Planning for Demand: How Growth Management, Water Efficiency, and Climate Shape Residential Water Use in the Puget Sound Region

White Paper #2

Human Use of Water in Puget Sound: Managing Residential Water Demand for Resilient Communities and Healthy Ecosystems in a Changing Climate

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ABOUT THIS DOCUMENT

This document is the second in a series of white papers associated with the Puget Sound Partnership project '*Human Use of Water in Puget Sound: Managing Residential Water Demand for Resilient Communities and Healthy Ecosystems in a Changing Climate*.' This document shares findings from our analysis evaluating the impacts of growth management, water use efficiency, and climate change on residential water demand in the Puget Sound Region. The focus of this white paper is on residential water use. Other uses, such as agriculture and power generation, are discussed as needed to provide context, but are not the focus of this document. Data sets produced in this analysis are available via the project webpage on the University of Washington, Climate Impacts Group's website.

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EXECUTIVE SUMMARY

APPROACH

This analysis estimated 2020 (baseline) residential water demand and changes in future (2080) demand across a range of potential future scenarios in the Puget Sound Region, including more compact urban growth (hybrid growth scenario), increased water efficiency, and climate change impacts on precipitation and evapotranspiration. These changes were compared against a do-nothing alternatives ('Business-as-Usual' growth scenario and 'Status Quo' efficiency scenario).

TOTAL RESIDENTIAL DEMAND

Without changes to current water use practices, residential water demand in the Puget Sound Region could nearly double by 2080—reaching 284,000 MGY[1] (780 MGD)—driven primarily by an expected population increase of 4.8 million people (Figure ES1). However, our projections also show that, at the regional scale, modest, but widespread adoption of water efficiency measures (highly efficient scenario) could offset much of the additional demand associated with projected population growth (Figure ES2).

INDOOR RESIDENTIAL DEMAND

Relative to the status quo scenario (38.5 gpcd), meeting the levels of indoor water use in the highly efficient scenario (22.8 gpcd) would result in around 82,000 MGY of water savings in 2080 (Table ES1). In the highly efficient scenario, future indoor demand is roughly equivalent to current indoor demand. Our highly efficient indoor demand scenario assumed that when devices (e.g., washing machines, faucets) hit their end of life, they are replaced with devices equivalent to current leading edge technologies. Given typical device life spans, by 2080 the majority of current devices will have been replaced (many several times over) suggesting that even the highly efficient scenario is relatively conservative. We did not incorporate conservation behaviors (e.g., taking shorter showers) into our estimates, but increases in conservation behaviors could lead to further decreases in indoor water demand.

OUTDOOR RESIDENTIAL DEMAND

Outdoor residential demand is the product of a complex range of factors such as local weather, landscape characteristics, community norms around landscape appearance, and irrigation practices. Practically, this means there are lots of ways to have an impact on

[1] MGY (million gallons per year); 1 MGY = 3.57 ac-ft/yr

outdoor water demand. However, there is also uncertainty around the relative impact of different changes on outdoor water demand. Given this uncertainty, we focused our analysis on understanding the impacts of three key factors—patterns of urban growth, water use efficiency improvements, and climate change—on outdoor residential demand. In our analysis, water use efficiency had the largest impact on future outdoor water demand. Projected water savings under the highly efficient scenario (45-52,000 MGY) would nearly offset potential increases in outdoor residential demand (53-65,000 MGY) (Table ES1). Water savings under the efficient scenario are roughly half of the savings under the highly efficient scenario. The impacts of climate change and urban growth practices are important, but more nuanced and worthy of additional investigation.

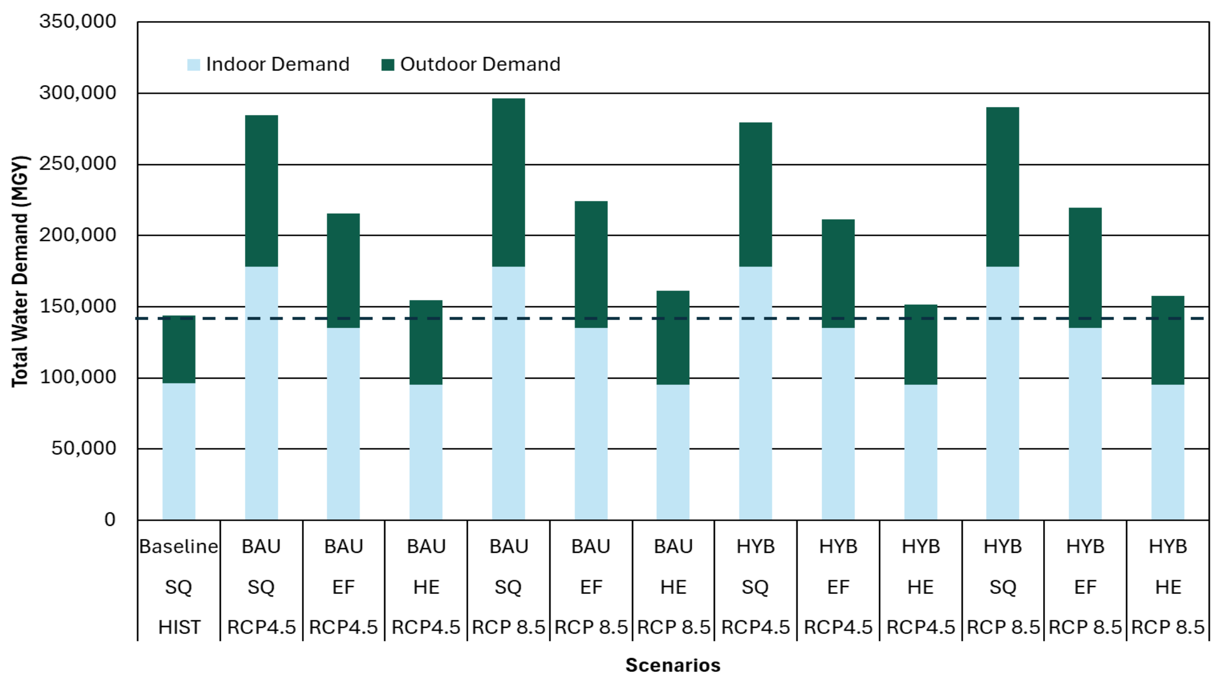

Figure ES1. Total (indoor+outdoor) annual water demand by scenario. Dashed line is modeled 2020 baseline water demand. Scenarios in figure: Growth (Business as Usual (BAU), Hybrid (HYB)); Efficiency (Status Quo (SQ), Efficient (EF), Highly Efficient (HE)); Climate (Moderate (RCP4.5), High (RCP 8.5) emissions).

