based on recent DOH information. Based on estimated public water system use, the top 20 Western Washington water systems are shown in Figure 4.

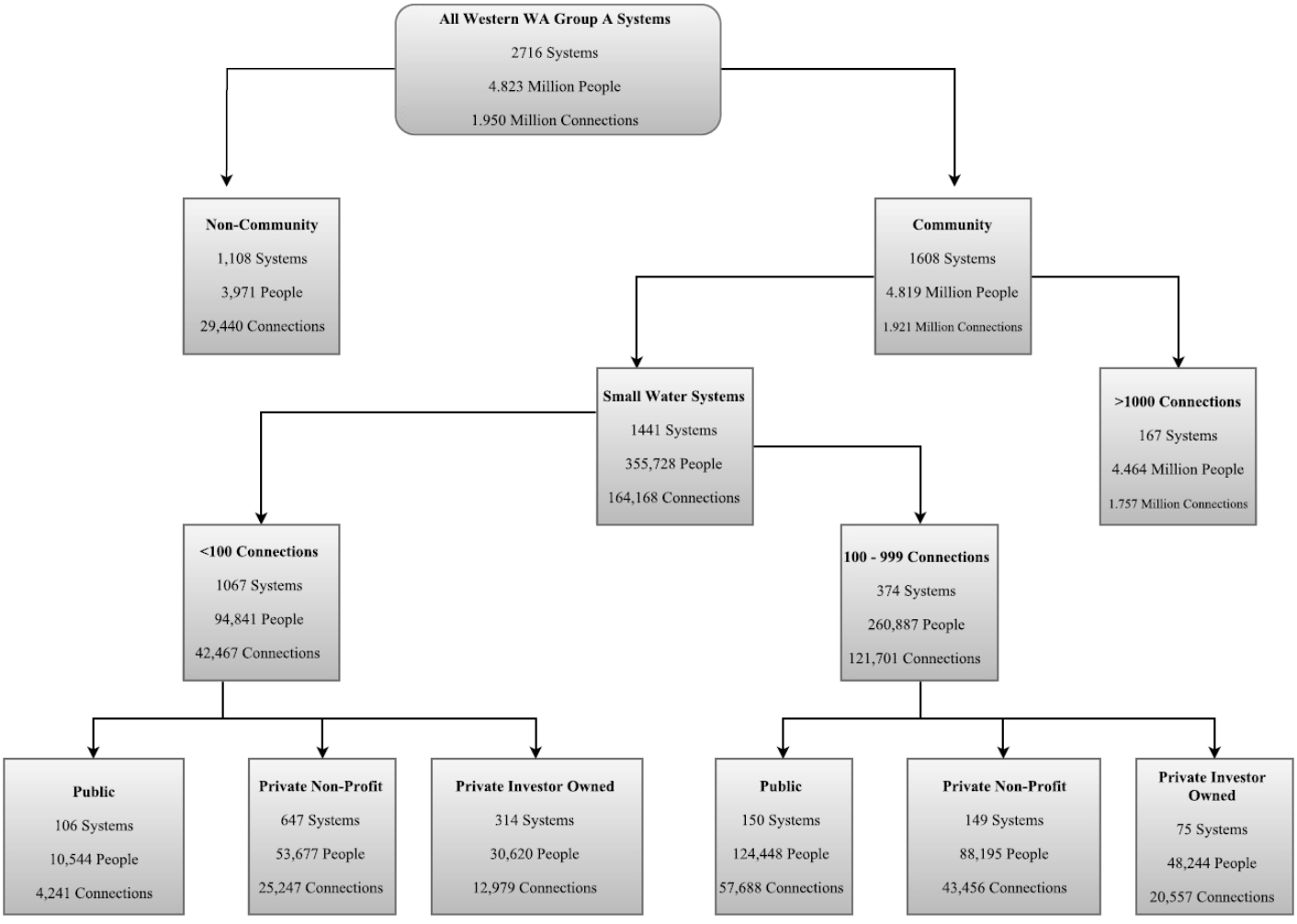


Figure 3. Summary of Water Systems in Western Washington

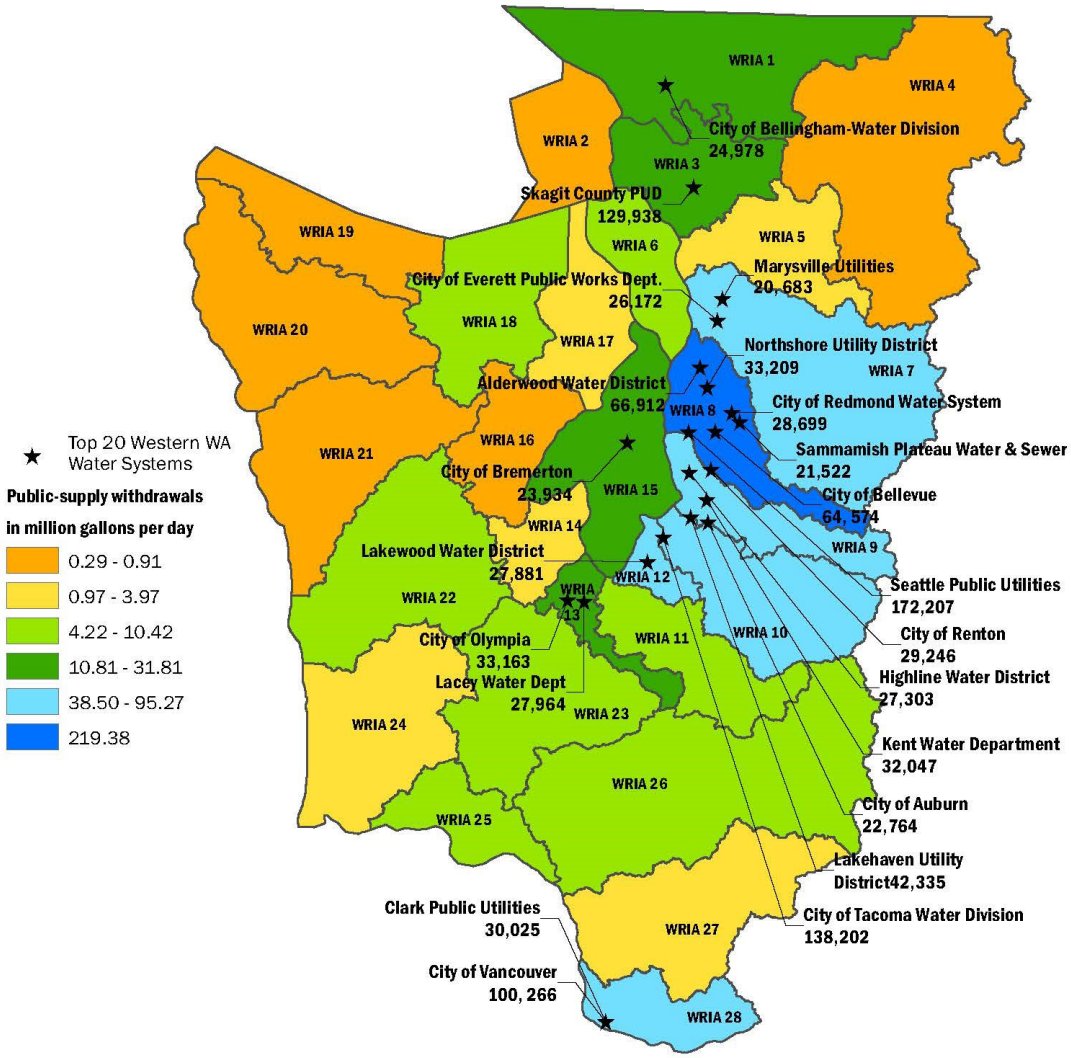


Figure 4. Estimated Public Water System Use and Top 20 Systems in Western Washington

Growth Management Act Planning

Growth management planning is mandated in Washington State under the 1990 Growth Management Act (GMA) (RCW 36.70A) and can influence regional water demand patterns. Of the 19 counties in Western Washington, 11 counties are mandated to plan. In addition, one more county opted to plan, and four counties planned for critical areas and resource lands only.

GMA requires state and local governments to manage Washington's growth by identifying and protecting critical areas and natural resource lands, designating urban growth areas, preparing comprehensive plans and implementing them through capital investments and development regulations. Counties planning under GMA are required to adopt county-wide planning policies to guide plan adoption within the county and to establish urban growth areas (UGAs). State agencies are required to comply with comprehensive plans and development regulations of jurisdictions planning under the GMA.