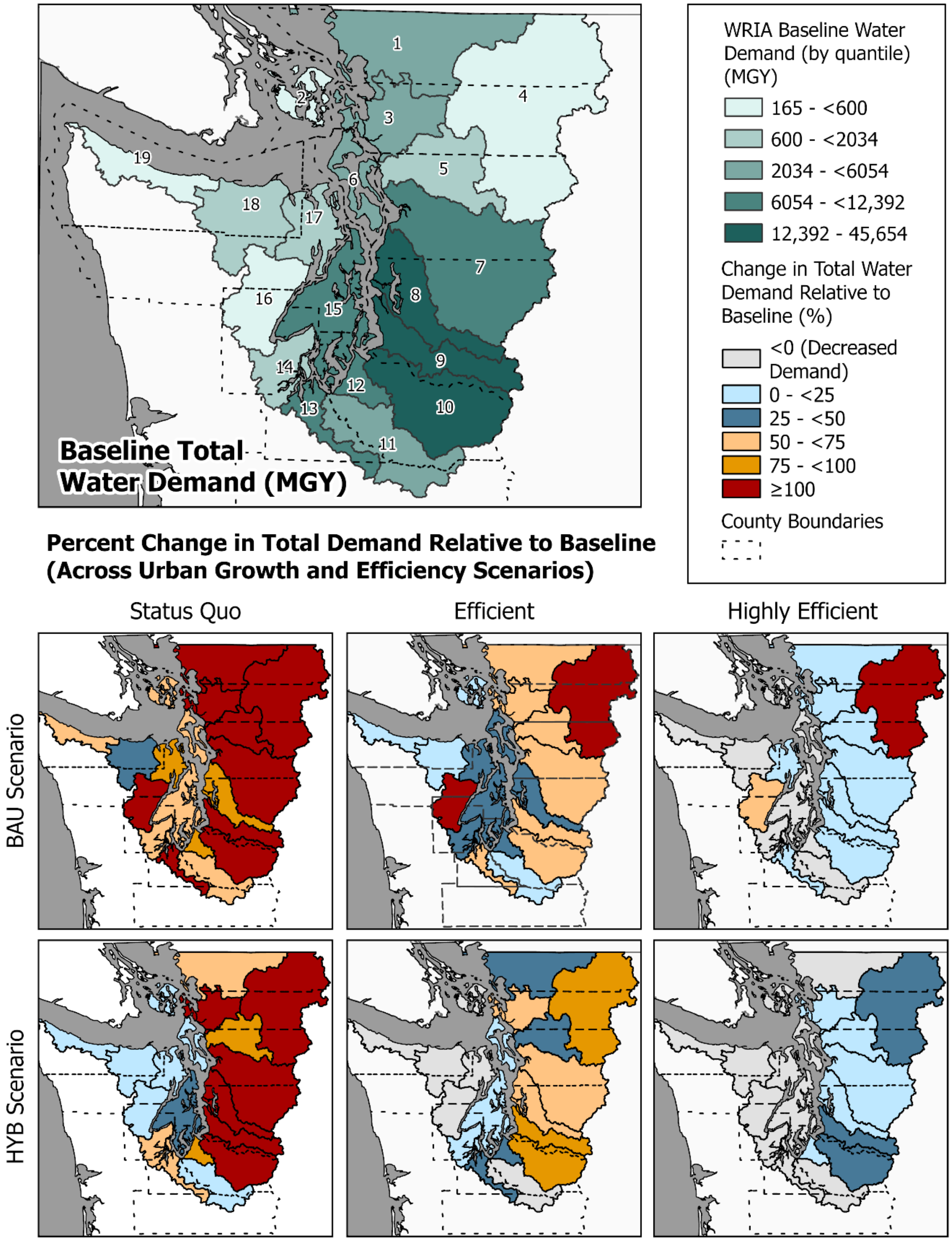

Figure ES.2. Baseline water demand by WRIA and percent change associated with each urban growth (BAU and HYB) and water use efficiency scenario. All future projections use the RCP 4.5 climate scenario.

Table ES1. 2080 Puget Sound Residential Water Demand – At a Glance.

Metric	Value/Range	Notes
Population Growth (2020-2080)	+4.8 million	Forecasted regional population increase
2020 Residential Water Demand	144,000 MGY	MGY = million gallons per year
2080 Residential Water Demand Projections (MGY)		
Status Quo	279,000-284,000	+94-98% above 2020
Efficient	211,000- 215,000	+47-50% above 2020
Highly Efficient	151,000-154,000	+5-7% above 2020
Potential Water Savings (MGY) *(Relative to Status Quo scenario)*		
Indoor Efficiency	~82,000	From fixture/appliance upgrades
Outdoor Efficiency	~45,000-47,000	From landscape/irrigation improvements
Climate-Driven Demand Increase	~11,000	Additional demand under RCP 8.5 vs RCP 4.5

INTRODUCTION

Many water supplies within the Puget Sound region are under increasing stress (Traynham et al. 2011). The region's population is expected to increase from 5.7 M to 10.5 M by 2080 (Puget Sound Partnership 2024). Concomitant with changes in population are more fundamental shifts in the region's hydrology and water supply availability (Vano et al. 2010). Climate change is expected to lead to more intense winter precipitation events and hotter, drier summers (Mauger and Vogel 2020). In the absence of other mitigating measures, water demand in the region could increase significantly. However, there are strategies such as water efficiency and growth management practices that can help reduce per capita demand, avoiding significant increases in regional water demand.

In this analysis, we estimate current and future (2080) residential water demand in the Puget Sound Region using a scenario-based approach. Our primary goals in this analysis were two-fold:

1) Estimate current and future residential water demand in the region; and
2) Understand the relative impacts of growth management practices, water efficiency, and climate change on residential water demand.

Project scenarios were defined based on changes in three key variables—urban growth, water use efficiency, and climate change[2]. Total residential water demand is broken down into two classes—indoor and outdoor. Scenario inputs are described below with additional details in Appendices A and B.

RESIDENTIAL DEMAND MODELING APPROACH

MODELING OVERVIEW

The geographic scope of our analysis mirrors that of the Puget Sound Future Scenarios Project and includes all WRIAs draining into Puget Sound (Figure 1). County level results shared in subsequent sections only include the portion of the county within the Puget Sound Basin.

While the population and land use transition data underlying our demand modeling efforts are the same, indoor and outdoor demand models are independent of each other and described in more detail in subsequent sections. Total water demand estimates in the final section are the sum of indoor and outdoor demand estimates.

[2] Climate change impacts on precipitation and evapotranspiration.

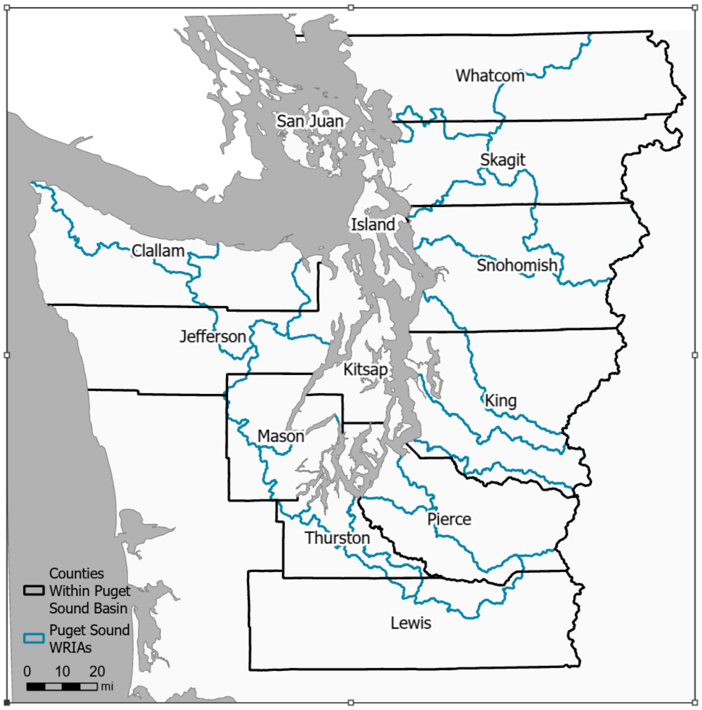

Figure 1. Puget Sound counties and WRIAs included in demand modeling.

SCENARIOS CONSIDERED

Urban Growth

Indoor and outdoor water demand[3] estimates use projected changes in population and patterns of urban growth from Puget Sound Partnership's Future Scenarios project (Puget Sound Partnership 2024). Our estimates of 2020 (baseline) and 2080 (future) demand use population, land use, and zoning data from Future Scenarios' Phase 3 Business as Usual (BAU) and Hybrid (HYB) high-growth scenarios. The total regional population in the 2080 BAU and HYB scenarios is the same (10.5 M), but that population is distributed differently across the landscape in the BAU and HYB scenarios (Figure 2). In the BAU scenario, current development patterns continue and urban growth expands outward. The HYB scenario places additional constraints on where urban growth can occur, prioritizing densification and growth within existing urban growth boundaries and developed areas. Additional details on the modeling approach used by the Future Scenarios project can be found on that project's website.[4]

[3] For the sake of brevity, we may at times refer only to 'water demand', 'indoor demand', 'outdoor demand', etc. Unless noted otherwise in this report these values are referring to 'residential' demand. Residential and domestic demand are considered synonymous on this report.

[4] Puget Sound Future Scenarios Modeling Details https://commonfutures.biz/PugetSound/

In both scenarios, the majority of population growth is concentrated in King, Pierce, and Snohomish counties and the Cedar-Sammamish, Duwamish-Green, Puyallup-White, and Snohomish WRIAs (8, 9, 10, 7) (Figure 2). Many less populous counties and WRIAs are projected to see locally-significant growth (e.g., 50-200% increases), especially under the BAU scenarios. The difference between baseline and future population is generally far greater than the difference in population between the BAU and HYB scenarios in each county or WRIA.

Water Efficiency

Three different water efficiency scenarios were evaluated in the indoor and outdoor demand estimates—status quo, efficient, and highly efficient water use. Specifics on how efficiency was incorporated into indoor and outdoor demand estimates are included in the sections below and Appendices A and B, but generally, the status quo scenario assumes no significant changes from current practices, the efficient scenario assumes partial adoption of best practices, and the highly efficient scenarios assumes full adoption of current leading-edge technologies/best practices.

Climate Change

Future climate-related impacts on indoor water use are difficult to predict and expected to be small relative to impacts on outdoor water use. As such, climate-related impacts were only considered in the outdoor water demand analysis. The outdoor water demand scenarios incorporate estimates of future changes in growing season precipitation and evapotranspiration under moderate and high emissions scenarios (Representative Concentration Pathways (RCP) 4.5 and 8.5).

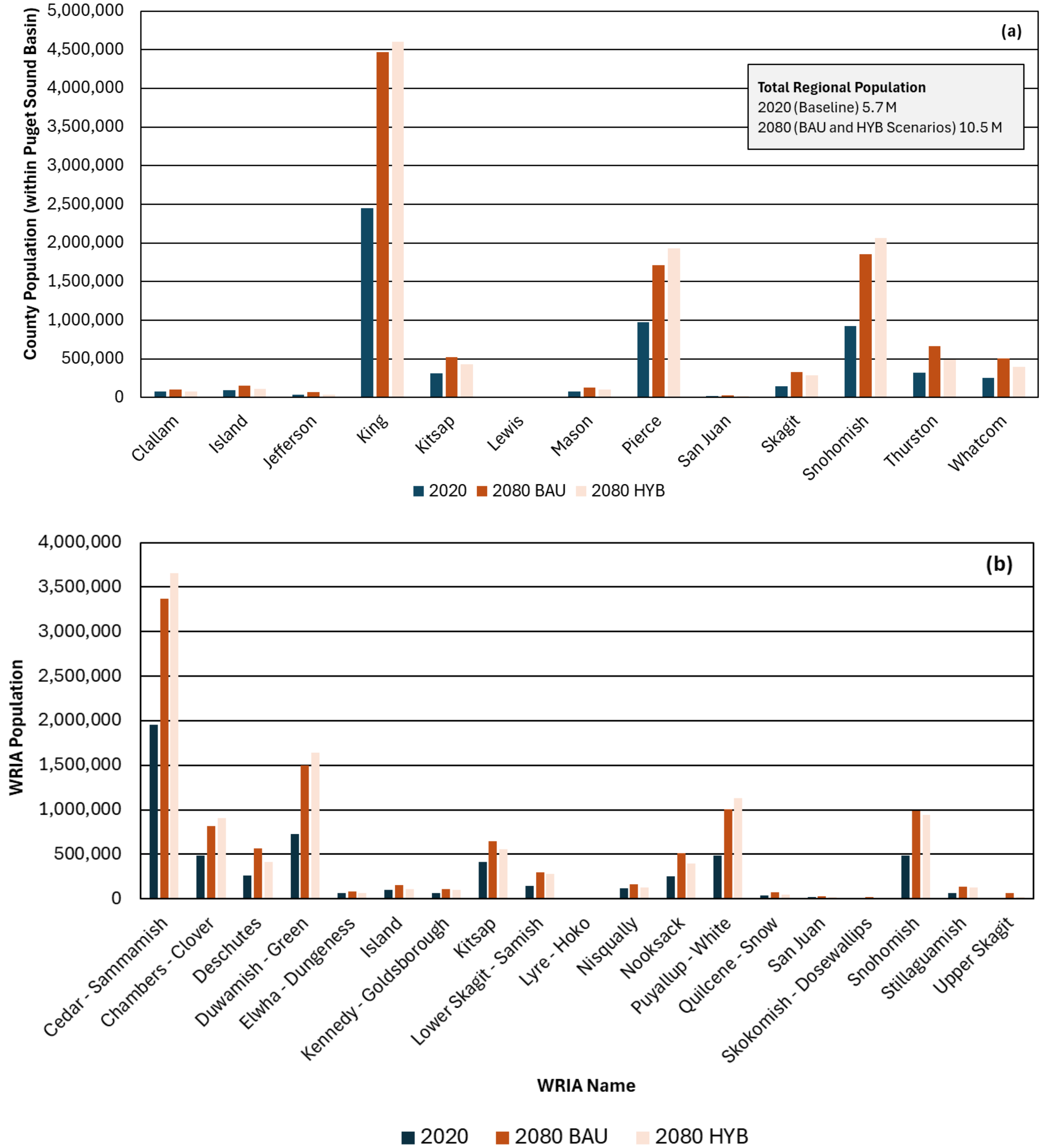

Figure 2. County (a) and WRIA (b) population across the Puget Sound Region in baseline (2020), Business as Usual (BAU) (2080), and Hybrid (HYB) (2080) urban growth scenarios.

INDOOR RESIDENTIAL WATER DEMAND ESTIMATES

OVERVIEW

Our indoor demand estimates are the product of two main variables—per capita water use and population. In this analysis we estimated indoor water demand across three water efficiency scenarios and two urban growth scenarios for a total of six future estimates of indoor water demand plus a 2020 baseline estimate (Table 1). Climate change is not expected to have significant impacts on indoor water use, but may prompt accelerated adoption of water efficient devices in some households. Additional details on methods and data inputs are included in Appendix A.

Table 1. Indoor residential water demand scenarios evaluated.

Water Efficiency	**Urban Growth**		
	Baseline	Business-as-Usual	Hybrid
Status Quo	X	X	X
Efficient		X	X
Highly Efficient		X	X

INDOOR DEMAND APPROACH

Indoor Demand Scenarios

Water Use Efficiency Scenarios

Per capita indoor water use is the product of water use by devices within a household and typical patterns of device use (e.g., toilet flushes, loads of laundry per day) (Figure 3). Our indoor water use efficiency scenarios focus on changes in the devices installed in houses, not conservation behaviors (e.g., taking shorter showers). Given typical device replacement rates, nearly all devices currently in households will have been replaced by 2080 (see Appendix A). The efficiency scenarios we use explore the impacts of different device replacement scenarios.