Reference to the adopted plans can support an understanding of areas of significant population growth and increasing water demands. Figure 5 illustrates the extent of GMA planning in Western Washington.

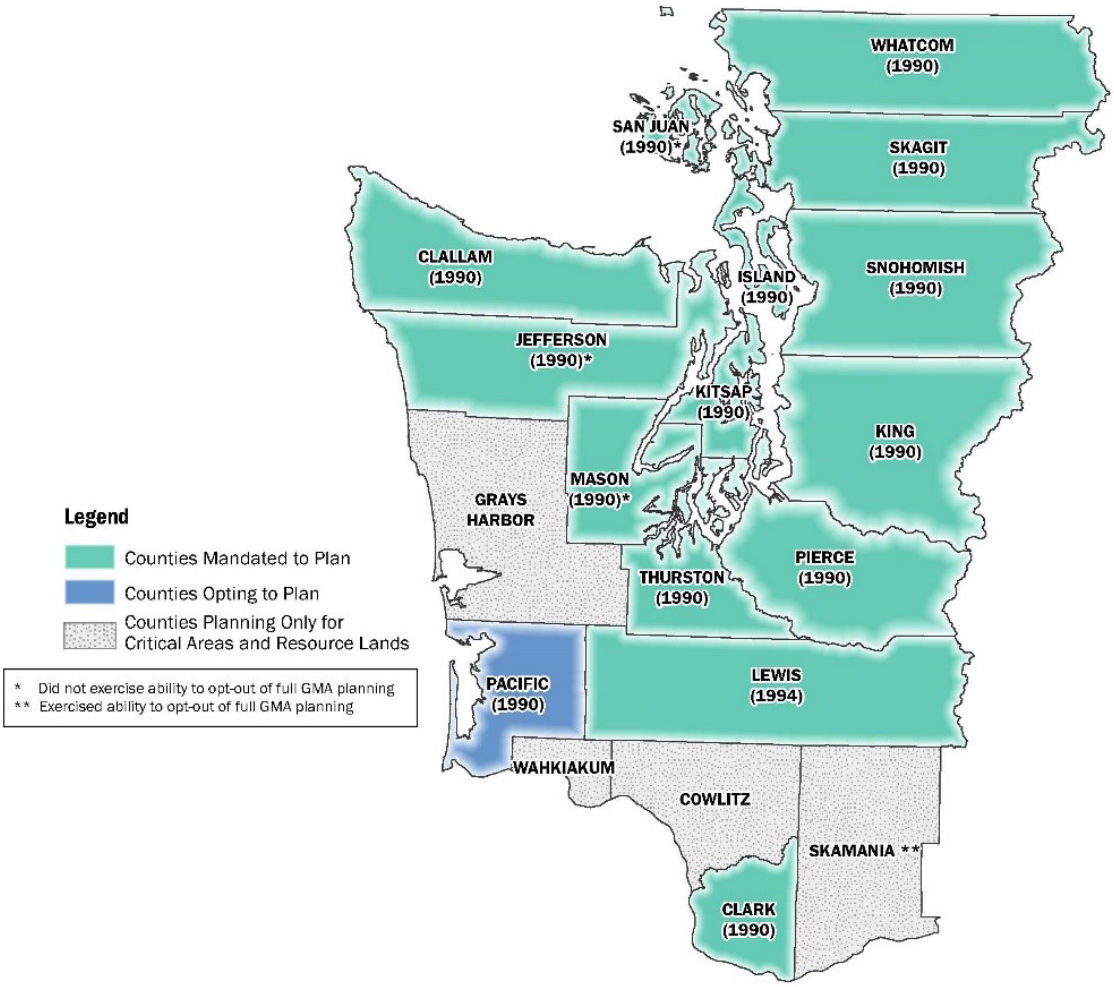


Figure 5. Growth Management Planning in Western Washington

Under the GMA, a Critical Aquifer Recharge Area (CARA) ordinance protects drinking water by preventing pollution and maintaining supply. The GMA defines CARAs as "areas with a critical recharging effect on aquifers used for potable water." A Critical Aquifer Recharge Areas Guidance Document provides details on these steps. The following steps characterize where groundwater resources are important to the community and how to protect them.

- Identify where groundwater resources are located.
- Analyze the susceptibility of the natural setting where ground water occurs.
- Inventory existing potential sources of groundwater contamination.
- Classify the relative vulnerability of ground water to contamination events.
- Designate areas that are most at risk to contamination events.
- Protect by minimizing activities and conditions that pose contamination risks.
- Ensure that contamination prevention plans and best management practices are followed.
- Manage groundwater withdrawals and recharge impacts to:
- Maintain availability for drinking water sources.
- Maintain stream base flow from ground water to support in-stream flows, especially for salmon-bearing streams.

All cities and counties are required to plan for critical areas. For example, King County has 5 Groundwater Management Areas: East King County, Issaquah Creek Valley, Redmond-Bear Creek Valley, South King County, and Vashon-Maury Island.

Stream Gauging

The USGS and Ecology collect streamflow data from stream gauging in Western Washington. The USGS collects data continuously at almost 400 streamflow, reservoir, water-quality, meteorological and groundwater sites in Washington State. Most of these data are transmitted via satellite and posted on-line in near real time.

The Department of Ecology's Environmental Assessment Program maintains a network of stream gauging stations that produce near real-time streamflow data for rivers and streams across the state. The networks of Western Washington Ecology and USGS stream gauges are shown on Figures 6 and 7, respectively.

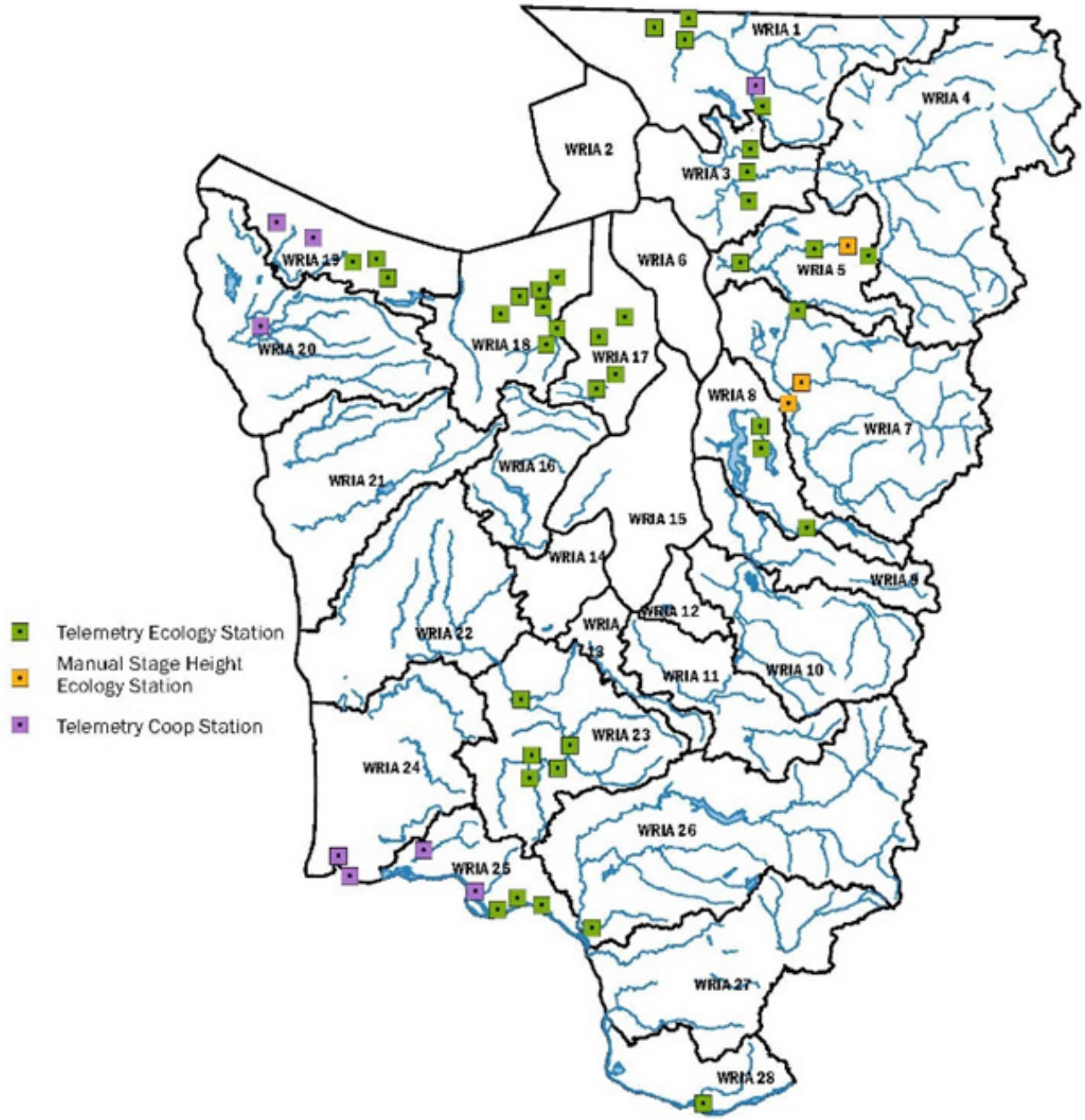


Figure 6. Ecology Stream Gage Network

Key Surface and Groundwater Studies

A number of studies have been completed that focus on surface and groundwater supplies in Western Washington. Many water systems rely primarily on surface water derived from mountain snowpack and runoff, but groundwater is an important source of supply for many communities and for exempt well use. Several studies have also focused on evaluating hydraulic connection between surface water and groundwater.