In the highly efficient scenario, we assumed all households have installed devices equivalent to current leading-edge technologies by 2080 (22.8 gpcd[5]). In the status quo

[5] Gallons per capita per day (gpcd)

scenario, all housing units meet current state standards (38.5 gpcd). The efficient scenario assumes *new households* install (current) leading edge technology' (22.8 gpcd) while all *existing households* meet (current) Washington State Standards (38.5 gpcd). Leaks are an important component of residential water use and were assumed to equal roughly 7.8 gpcd (DeOreo et al. 2016). We did not consider reductions in leaks (7.8 gpcd in this analysis), but water systems are actively working to reduce leaks which could reduce demand further.

Urban Growth Scenarios

'Integrated Decision Unit' (IDU)[6] population estimates from the Future Scenarios Phase 3 modeling were the primary input in the indoor demand urban growth scenarios. Findings from past research indicate that water pricing, housing type and age can impact indoor demand (Polebitski et al. 2011). Housing age is considered indirectly via the structure of our 'efficient' scenario. However, forward-looking data were not sufficient to justify more detailed, regionally varying assumptions around differences in indoor demand across different types and/or ages of housing in this analysis.

Approach

This project's approach to estimating indoor residential water demand is summarized in Figure 3. Device level usage and usage behaviors were used to estimate per capita water use for each of the three water use efficiency scenarios. Per capita use was multiplied by new and existing residential population under each urban growth scenario to estimate indoor residential water use within each IDU. Values were then summed to estimate total indoor residential water demand within each county[7] and WRIA. Sources of data used in these estimates are summarized in Table 2 with additional details in Appendix A.

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[6] Integrated Decision Unit (IDU). Geographic unit of analysis used in Future Scenarios Project's Envision modeling.

[7] County estimates only include totals for the portion of the county within the larger Puget Sound/Salish Sea Basin.

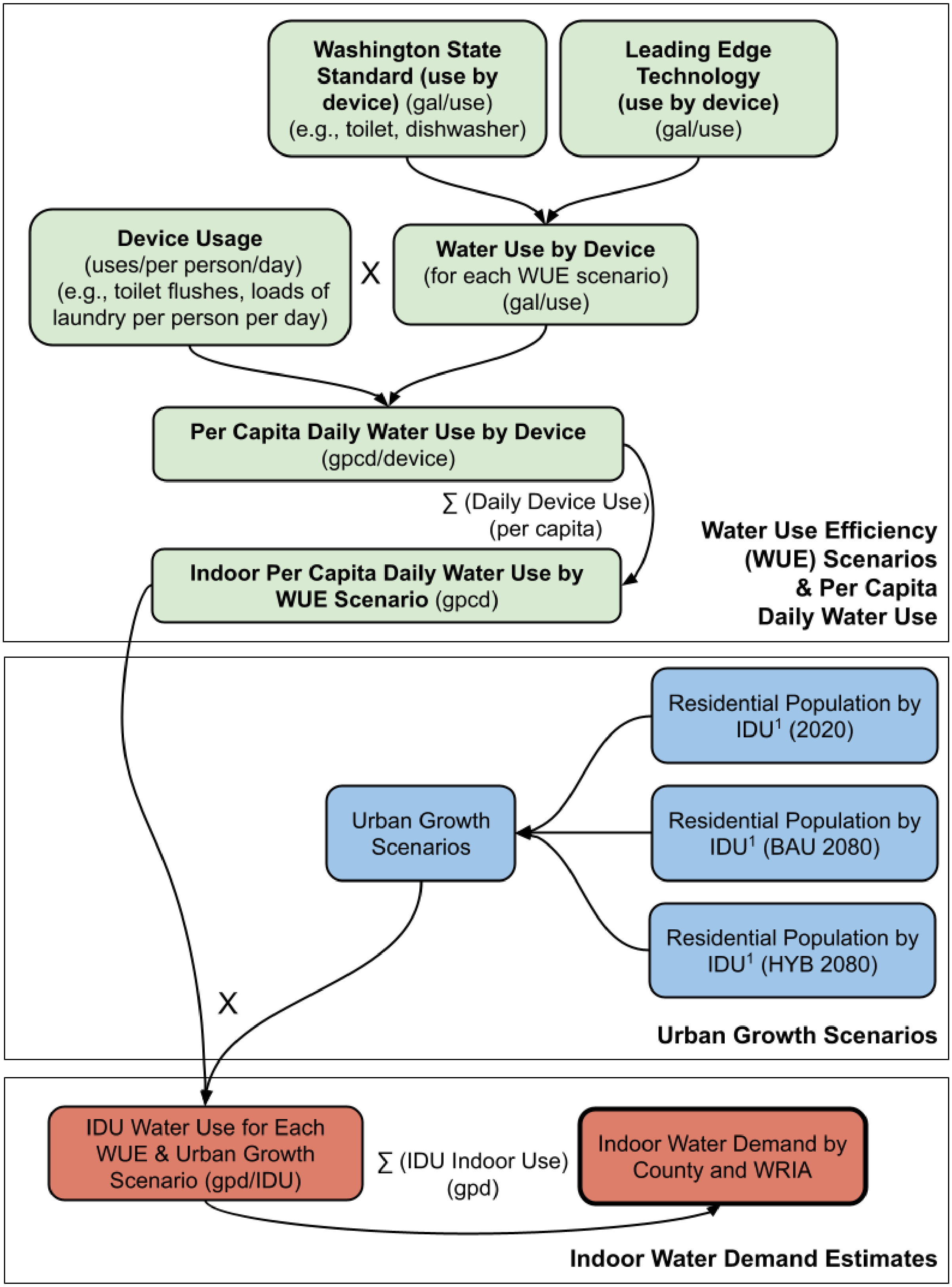

Figure 3. Overview of indoor water demand scenarios and analysis approach.

Table 2. Sources of data used to estimate indoor water demand.

Variable	Data Source	Notes
Water Use by Device	Washington State Standards; USEPA WaterSense Program	Leading edge technologies are the lowest use devices in the current WaterSense database.
Device Usage	Residential End Uses of Water (REUW) (2016)	Device usage data from Tacoma, WA
Population	Future Scenarios Phase 3 Model Outputs	Current and future population from high growth, BAU and HYB scenarios

INDOOR DEMAND RESULTS

Total Indoor Water Demand

Baseline indoor residential water demand in the region was approximately 96,000 MGY[8] (Figure 4). With anticipated population growth and no improvements in water efficiency, indoor demand could increase by approximately 1.85x to 178,000 MGY by 2080. Improvements in water use efficiency have substantial impacts on modeled future demand. In the highly efficient scenario, future indoor demand is comparable to 2020 baseline water demand (Figure 4), despite the regional population increasing from 5.7 to 10.5 M people. Because the regional population is the same in the BAU and HYB urban scenarios, total (regional) indoor demand is the same in both scenarios. Differences arise in how that demand is distributed within the region.

[8] MGY (million gallons per year); 1 MGY = 3.57 ac-ft/yr

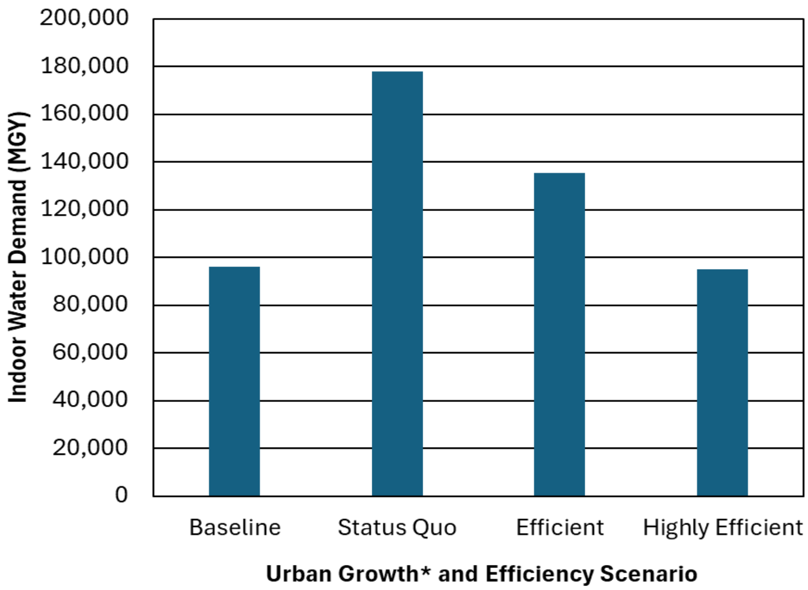

Figure 4. Total regional indoor water demand under urban growth and efficiency scenarios. *Total indoor demand across the region is the same in the BAU and HYB urban growth scenarios. Differences arise in how demand is distributed across the region.

Comparison of Modeled Demand to Observed Data

This section compares our modeled baseline estimates of indoor residential water demand to annual indoor demand derived from two years of observed Flume data and a variety of Seattle Public Utilities (SPU) sources (Table 3). Per capita daily use estimates (gpcd) were multiplied by 2020 population and the number of days in the month to estimate monthly demand. The Flume data include separate gpcd values for each month. SPU estimates include a general estimate of residential use (40 gpcd)[9] and winter household usage statistics (Seattle Public Utilities 2021).

Leaks are an important part of urban water use. The SPU-Saving Water Partnership (SWP) estimate assumes an additional 12% in leaks above the 40 gpcd for a total gpcd of 44.8 gpcd.[6] In this project, we assumed baseline per capita usage was 38.5 gpcd (see Appendix A) plus approximately 7.8 gpcd (DeOreo et al. 2016) of leaks for a total gpcd of 46.3 gpcd. This value is slightly higher than the SPU-SWP values, but this study includes a broader area that includes many systems with more limited efficiency programs/older devices. Average per capita use in the two years of Flume data is 34.6 gpcd. The Flume data would likely include leaks occurring on the customer's side of the meter, but not distribution system leaks.

[9] Personal communication with Saving Water Partnership staff (2025).

Comparing annual totals, our estimates are within three percent (~3000 MGY) of annual totals derived from the SPU-SWP estimates (44.8 gpcd). Differences between our baseline and estimates derived from the Flume and SPU wholesale (Seattle Public Utilities 2021) data are more variable. Using the high/medium/low winter[10] usage levels reported in the SPU wholesale report (Seattle Public Utilities 2021), we estimated bounding ranges of monthly and annual indoor water demand for the region (artificially assuming 100% of customers across the region are using water at a given level) and compared these values to our baseline estimates. Estimated indoor water demand was substantially higher than our modeled baseline at the SPU 'medium usage' level and lower at the SPU 'low usage' level (Table 3) suggesting our estimates fall within the range of SPU's observed usage. In reality, water usage across customers is heterogeneous and 'medium' usage is not necessarily reflective of average usage across the region. Winter water use by SPU retail customers (165 gpd) is significantly less than mean household use at wholesale agencies (233 gpd), highlighting inter-regional variability in indoor water use (Seattle Public Utilities 2021). Future work could dig deeper into local drivers of indoor water use.

Regional demand derived from Flume per capita usage is roughly comparable to use by a 'low use' SPU customer. However, there are important differences in how leaks are included in each of these estimates. For example, usage from Flume would likely capture leaks occurring within the household up to the water meter, but not within the distribution system. These differences plus the location and characteristics of households purchasing Flume devices may be contributing to observed differences in total indoor water demand between our modeled baseline and estimates derived from Flume data (Table 3).

Table 3. Comparison of estimates of total annual indoor demand.

Source	**Indoor Demand (MGY)**
Flume Water Years 2022-23, 2023-24	71,885
SPU-SWP Estimate (40 gpcd + 12% leaks)	93,053
SPU Wholesale 'Medium' Winter Use (6 ccf/mo)*	127,706
SPU Wholesale 'Low' Winter Use (3.5 ccf/mo)	75,530
2020 Project Baseline (38.5 gpcd + 7.8 gpcd leaks)	96,168

*6 ccf/mo (or 600 ft^3) is approximately 4488 gallons/mo. Assuming 2.4 people per household, this is approximately 62 gpcd.

[10] Winter use is commonly used as a proxy for indoor use because of low outdoor use in the winter months.

We also compared our modeled baseline to monthly estimates of water demand to evaluate our decision to use a single annual indoor per capita use value in our analysis. In the two years of observed Flume data, per capita use does appear to increase slightly in the summer months (~37-39 gpcd) (Figure 5). However, there is not enough information on the reasons for these increases to incorporate seasonal differences into our indoor demand estimates. All other estimates in Figure 5 extrapolate monthly usage from annual totals. Future work could conduct a deeper sensitivity analysis looking at indoor water demand response to water use behaviors and seasonal changes in behavior (e.g., shower length and frequency in the summer).

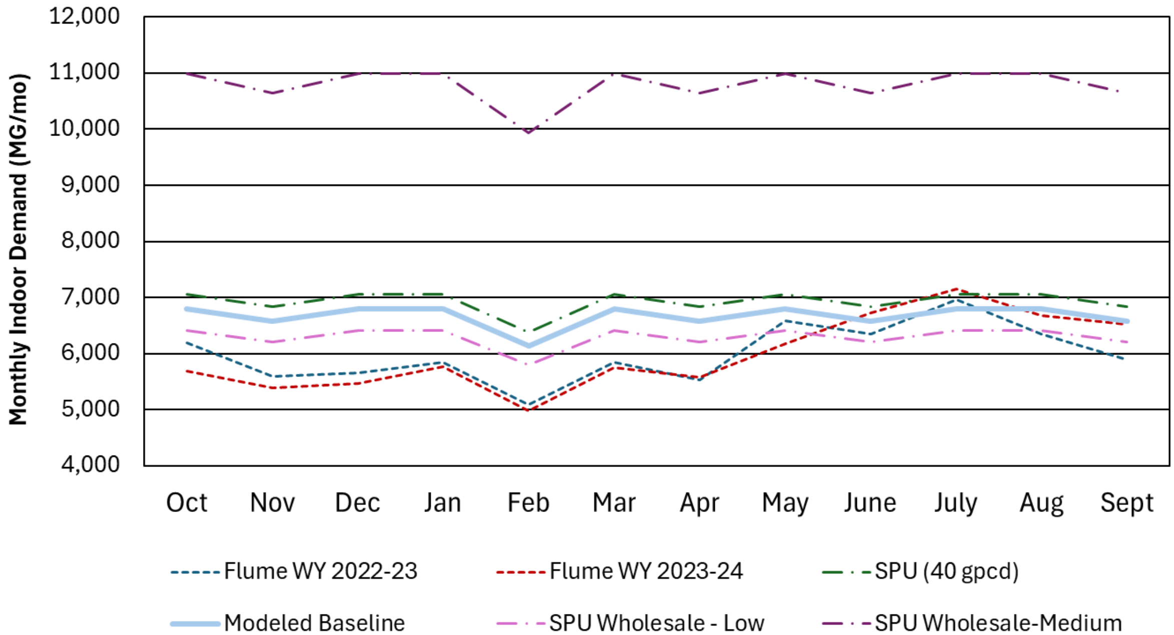

Figure 5. Comparison of 2020 modeled baseline to monthly Flume observations and decomposed annual estimates (e.g., SPU wholesale).