Key surface and groundwater studies for reference in extending the supply and demand forecast to Western Washington can be found in the bibliography and include: regional models, watershed studies, county-led studies, including groundwater management plans.

For the OCR Forecast, initial planning efforts focused on surface water supplies only and groundwater was presumed to not be limiting for existing or future demand. In the 2016 Forecast, additional effort was made to characterize 10 areas in Eastern Washington where declining groundwater has a significant effect on supply to agricultural, municipal, and industrial users, as well as conjunctive impacts on instream flows. For the 2021 OCR Forecast, a more robust curtailment model is planned in areas with declining groundwater to more accurately reflect economic and environmental impacts. Similar scrutiny should be given to basins or areas in Western Washington where groundwater supplies may be limited.

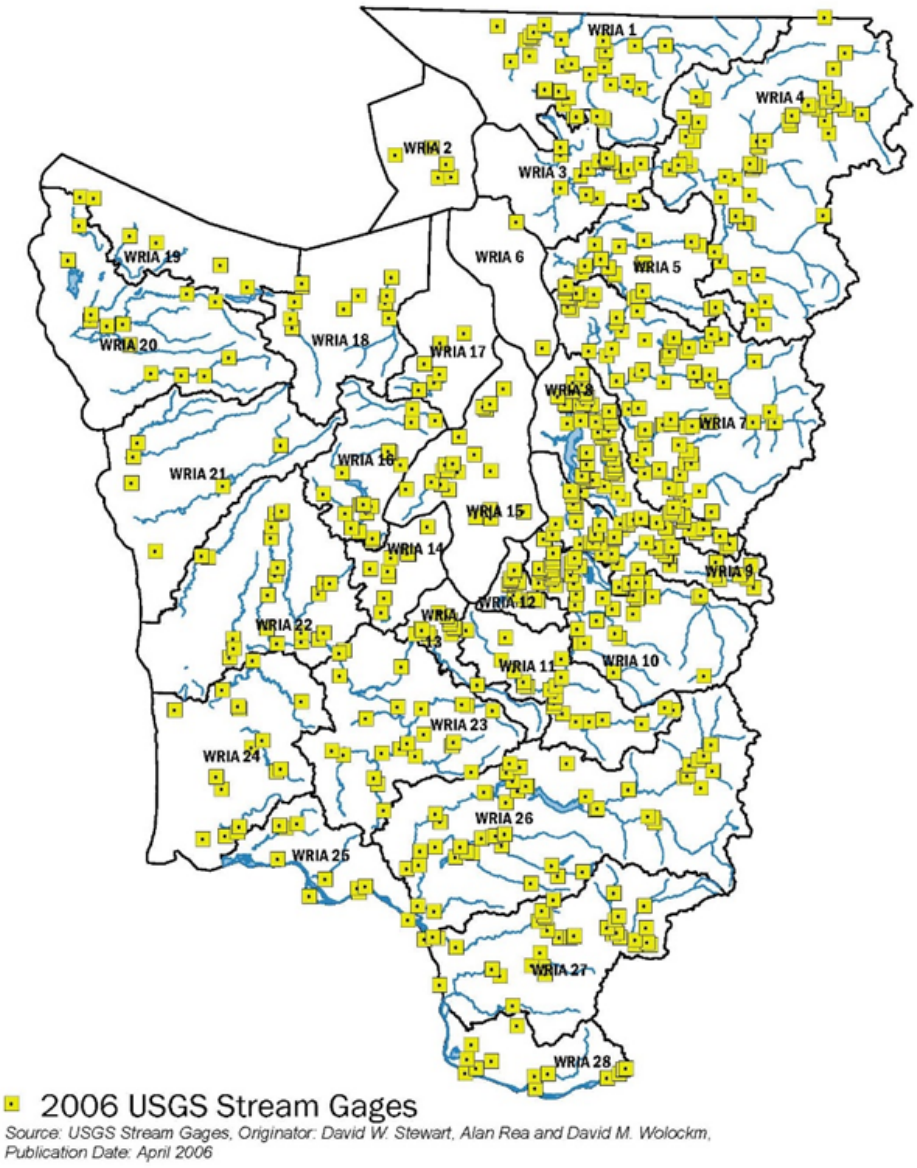


Figure 7. USGS Stream Gauges in Western Washington

Climate Change Considerations

Climate change considerations in Western Washington are largely similar to overall considerations for the entire Pacific Northwest region where model predictions point to warmer temperatures, decreases in summer precipitation, increases in winter precipitation, more precipitation as rain instead of snow, reduced snowpack and earlier snowmelt, all of which affect seasonality and magnitude of water availability and demands. In addition, the coastal regions in Western Washington are directly affected by sea level rise. Key studies related to climate change in Western Washington are listed in the bibliography.

Existing Responses to Water Supply Limitations

Stakeholders have implemented various means of response to water supply limitations. These include water banking, conservation, and alternative source development, which are described in the following sections.

Water Banking

Water banking is a water reallocation tool that can benefit both existing water rights holders and provide water for new uses to meet growing and changing water demands. The overall goal of a water bank is to facilitate water transfers using market forces. Figure 8 describes how a water bank bridges supply and demand needs.

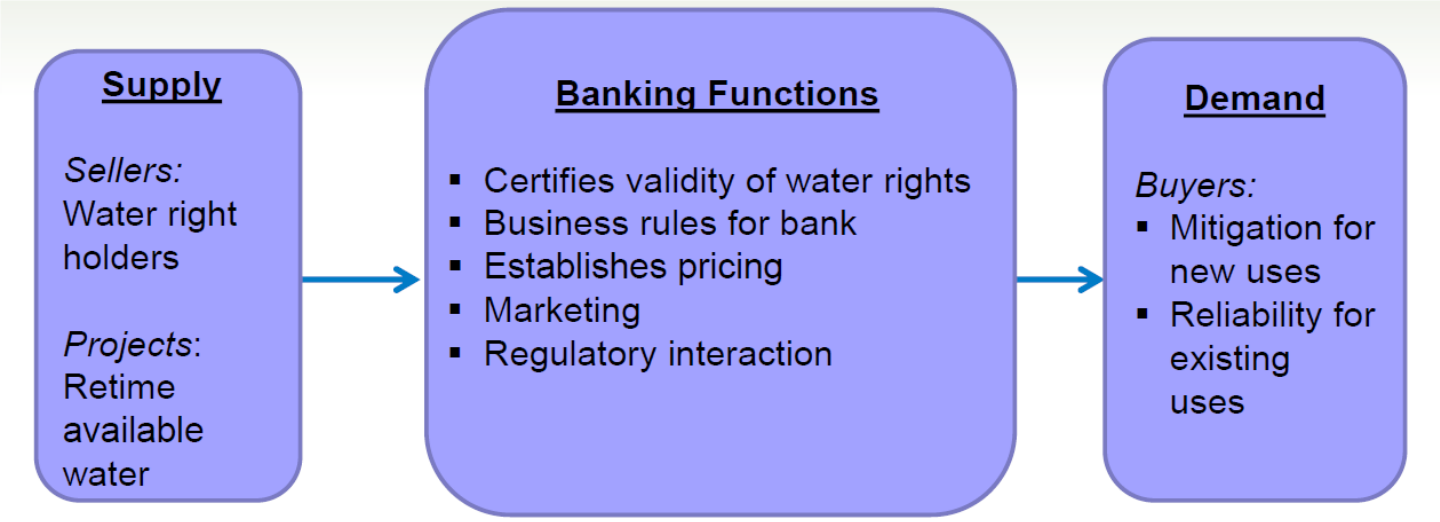


Figure 8. Water Bank Process Diagram

Objectives of water banking often include:

- Reallocating reliable water supplies during dry years;
- Creating seasonal water supply reliability;
- Ensuring future water supplies for people, farms, and fish;
- Promoting water conservation;
- Maximizing water right extent and validity; and
- Ensuring compliance with instream flow rules and intrastate water agreements.