Geographic Variation in Indoor Water Demand

If current indoor water use practices remain constant (status quo scenario), indoor residential water demand in the Puget Sound Region could increase from 263 MGD in 2020 to 487 MGD in 2080, an increase of approximately 85% (Tables 4 and 5). Where this water demand occurs depends on where people live within the basin. While total indoor water demand is the same in the BAU and HYB scenarios, water demand increases more in denser, urban counties (e.g., King, Pierce, Snohomish) in the HYB scenario while less urban counties see their most substantial increases in the BAU scenario (Table 4). The combination of King, Pierce, and Snohomish counties account for 76-81% of regional indoor water use in the BAU and HYB scenarios. Trends at the WRIA level are similar, with water use increasing the most in the most populous WRIAs (Table 5).

While small as a share of total regional water demand, increases in residential use in less populous areas can have significant local impacts—especially where current demand is low or supplies are constrained. For example, under the BAU scenario, indoor demand is projected to double in counties such as Whatcom and Thurston. The impacts of growth management policies—are most pronounced at the WRIA scale, where differences between the BAU and HYB scenarios are most pronounced in smaller watersheds (e.g., San Juan, Upper Skagit, Quilcene-Snow) (Table 5).

Table 4. Indoor residential water demand by county under baseline (2020), BAU and HYB (2080) scenarios and status quo water use efficiency.

County	2020 Indoor Water Demand (MGD)	2080 Indoor Water Demand (MGD)	
		BAU	HYB
Clallam*	3.5	4.6	3.6
Island	4.4	7.2	5.0
Jefferson*	1.7	3.1	1.8
King	113.6	206.8	212.9
Kitsap	14.4	24.0	19.8
Lewis*	0.0	0.0	0.0
Mason*	3.4	6.0	4.8
Pierce*	45.2	79.4	89.2
San Juan	0.8	1.2	0.8
Skagit	6.8	15.2	13.2
Snohomish	43.0	85.8	95.6
Thurston*	15.0	30.8	22.4
Whatcom	11.7	23.4	18.3
TOTAL	**263.4**	**487.5**	**487.5**

* Totals only include the portion of the county within the Puget Sound Basin.

Table 5. Indoor residential water demand by WRIA under baseline (2020), BAU and HYB (2080) scenarios and status quo water use efficiency.

WRIA Number	WRIA Name	2020 Indoor Water Demand (MGD)	2080 Indoor Water Demand (MGD)	
			BAU	HYB
1	Nooksack	11.6	23.5	18.2
2	San Juan	0.8	1.2	0.8
3	Lower Skagit - Samish	6.7	13.6	13.0
4	Upper Skagit	0.3	2.9	0.7
5	Stillaguamish	3.0	6.4	5.7
6	Island	4.4	7.2	5.0
7	Snohomish	22.4	45.7	43.8
8	Cedar - Sammamish	90.4	155.9	169.4
9	Duwamish - Green	33.6	69.5	75.9
10	Puyallup - White	22.6	46.4	52.1
11	Nisqually	5.3	7.6	5.8
12	Chambers - Clover	22.6	37.8	42.0
13	Deschutes	12.0	26.0	19.3
14	Kennedy - Goldsborough	3.1	5.1	4.5
15	Kitsap	19.3	30.1	25.7
16	Skokomish - Dosewallips	0.3	0.9	0.3
17	Quilcene - Snow	1.9	3.2	2.0
18	Elwha - Dungeness	2.8	3.9	2.9
19	Lyre - Hoko	0.4	0.6	0.4
TOTAL		**263.4**	**487.5**	**487.5**

Impact of Scenarios on Indoor Residential Water Demand

Urban Growth

Comparing indoor demand between the baseline and 2080 status quo scenarios allows for the development of some basic estimates of the amount of demand increase attributable to population growth under the BAU and HYB scenarios. The blue bars in Figure 6 show the change in indoor demand associated with population growth. Increases in demand track with regional population gains and distribution (BAU and HYB scenarios). In general, water demand increases more in less populous WRIAs in the BAU scenario. The inverse (greater increases in more populous WRIAs) is true in the HYB scenario.

Water Use Efficiency

Water use efficiency improvements can help offset increases in demand associated with population growth. To look at potential savings associated with water use efficiency improvements, we compare the increase in indoor water demand in the 2080 status quo scenario (no efficiency gains) (Figure 6, solid orange and navy bars) to indoor water savings in the 2080 efficient and highly efficient scenarios (Figure 6, peach and light blue stacked bars).

Under the high efficiency scenario, potential indoor water savings via efficiency exceed population-related increases in indoor water demand in 52 percent of WRIAs in the BAU scenario and 63 percent of WRIAs in the HYB scenario (Figure 6). In the efficient scenario, efficiency gains exceed increased indoor demand in seven WRIAs (under the HYB scenario). In many of the less populous WRIAs, 2080 water demand under the HYB scenario was noticeably less than the BAU scenario due to lower levels of development in these watersheds in the HYB scenario. Likewise, in some WRIAs water savings from efficiency significantly exceed the increase in demand due to population growth. This is because efficiency gains are realized across all households—existing and new—in a WRIA.

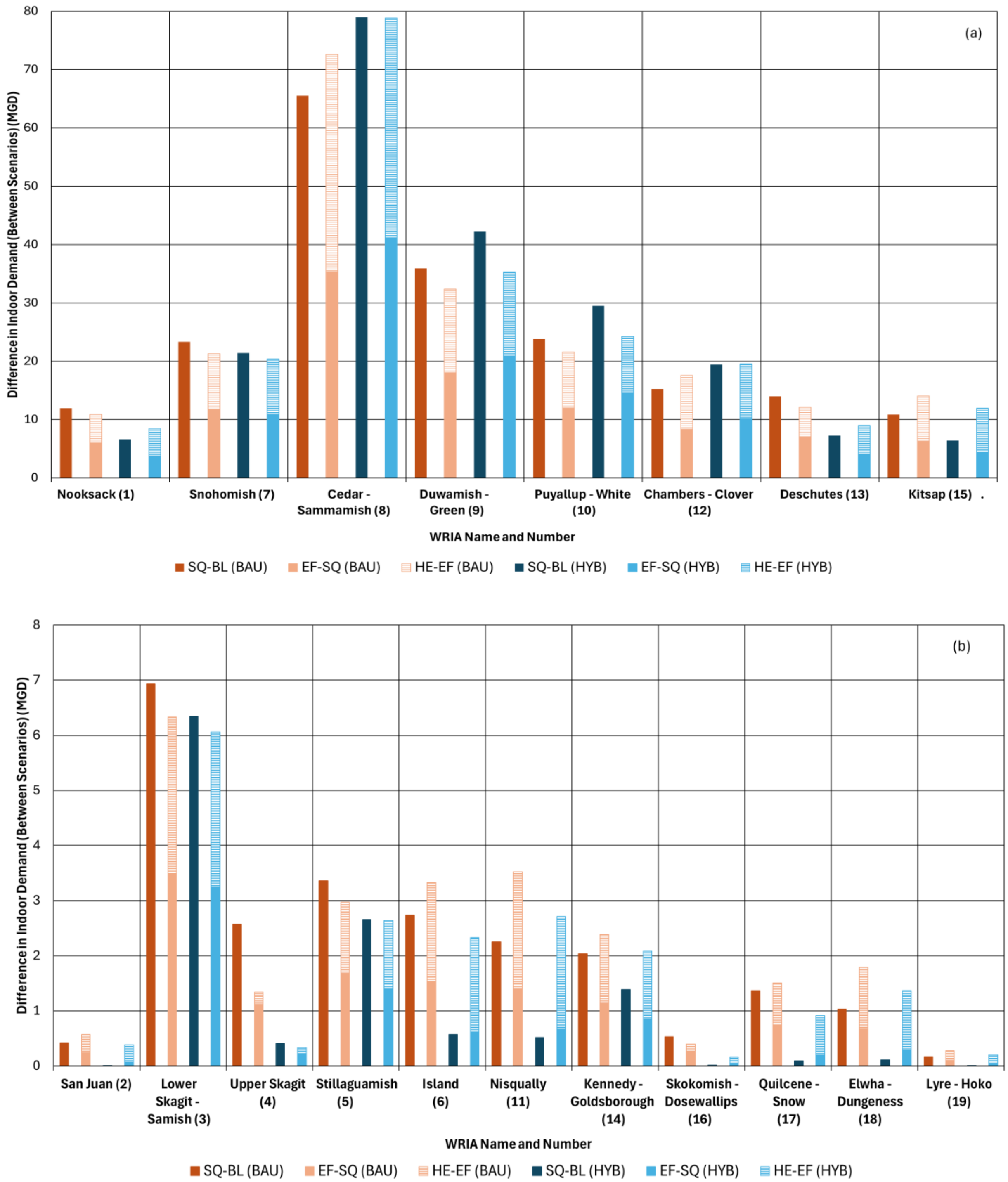

Figure 6. For WRIAs with more than 250,000 people (a) or less than 250,000 people (b) in 2020, increase in indoor water demand between 2020 baseline and 2080 status quo scenario (SQ-BL) compared to potential water savings in 2080 efficient (EF) and highly efficient (HE) scenarios (EF-SQ + HE-EF). Note: The maximum value on the y-axis in (a) is 80 MGD compared to 8 MGD in (b).

OUTDOOR RESIDENTIAL WATER DEMAND ESTIMATES

OVERVIEW

Current and future outdoor residential demand was modeled across a range of plausible scenarios using an evapotranspiration (ET) based water budget approach (United States Environmental Protection Agency 2014). In the Puget Sound Region, outdoor water use typically occurs between April-October, with most outdoor demand occurring in the dry summer months. Climate change is expected to make summers in the region hotter and drier.

In this analysis, we estimated outdoor water demand across three water efficiency, two urban growth, and two climate change scenarios for a total of twelve estimates of future outdoor water demand plus a 2020 baseline estimate (Table 6). Additional details on methods and data inputs are included in Appendix B.

Table 6. Outdoor water demand scenarios evaluated.

		Urban Growth		
		Baseline	*Business as Usual*	*Hybrid*
Water Use Efficiency	*Status Quo*	X	X	X
	Efficient		X	X
	Highly Efficient		X	X
Climate	*RCP 4.5*		X	X
	RCP 8.5		X	X

OUTDOOR RESIDENTIAL DEMAND APPROACH

Landscape water requirement (LWR) is an estimate of the amount of water needed to maintain a healthy landscape and is a function of the irrigated landscape area, evapotranspiration and precipitation (ET_{net}), water requirements of the selected landscape vegetation (K_c), and irrigation efficiency (e). Each portion of the outdoor demand analysis calculates an input variable in the LWR equation (below). LWR was estimated for the landscaped area within each IDU then summed to obtain total outdoor demand within a WRIA or county. Additional details are available in Appendix B.

$$Landscape\ Water\ Requirement\ (LWR) = \frac{Irrigated\ Area\ (A) * ET_{net} * Plant\ Factor(K_c)}{Irrigation\ System\ Efficiency(e)}$$

Outdoor Demand Scenarios

Outdoor demand scenarios incorporated changes in three areas – urban growth, water use efficiency, and climate change. Additional details on data and methods are included in Appendix B.

Urban Growth

Patterns of residential landscaping vary across different types of residential development. For example, suburban lots often have large lawns while urban multi-family developments commonly have a small, shared, highly managed landscape area. These differences can have important impacts on outdoor water demand. The degree to which patterns of urban growth impact outdoor demand will vary depending on the area of a landscape that is irrigated and the area of previously non-irrigated land converted into irrigated residential uses. We estimated typical irrigated landscape area for different types of residential development then used changes in population and transitions in zoning and land use to estimate changes in irrigated area associated with residential development under each urban growth scenario.

Water Use Efficiency

Changes in outdoor water use efficiency were included through changes in landscape composition (e.g., transitioning from higher water use turf to lower water use landscapes) and irrigation efficiency.

Climate Change

Climate change impacts on outdoor demand were considered via projected changes in precipitation and evapotranspiration under medium and high emissions scenarios (RCP 4.5 and 8.5).

Approach

Outdoor residential demand estimates are the product of four sub-analyses incorporating each of the three classes of scenarios considered (Figure 7). Outputs from each sub-analysis were used as inputs in the LWR equation (above). Specifics on the methods are included in Appendix B. Key data inputs in the outdoor demand analysis are listed in Table 7 with additional details in Appendix B.