The majority of water banks in Washington are in Eastern Washington, but more are expected to develop in Western Washington over the next several years. Figure 9 depicts where water banks are currently operating or being studied throughout Washington State.

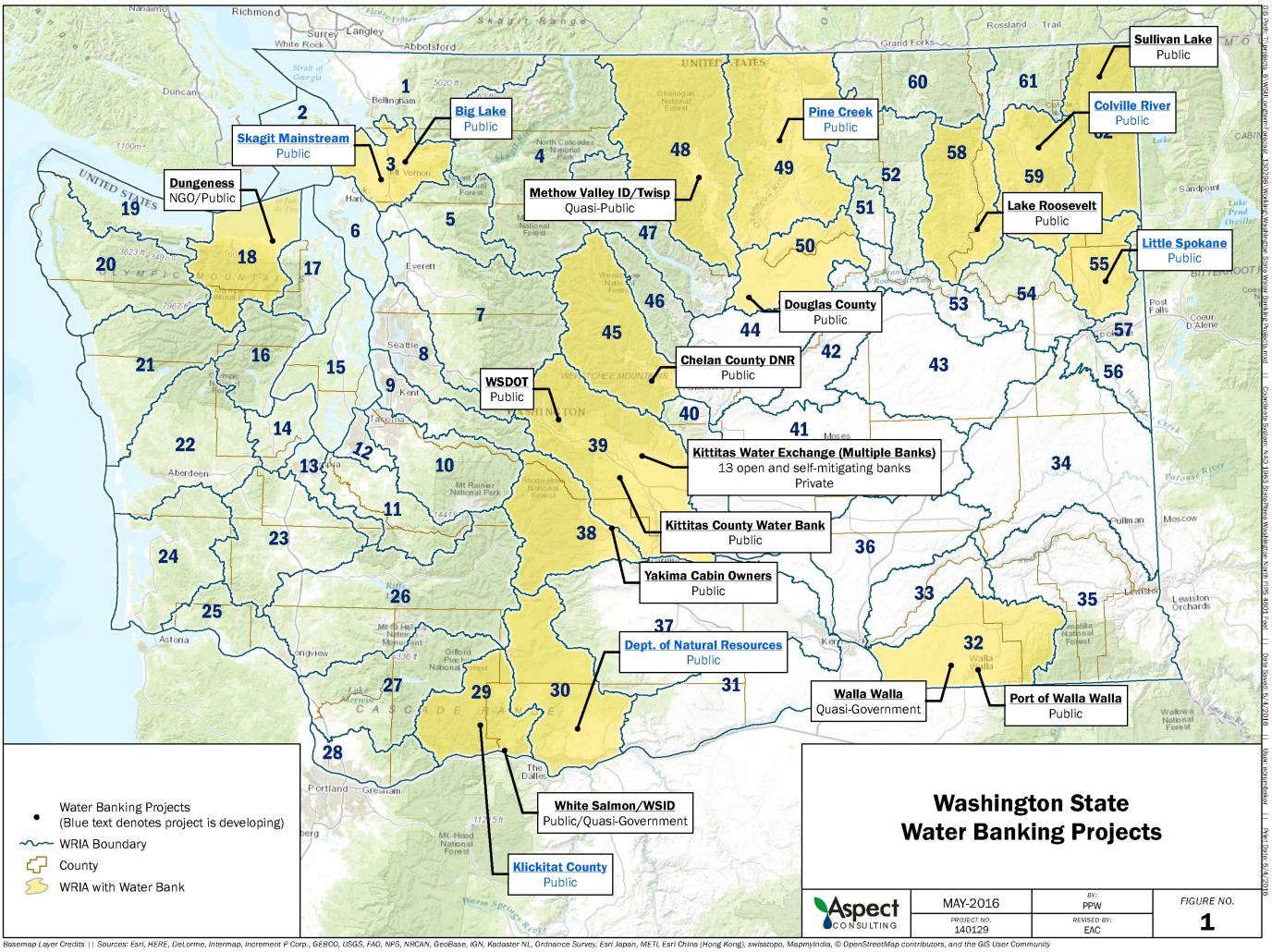


Figure 9. Water Banking in Washington.

Water banking has been implemented or is in the process of being implemented in the following watersheds in Western Washington:

- Dungeness Water Exchange (DWE) (active) – On January 2, 2013, the Dungeness Water Management Rule (Dungeness Rule) was adopted by Ecology. The Dungeness Rule is guides water use planning and decision-making for new water users, and sets policies to help protect the availability of water for current and future needs of people and the environment. All water use established after the Dungeness Rule was implemented needs to be mitigated. The DWE has restoration and mitigation programs. The mitigation packages are described below.

Mitigation Package Descriptions

Package Description	Average Amount of Indoor Use (Gallons/Day)	Average Amount of Outdoor Use (Gallons/Day)	Amount of Irrigated Lawn Area (Square Feet)	Amount of Irrigated Lawn Area (Acres)
Indoor Only Package (minimal incidental outdoor use only) $1,000	150* (average)	0	0	0
Indoor with Basic Out-door Package $2,000	150* (average)	89	2,500 sq. ft. (approx. 50 x 50 ft.)	.06 acres
Indoor with Extended Outdoor Package $3,000	150* (average)	200	5,625 sq. ft. (approx. 75 x 75 ft.)	.13 acres

*Note: The Exchange accounts for domestic mitigation using a standard average daily amount of 150 gallons (WAC 173-518-080 (b). This is the annual amount of water that the Exchange and the mitigation certificate purchaser agree upon as the basis for their transaction.

- Snoqualmie Valley Water Bank/Exchange (funded, implementation starting) – The Snoqualmie Watershed has instream flows that are frequently not met during the irrigation season. The future Snoqualmie Bank will facilitate intra-district seasonal and temporary water right transfers by moving water rights downstream, and implement conservation benefitting both in-stream and out of stream users. A draft agreement between Ecology and the future Snoqualmie Bank has been written. It builds on the water strategy development that the Snoqualmie Valley Preservation Alliance (SVPA) conducted through a Washington State Department of Agriculture-funded investigation.

- Skagit (in progress) – On April 14, 2001, the Skagit River Basin Water Management Rule (Skagit Rule) was adopted by Ecology then amended in 2006 to established finite "reservations" of surface and groundwater for future out-of-stream uses. On October 3, 2013, the Washington Supreme Court ruled that Ecology cannot set aside reservations of water where water was previously set aside to support set instream flows. This ruling means nearly 500 homes and businesses that have relied on the Skagit reservations for water supplies since 2001 and any new users will have to mitigate use.

Conservation

Water conservation is a common method used to create more water availability from existing supplies. Some of the ways that conservation is being initiated and applied are:

- Water system conservation requirements for public water systems can include:
  - Collecting data and forecasting demand and setting conservation goals,
  - Calculate distribution system leakage and reducing leaks,
  - Outreach to residents to promote efficient water use,
  - Low water use infrastructure replacement programs,
  - Conservation-based rate structures,
  - Water reclamation or reuse, and
  - Lawn watering ordinanes, covenants, or buy-back programs.
- Irrigation efficiency improvements can include:
  - Canal lining and pipe replacement
  - On-farm efficiency programs (drip, microspray sprinklers)
  - Automation to reduce spills
  - Re-regulation reservoirs

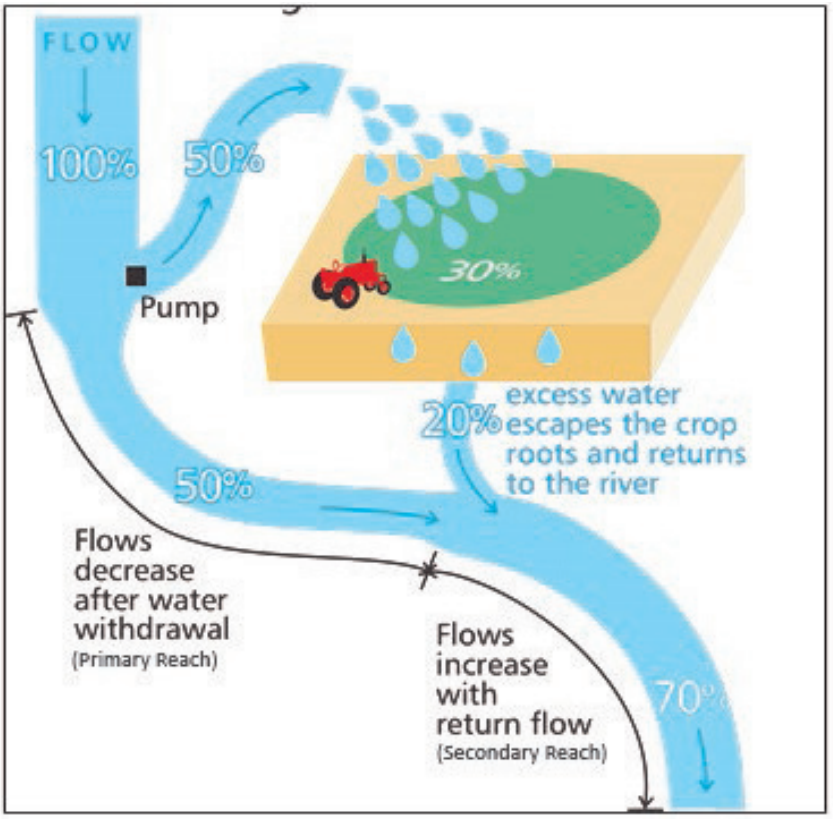


Figure 10: Conservation Benefits for Instream Flows

Conservation has the effect of making out-of-stream diversionary water rights meet increasing population or farming pressures, and benefiting instream flows. Figure 10 summarizes how conservation can benefit instream flows, which is often incentivized through state-funded grant programs, such as the Irrigation Efficiency Grant Program administered by Ecology.

Generally, there is continued regulatory and economic pressure for increased efficiency in water use, which can be considered in successive forecasts.

Alternative Sources and Retiming of Water Availability

Seasonal precipitation has a great effect on supply and demand issues for both people and aquatic needs. To compensate for times of high demand and low supply, storage and reuse projects are being implemented in Western Washington that would be integrated into the forecasting effort, including the following:

- Aquifer Storage Recovery (ASR)/ Shallow Aquifer Recharge (SAR) – ASR and SAR increase existing groundwater supplies by artificially recharging groundwater. Water is stored during times of abundant supplies and withdrawn or allowed to enhance instream flows during times when water availability would be otherwise limited. Three operating ASR projects are Western Washington, and several other feasibility studies have been conducted. Use of SAR has also been investigated at several locations. Implementation of new ASR and SAR projects is anticipated in the future to address seasonal availability of water. Projects include:
  - Lakehaven Utility District ASR (active)
  - Sammamish Plateau Water & Sewer District ASR (active)
  - Seattle Public Utilities Highline Wellfield ASR (active)
  - Dungeness watershed SAR (under development)
  - Lacey, Olympia, Tumwater and Thurston County (LOTT) reclaimed water infiltration (under development)
- Surface storage projects – Surface reservoirs are commonly used for hydropower, irrigation, municipal water supply, and flood control. There are more than 1,100 dams in Washington with the majority of large dams built for hydropower uses. Some of the largest municipal supply reservoirs are the masonry/Chester Morse Reservoir Dams and South Fork Tolt River Dam for the City of Seattle, the Casad Dam/Union River Reservoir for the City of Bremerton, and the George Culmback Dam/Spada lake for Snohomish county and the City of Everett. Most flood control reservoirs were built by the U.S. Army Corps of Engineers. Some recent surface storage reoperation or enlargement projects include:
  - Lake Tapps Water Supply Project
  - Cowlitz Falls Dam
  - Indian Creek reservoir
  - Judy Reservoir Enlargement
- Reclaimed water – Use of reclaimed water is increasing in western Washington. Two demonstration projects in Sequim and Yelm were developed in 1998 and 1999 and now there are many sites actively using reclaimed water. Some examples include:
  - Sequim Water Reclamation Facility and Water Reuse System – In 1998, the City of Sequim upgraded its wastewater treatment facility into a Class A Water Reclamation Facility. The City developed a reclaimed water distribution system that seasonally diverts water for irrigation, toilet-flushing, stream flow augmentation, vehicle washing, street cleaning, fire truck water, and dust control uses.
  - Yelm Water Reclamation Facility and Reclaimed Water System – In 1999, the City of Yelm upgraded its wastewater treatment facility into a Class A Water Reclamation Facility. The City uses the reclaimed water for irrigation, school bus washing, and groundwater recharge.
  - Brightwater Water Reclamation Facility and conveyance system – The Class A reclaimed water treatment began in September 2011 and conveyance began full operations in fall of 2012. Water is used for irrigation and streamflow augmentation.
  - City of Renton Reclamation Facility – Class A reclaimed water for landscape irrigation
  - Westpoint Reclamation Facility – Class A reclaimed water for irrigation and plant process water
  - Chambers Creek Properties – Reclaimed water for site restoration and irrigation
  - King County South Plant Reclaimed Water Plant – Irrigation, wetland enhancement, sewer flushing, and street sweeping.

Action Plan/Scoping Details – 2021 Supply/ Demand Forecast for Western Washington

This section describes whether data sets and approaches historically used to forecast supply and demand in Eastern Washington can be expanded to Western Washington watersheds. For a full description of the modeling and forecasting effort currently being used, see the 2016 Water Supply and Demand Forecast. Figure 11 below provides a summary of the integrated approach to modeling physical parameters, water rights, storage, crop demand, and economic drivers in the current forecasting effort.

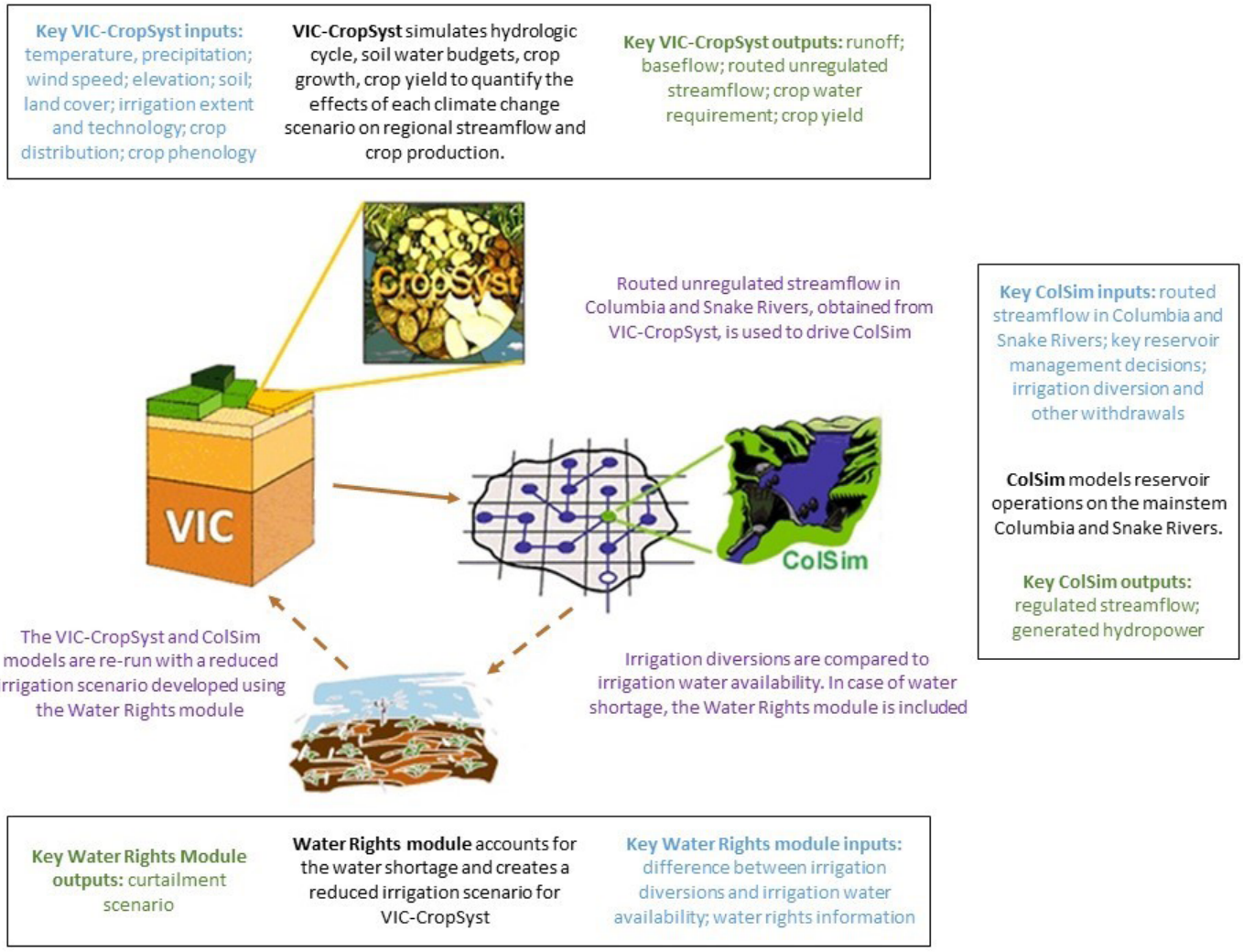


Figure 11: Overview of 2016 Water Supply and Demand Forecast Modeling

Demand Estimates

Agricultural demands

VIC-CropSyst is the modeling framework used to estimate irrigation demands for Eastern Washington in the 2016 forecast. The major inputs required by VIC-CropSyst are gridded meteorological data, land cover classification, irrigation extent classification, soil characteristics and elevation information. The data sources used to develop these inputs for Eastern Washington also extend to Western Washington and can be processed to create necessary inputs. Some of these data source include:

- U.S. Department of Agriculture long term projections
- U.S. Bureau of Reclamation reports/data compilations
- Washington State Department of Agriculture
- USGS investigations/data compilations
- Ecology water rights tracking system (for existing rights and pending applications)
- Modeled demands

Some additional considerations to be made for Western Washington include a needs assessment for the following.

- Do certain Western Washington WRIAS have small farm acreage as a significant fraction of total crop acreage? If the current data sources for cropland and irrigation extent classification do not capture small farm acreage, the modeled demands would be underestimated and other data sources will need to be explored in these WRIAs.
- What proportion of the Western Washington WRIA demands come from Nursery/Greenhouse, Aquaculture, Dairy and other Livestock activities which are not part of the current crop modeling efforts in Eastern Washington? The 2012 USDA Census of Agriculture indicates these to be leading commodities by market value for several WRIAS in Western Washington. An alternate method of estimating demands for these commodities both historically and under future climate projections may need to be explored.

Municipal and Industrial demands

A process similar to that used in Eastern Washington will be used to extend this to Western Washington. Rather than integrated modeling of these demands, forecasting would rely on the multitude of other required planning and forecasting responsibilities through local and state jurisdictions, including:

- Water system plans
- Census information for each Western Washington county is available at: http://quickfacts.census.gov/qfd/states/53000.html
- USGS data compilations
- Watershed planning documents
- Groundwater Management areas
- Ecology water rights tracking system (for existing rights and pending applications)

Hydropower demands

A process similar to that used in Eastern Washington will be used to extend this to Western Washington. A combination of published documents, information from the Northwest Power Planning Council, data from the FERC application tracking system and interviews will be used to assess these demands.

Instream Flow and Interruptible Demands

Curtailment of water rights in Western WA are primarily based on instream flow rules. This is unlike Eastern Washington where curtailment is a combination of water rights subject to instream flow requirements as well as areas where junior rights holders are routinely curtailed to ensure senior rights are met. From a modeling perspective, the process used to identify curtailment in Eastern Washington interruptible rights subject to instream flow rules can be extended to Western Washington.

- Unmet demand from adopted instream flow rules for the Western Washington WRIAs would be evaluated by comparing adopted flows to a range of water year forecasts, including wet, dry, and average years both now and in the future.

- Interruptible right holders are available through the Department of Ecology's WRTS database, and the frequency of their interruption (and the resulting demand for water) can be forecasted.
- Evaluation of WRIA level supply and demand estimates will determine whether or not it is appropriate to estimate curtailment based on instream flow requirements for specific locations.
- Economic drivers and forecasting methods for Western Washington should be analogous to the approach used in the 2016 Water Supply and Demand Forecast.

Supply Estimates

As in the previous forecasts, we will build on work by the Climate Impacts Group at University of Washington, to get supply estimates through VIC-CropSyst simulations.

Additional considerations for Western Washington include:

- Evaluation of whether a "large scale" model such as VIC-CropSyst is suitable to estimate supply for all WRIAs in Western Washington. As compared to Eastern Washington, some of the watersheds in Western Washington are much smaller in drainage area.
- Inventory Western Washington WRIAs where supply is regulated by reservoirs and results in significant shifts to the hydrograph. Ratio of reservoir capacities to inflow can be used to determine the list of reservoirs whose operations need to modeled to better capture supply in the respective WRIAs. Reservoir models can be inventoried and used where they exist (eg. Skagit basin).
- Tidal effects on supply in coastal WRIAS.
- Assess ground water versus surface water sources of supply by WRIA. Inventory WRIAs where location-specific ground water models might be needed to accurately represent supply, and where ground water declines are an important consideration. Ground water withdrawals as percentage of total withdrawals for the Agriculture, Municipal and industrial secotors are higher in Western Washington (40%) as compared to Eastern Washington (30%) (Lane and Welch, 2010).

Summarize Scope and Conceptual Budget for 2021 Forecast

The 2021 effort in Western Washington will be exploratory in that the framework developed for Eastern Washington will be applied and evaluated to identify WRIAs where additional information or changes in the framework will be required to better capture supply and demand estimates in Western Washington. The scope includes the following.

- Apply the VIC-CropSyst framework to Western Washington.
    - Process and set up gridded input data including meteorological data, agricultural land use data, and irrigation extent for Western Washington.
    - Model calibration and evaluation.
    - Model application for supply and demand estimates.
- Estimate municipal/industrial and hydropower demands.
- WRIA level evaluation of appropriateness of VIC-CropSyst framework to capture supply and agricultural demand.
    - Comparison against published documents.
    - Stakeholder engagement (surveys, meetings, outreach materials, coordination with University of Washington, coordination with planning jurisdictions, coordination with Western Washington Tribes).

  - Comparison of modeled demand categories relative to non-modeled demand categories – dairy/livestock, nursery/greenhouse, aquaculture demands, and demands from small farm acreage missing in the land cover data.
  - Explore secondary sources of non-modeled category demand estimates in relevant WRIAs.
- Inventory WRIAs where regulation through reservoirs alters the hydrograph.
  - Dam inventory databases will be used to find reservoirs where the ratio WRIA level supply to reservoir storage is above a specific threshold.
  - Potential to use reservoir models where they currently exist or potential to create simple reservoir operations models will be explored.
- Unmet demand analysis based on instream flow requirements.
  - Information related to interruptible water right holders from the Department of Ecology's WRTS database and WAC instream flow rules will be use to estimate unmet demands.
  - Evaluation of unmet demand analysis based on supply and demand evaluation.
  - Economic curtailment analysis.
- Inventory of WRIAs where consideration of ground water modeling and ground water declines is important.
  - Ground water models where relevant will be explored for future use.

Budget

The total budget effort for the 2016 Water Supply and Demand Forecast for Eastern Washington, including separate study efforts on related forecasting efforts related to METRIC, Water Banking, Declining Groundwater Supplies, Effects of User-Pay Requirements on Water Permitting, and West-Side Scoping was $1.8 million dollars over two years. Because this is the third such forecast by the Office of Columbia River, this effort benefited from some efficiency in stakeholder involvement, model foundation, and methodology. Some of the core research team has been together for the 2006, 2011, and 2016 forecast work, which also helped streamlining the process. However, the 5 modules developed during the 2016 Forecast were new efforts.

It is anticipated that extending this work to develop a holistic State Water Plan will require a significant effort. Western Washington stakeholders will rightly want robust involvement from plan inception to ensure their unique issues are being appropriately modeled. If unique policy research (e.g. like the 5 modules) is desired to address Western Washington issues, or to address emerging changes statewide by 2021, then those costs would need to be scoped separately.

WSU is projecting an overall budget requirement of $3 to $4 million for the 2021 Statewide Forecast to be completed over 2 years. In advance of the launch of such an effort, WSU recommends Ecology hold a series of scoping meetings with the parties identified herein, to ensure that the data sets, data gaps, policy issues, jurisdictional planning overlap, and other factors are adequately scoped. From those meetings, a more refined budget would be developed. Additionally, WSU recommends that several meetings be held with other key Western States with State Water Plans to understand their issues, identify successful modeling and stakeholder involvement tools, and budgetary considerations.

Bibliography

State Water Plans

State	State Plan?	Resource	Comments
Alabama	N	http://governor.alabama.gov/assets/2014/04/AWAWG-Report-FINAL-2-Side-Print.pdf	In process
Alaska	N	http://dnr.alaska.gov/mlw/water/	
Arizona	Y	http://www.azwater.gov/AzDWR/StatewidePlanning/WaterAtlas/	
Arkansas	Y	http://arkansaswaterplan.org/plan/ArkansasWaterPlan/Update.htm	
California	Y	http://www.water.ca.gov/waterplan/	
Colorado	Y	https://www.colorado.gov/cowaterplan	
Connecticut	N	http://www.ct.gov/water/cwp/view.asp?a=4801&q=574956 https://www.cga.ct.gov/2013/rpt/2013-r-0159.htm	In process
Delaware	N	http://www.nj.gov/drbc/programs/basinwide/	
Florida	Y	http://www.dep.state.fl.us/water/waterpolicy/fwplan.htm	
Georgia	Y	http://www.georgiawaterplanning.org/	
Hawaii	Y	http://dlnr.hawaii.gov/cwrm/planning/hiwaterplan/	
Idaho	Y	https://www.idwr.idaho.gov/waterboard/WaterPlanning/Statewaterplan-ning/State_Planning.htm	
Illinois	N	https://www.dnr.illinois.gov/WaterResources/Documents/Jan%202015%20-%20Action%20Plan%20for%20Statewide%20Water%20Supply%20Planning.pdf http://www.isws.illinois.edu/wsp/	In process
Indiana	N	http://www.indianachamber.com/index.php/water-study	Proposed
Iowa	N	http://www.iowadnr.gov/Environment/WaterQuality/IowaWaterPlan.aspx http://www.agriculture.state.ia.us/WRCCArchives.asp	
Kansas	Y	http://kwo.org/Water-Plan.html	
Kentucky	N	http://water.ky.gov/Pages/default.aspx	
Louisiana	N	http://dnr.louisiana.gov/assets/OC/env_div/gw_res/WRC.Oct.13.Re.pdf	Proposed
Maine	N	http://www.maine.gov/dep/water/index.html	
Maryland	N	https://planning.maryland.gov/PDF/OurProducts/Publications/ModelsGuide-lines/mg26.pdf	In process
Massachusetts	N	http://www.mass.gov/eea/docs/dep/water/laws/i-thru-z/iwrmp.pdf https://www.cga.ct.gov/2013/rpt/2013-r-0159.htm	
Michigan	Y	http://www.michigan.gov/deq/0,4561,7-135-3313_3677_64891---,00.html	Draft
Minnesota	Y	https://www.eqb.state.mn.us/sites/default/files/documents/2010_Minneso-ta_Water_Plan.pdf	
Mississippi	N	http://www.deq.state.ms.us/mdeq.nsf/page/l&w_home	
Missouri	Y	http://www.dnr.mo.gov/env/wrc/statewaterplanMain.htm	

State	State Plan?	Resource	Comments
Montana	Y	http://dnrc.mt.gov/divisions/water/management/state-water-plan	
Nebraska	N	http://www.dnr.ne.gov/iwm/statewide-water-planning	
Nevada	Y	http://water.nv.gov/programs/planning/stateplan/	
New Hampshire	N	https://www.cga.ct.gov/2013/rpt/2013-r-0159.htm	In process
New Jersey	N	http://www.nj.gov/dep/infofinder/topics/water.htm	
New Mexico	Y	http://www.ose.state.nm.us/Planning/state_plan.php	
New York	N	http://www.dec.ny.gov/chemical/290.html	
North Carolina	N	http://deq.nc.gov/about/divisions/water-resources/planning	
North Dakota	Y	http://www.swc.nd.gov/	
Ohio	N	http://www.epa.ohio.gov/dsw/mgmtplans/208index.aspx	
Oklahoma	Y	http://www.owrb.ok.gov/supply/ocwp/ocwp.php	
Oregon	Y	http://www.oregon.gov/owrd/pages/law/integrated_water_supply_strategy.aspx	
Pennsylvania	Y	http://www.pawaterplan.dep.state.pa.us/statewaterplan/docroot/default.aspx https://www.cga.ct.gov/2013/rpt/2013-r-0159.htm	
Rhode Island	Y	http://www.planning.ri.gov/statewideplanning/land/water.php https://www.cga.ct.gov/2013/rpt/2013-r-0159.htm	
South Carolina	Y	http://www.dnr.sc.gov/water/waterplan/index.html	
South Dakota	Y	http://denr.sd.gov/dfta/wwf/statewaterplan/statewaterplan.aspx	
Tennessee	N	http://www.tn.gov/environment	
Texas	Y	http://www.twdb.texas.gov/waterplanning/swp/	
Utah	Y	http://www.water.utah.gov/planning/swp/ex_swp.htm	
Vermont	N	http://dec.vermont.gov/watershed	
Virginia	Y	http://www.deq.virginia.gov/Programs/Water/WaterSupplyWaterQuantity/WaterSupplyPlanning/StateWaterResourcesPlan.aspx	
Washington	N		Scoping
West Virginia	Y	http://www.dep.wv.gov/WWE/wateruse/WVWaterPlan/Pages/default.aspx	
Wisconsin	N	http://dnr.wi.gov/topic/surfacewater/planning.html	
Wyoming	Y	http://waterplan.state.wy.us/frameworkplan-index.html	
United States		http://streamingwater.org/state-water-plans/	Link to state planning

Washington Watershed Plans (WRIA)

1. http://www.ecy.wa.gov/water/wria/index.html

Comprehensive Water System Plans

1. Seattle Public Utilities et al., 2007, 2007 Water System Plan, Volume 1, Prepared by Seattle Public Utilities, Brown and Caldwell, and Johansen Consulting, November 2006.
2. Tacoma Public Utilities, 2006a, 2006 Comprehensive Water Plan Update, Volume 1, Prepared by Tacoma Public Utilities Water Division, August 2, 2006.
3. Tacoma Public Utilities, 2006b, Green River Watershed Management Plan, Volume II, Prepared by Tacoma Public Utilities Water Division, August 2006
4. Alderwood Water and Wastewater District et al., 2009, 2009 Water Comprehensive Plan, Summary, Prepared by Alderwood Water and Wastewater District, HDR Engineering, Inc., and Confluence Engineering Group, August 2009.
5. City of Bellevue, 2015, City of Bellevue Water System Plan, Volume 1, Draft, Prepared by City of Bellevue, October 2015.
6. PACE Engineers, Inc., 2008, Lakehaven Utility District 2008 Comprehensive Water System Plan, Prepared by PACE Engineers, Inc., November 2008.
7. Gray & Osborne, Inc., 2009, Northshore Utility District, Water System Plan, Prepared by Gray & Osborne, Inc., March 2009.
8. PACE Engineers, Inc. and Aspect Consulting, LLC, 2011, City of Kent Public Works Department, 2011 Water System Plan, Prepared by PACE Engineers, Inc. and Aspect Consulting, LLC, 2011.
9. Public Utility District No. 1 of Skagit County, 2007, 2007 Water System Plan, Volume 1, Prepared by Public Utility District No. 1 of Skagit County, September 2008.
10. City of Everett et al., 2007, City of Everett 2007 Comprehensive Water Plan, Prepared by Everett Public Works, Everett Water Utility Committee, HDR Engineering, Inc., FCS Group, Inc., and Washington State Department of Health, November 21, 2007.
11. CH2MHILL, 2009, City of Bellingham 2009 Water System Plan, Prepared by CH2MHILL, September 2009.
12. CH2MHILL, 2012, City of Bellingham 2012 Water System Plan Update, Agency-Review Draft, Prepared by CH2MHILL, December 2012.
13. City of Vancouver and Carollo Engineers, 2015, City of Vancouver Comprehensive Water System Plan April 2015, Draft, Prepared by City of Vancouver and Carollo Engineers, June 2015.
14. City of Olympia Public Works and HDR Engineering, Inc., 2015, City of Olympia 2015-2020 Water System Plan, Prepared by City of Olympia Public Works and HDR Engineering, Inc., October 2015.
15. Clark County et al., 2011, Clark County Coordinated Water System Plan Update, Regional Supplement, Draft, Prepared by Clark County, Clark Public Utilities, Clark County and Washington State Departments of Health under the Clark County Water Utility Coordinating Committee, Mary 2011.
16. City of Lacey and Corollo Engineers, 2013, City of Lacey Water System Comprehensive Plan Update, Prepared by City of Lacey and Carollo Engineers, February 2013.
17. 17. City of Bremerton, 2004, City of Bremerton Comprehensive Plan, City Service Appendix, Prepared by City of Bremerton, 2004.

Regional Water Plans

1. Vaccaro, J.J., Hansen, A.J. Jr, and Jones, M.A., 1998, Hydrogeologic Framework of the Puget Sound Aquifer System, Washington and British Columbia, USGS
2. Vaccaro, J.J., 1992, Plan of Study for the Puget-Willamette Lowland Regional Aquifer System Analysis, Western Washington and Western Oregon, USGS

Growth Management Planning Documents

1. http://www.whatcomcounty.us/1170/Comprehensive-Plan-Updates
2. http://www.skagitcounty.net/PlanningAndPermit/Documents/CompPlan/2007%20Comp%20Plan%20All-In-One.pdf
3. http://snohomishcountywa.gov/2139/Comprehensive-Plan
4. http://www.kingcounty.gov/depts/executive/psb/regional-planning/king-county-comprehensive-plan.aspx
5. https://www.co.pierce.wa.us/index.aspx?NID=950
6. http://lewiscountywa.gov/communitydevelopment/comprehensive-plan
7. https://www.clark.wa.gov/community-planning/documents
8. http://www.co.thurston.wa.us/planning/comp_plan/comp_plan_home.htm
9. http://www.co.mason.wa.us/code/comp_plan/
10. http://www.co.jefferson.wa.us/commdevelopment/compplangeneral.htm
11. http://www.clallam.net/LandUse/comprehensiveplan.html
12. http://www.co.pacific.wa.us/pdf%20files/Comprehensive%20Plan.pdf

Stream Gauging

1. http://www.ecy.wa.gov/programs/eap/flow/index.html
2. http://waterdata.usgs.gov/wa/nwis/rt.

Key Groundwater and Surface Water Studies

1. Dion, N.P., T.D. Oleson, and K.L. Payne, 1988, Preliminary Evaluation of the Ground-Water Resources of Bainbridge Island, Kitsap County, Washington, Untied States Geological Survey.
2. Drost, B.W., D.M. Ely, and W.E. Lum II, 1999, Conceptual Model and Numerical Simulation of the Ground-Water-Flow system in the Unconsolidated Sediments of Thurston County, Washington, United States Geological Survey.
3. Fasser, E.T. and R.J. Julich, 2009, Hydrographs Showing Ground-Water Level Changes for Selected Wells in the Lower Skagit River Basin, Washington, United States Geological Survey Data Series 441.
4. Fasser, E.T., K.H. Johnson and M.E. Savoca, 2009, Shallow Groundwater Movement in the Skagit River Delta Area, Skagit County, Washington, United States Geological Survey Scientific Investigations Report 2009-5208, 22 pages.
5. Golder Associates Inc., 2015, Johns Creek and Goldsborough Creek Groundwater Modeling Study, 2015.
6. Hydrogeologic Framework, Groundwater Movement, and Water Budget in Tributary Subbasins and Vicinity, Lower Skagit River Basin, Skagit and Snohomish Counties, Washington Scientific Investigations Report 2009-5270.

7. Johnson, K.H. and J.L. Jones, 2013, Transient Calibration of a Groundwater-Flow Model of Chimacum Creek Basin and Vicinity, Jefferson County, Washington—A Supplement to Scientific Investigations Report 2013-5160, United States Geological Survey.

8. Johnson, K.H. and M.E Savoca, Numerical simulation of the groundwater-flow system in tributary subbasins and vicinity, lower Skagit River basin, Skagit and Snohomish Counties, Washington Scientific Investigations Report 2010-5184, Prepared in cooperation with the Skagit County Public Works Department and the Washington State Department of Ecology and Skagit County Public Utility District No. 1.

9. Johnson, K.H., M.E. Savoa, and B. Clothier, Numerical simulation of the groundwater-flow system in the Chambers-Clover Creek Watershed and Vicinity, Pierce County, Washington Scientific Investigations Report 2011-5086, Prepared in cooperation with the Pierce Conservation District and the Washington State Department of Ecology.

10. Jones, J.L., K.H. Johnson, and L.M. Frans, 2013, Numerical Simulation of the Groundwater-Flow System in Chimacum Creek Basin and Vicinity, Jefferson County, Washington, Washington Scientific Investigations Report 2009-5270, United States Geological Survey.

11. Justin, G.B., R.J. Julich, and K.L. Payne, 2009, Hydrographs showing groundwater level changes for selected wells in the Chambers-Clover Creek watershed and vicinity, Pierce County, Washington, United States Geological Survey Data Series 453.

12. King County Department of Natural Resources and Parks, 2010, Working Draft Lowered Groundwater Levels in King County, Washington: A Preliminary Review of Reports, 2010.

13. Lane, R. C. and W.B Welch, 2010, Estimated freshwater withdrawals in Washington, 2010 Scientific Investigations Report 2015-5037.

14. Lindsay, C.S. and J.S. Koreny, 2003, Lower and Upper Skagit Watershed Plan, Samish River Sub-Basin, Ground Water Hydrology Evaluation, GeoEngineers.

15. McCarthy, K.A., 1996, Surface-water quality assessment of the Clover Creek basin, Pierce County, Washington, 1991-1992 Water-Resources Investigations Report 95-4181, United States Geological Survey.

16. Savoca, M.E., W.B. Welsh, K.H., Johnson, R.C. Lane, and E.T. Fasser, Hydrogeologic Framework, Groundwater Movement, and Water Budget in the Chambers-Clover Creek Watershed and Vicinity, Pierce County, Washington Scientific Investigations Report 2010-5055, Prepared in cooperation with the Pierce Conservation District and the Washington State Department of Ecology.

17. Sceva, Jack E., 1950, Preliminary report on the ground-water resources of southwestern Skagit County, Washington Ground-water Report 1, Prepared in cooperation with State of Washington, Department of Conservation and Development, Division of Hydraulics.

18. Schwartzman, P., 2008, 2008 Dungeness Groundwater Flow Model Design, Construction, Calibration and Results, Pacific Groundwater Group.

19. Turney, G.L., 1981, Quality of Ground Water in the Puget Sound Region, Washington, Untied States Geological Survey, 1981.

20. Welch, W.B., K.H. Johnson, M.E. Savoca, R.C. Lane, E.T. Fasser, A.S. Gendaszek, C. Marshall, B.G. Clothier, and E.N. Knoedler, 2015, Hydrogeologic framework, groundwater movement, and water budget in the Puyallup River Watershed and vicinity, Pierce and King Counties, Washington, United States Geological Survey Scientific Investigations Report 2015–5068, 54 pages, 4 plates, http://dx.doi.org/10.3133/sir20155068.

Key Climate Change Considerations Studies

1. Dalton, Meghan M. Climate change in the Northwest: implications for our landscapes, waters, and communities. Island Press, 2013.
2. Hamman, Joseph J., et al. "Combined Effects of Projected Sea Level Rise, Storm Surge, and Peak River Flows on Water Levels in the Skagit Floodplain." Northwest Science 90.1 (2016): 57-78.
3. Lee, Se-Yeun, Alan F. Hamlet, and Eric E. Grossman. "Impacts of Climate Change on Regulated Streamflow, Hydrologic Extremes, Hydropower Production, and Sediment Discharge in the Skagit River Basin." Northwest Science 90.1 (2016): 23-43.
4. Mauger, Guillaume, Joseph Casola, Harriet Morgan, Ronda Strauch, Brittany Jones, Beth Curry, Tania Busch Isaksen, Lara Whitely Binder, Meade Krosby, and Amy Snover. "State of Knowledge: Climate Change in Puget Sound." (2015).
5. Pitz, C. (2016) Predicted impacts of climate change on groundwater resources of Washington State. Department of Ecology. Publication number: 16-03-006
6. Stumbaugh, M., & Hamlet, A. F. (2016). Effects of Climate Change on Extreme Low-Flows in Small Lowland Tributaries in the Skagit River Basin.Northwest Science, 90(1), 44-56.
7. Vano, J.A., Voisin, N., Cuo, L., Hamlet, A.F., Elsner, M.M., Palmer, R.N., Polebitski, A. and Lettenmaier, D.P., 2010. Climate change impacts on water management in the Puget Sound region, Washington State, USA. Climatic Change, 102(1-2), pp.261-286.