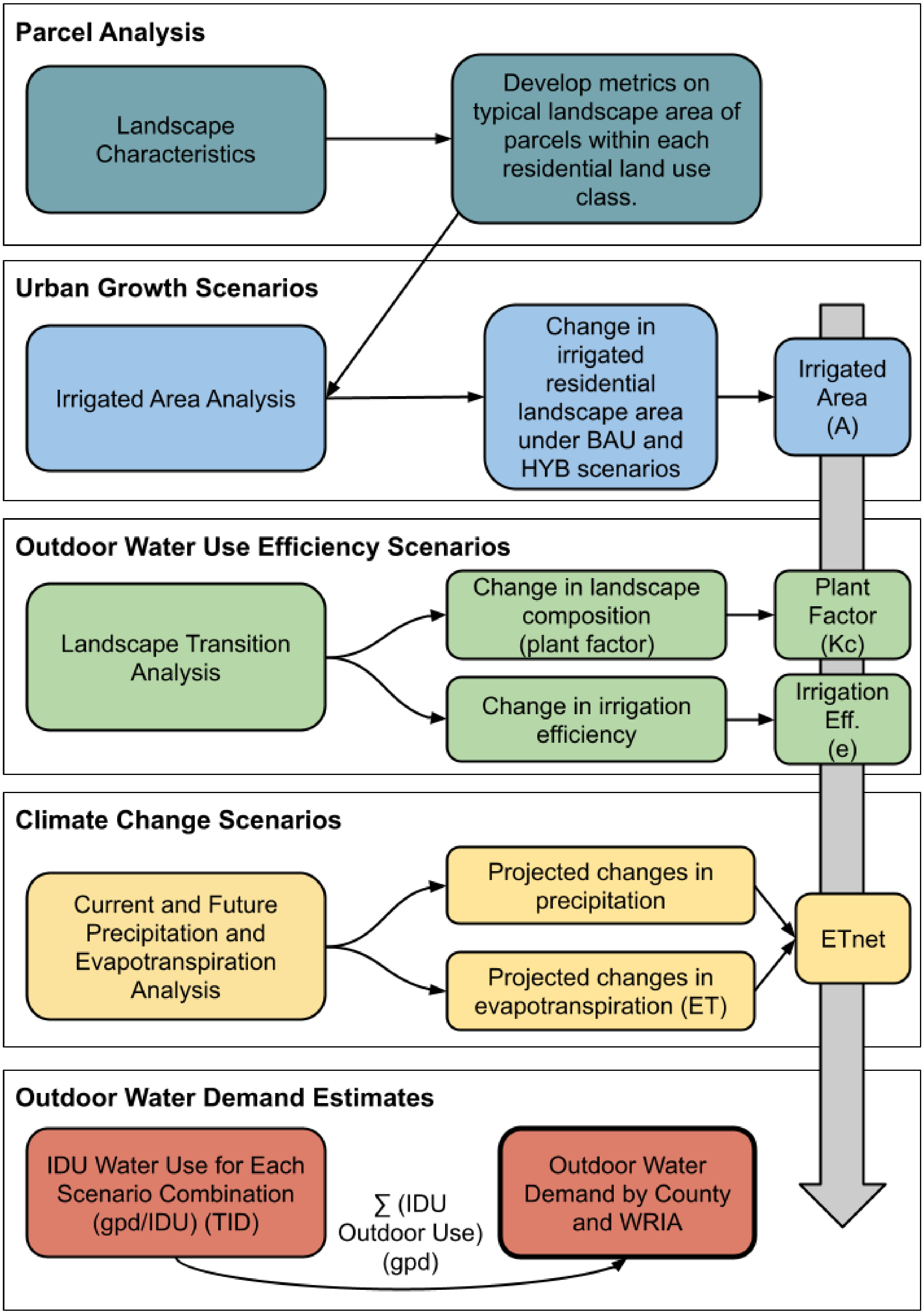

Figure 7. Outdoor water demand analysis approach.

Table 7. Sources of data used to estimate outdoor water use.

Variable	Data Source	Notes
Current and future land use by IDU	Future Scenarios Phase 3 Model Outputs	Derived from NOAA CCAP 2016 data
Current and future zoning by IDU	Future Scenarios Phase 3 Model Outputs	Compiled from city/county data; Developed aggregate classes
Impervious cover	1m NOAA CCAP (2020)	
Parcel boundaries	WA Department of Commerce	
Plant factors (Kc)	See Appendix B	0.5, 0.6, 0.7
Irrigation efficiency (e)	See Appendix B	0.7, 0.8, 0.9
Total Precipitation by season	Climate toolbox (MACAv2-METDATA)	Multi-model mean derived from 20 downscaled CMIP5 models
Total potential evapotranspiration by season	Climate toolbox (MACAv2-METDATA)	Multi-model mean derived from 20 downscaled CMIP5 models

OUTDOOR WATER DEMAND RESULTS

Total Outdoor Water Use by Season

In all scenarios, outdoor residential water demand increases relative to the 2020 baseline (Figure 8). However, the magnitude of this increase in the 2080 scenarios varies substantially depending on impacts from climate change, water use efficiency, and growth management practices. Across all growth and climate scenarios, outdoor demand more than doubles under the Status Quo scenario. However, outdoor efficiency measures can significantly reduce this increase. Under the high efficiency scenarios, outdoor demand rises by only 7-15 percent—even with substantial population growth. The scale and distribution of outdoor demand changes vary considerably across the region's diverse geographies, and discussed in greater detail in subsequent sections.

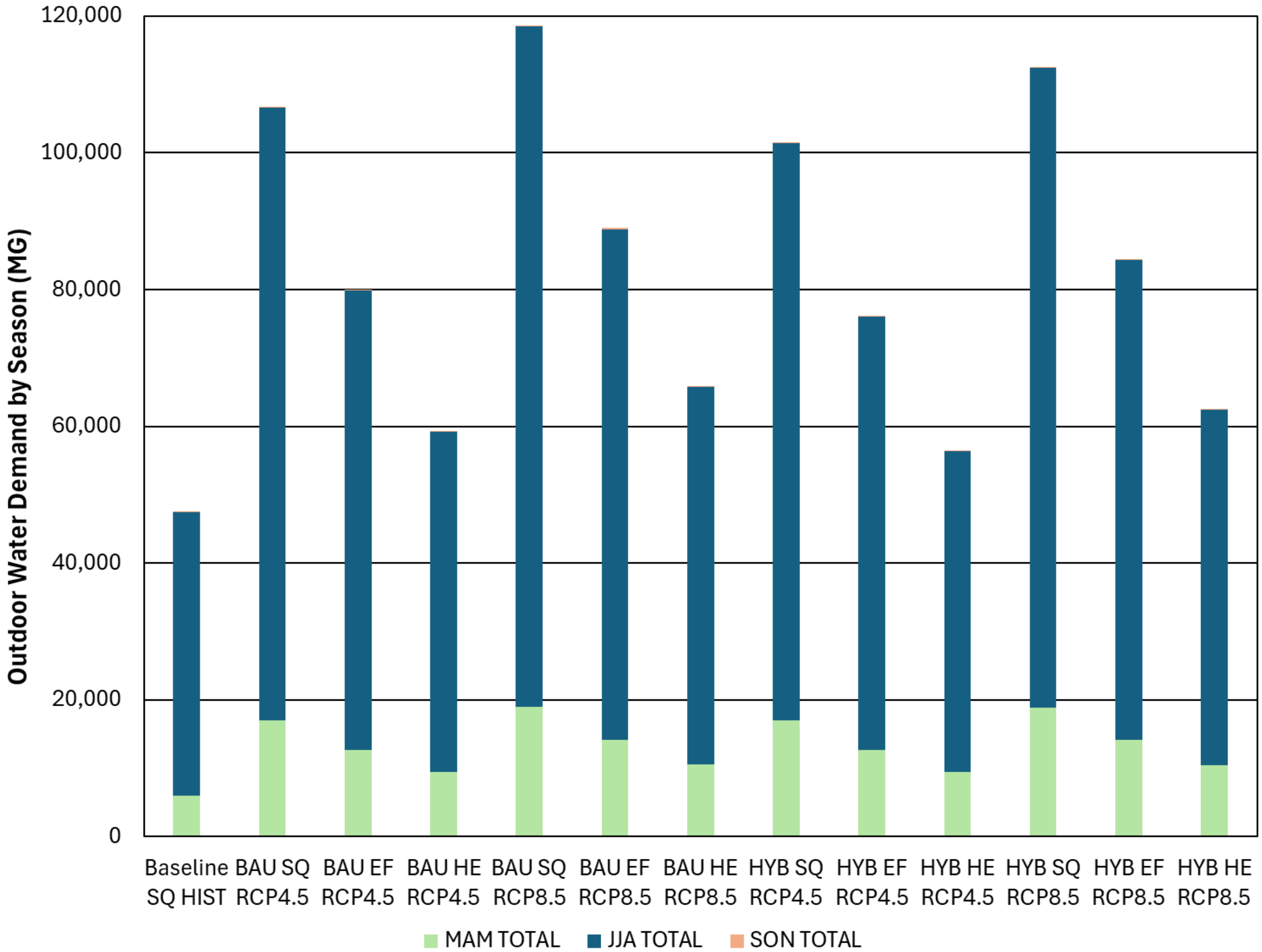

Figure 8. Total outdoor water demand by season for each scenario evaluated. X-axis labels indicate the growth scenario (Baseline, BAU, HYB), water use efficiency scenario (status quo (SQ), efficient (EF), or highly efficient (HE)), and climate scenario (RCP 4.5 or RCP 8.5). Demand by season is denoted in bar colors with minimal to no modeled demand in fall and winter. SON (Sept-Oct-Nov); DJF (Dec-Jan-Feb); MAM (Mar-Apr-May); JJA (Jun-Jul-Aug).

Comparison of Modeled Demand to Observed Data

In this portion of the analysis we compared our modeled baseline outdoor demand to recent observed outdoor use data from Flume monitoring devices (Figure 9). Monthly Flume data on gallons of outdoor use per household per month (October 2022-Sept 2024) was multiplied by the number of households in the 2020 baseline year (2.27 M households) and summed within each season to facilitate comparison to our regional seasonal modeled data.

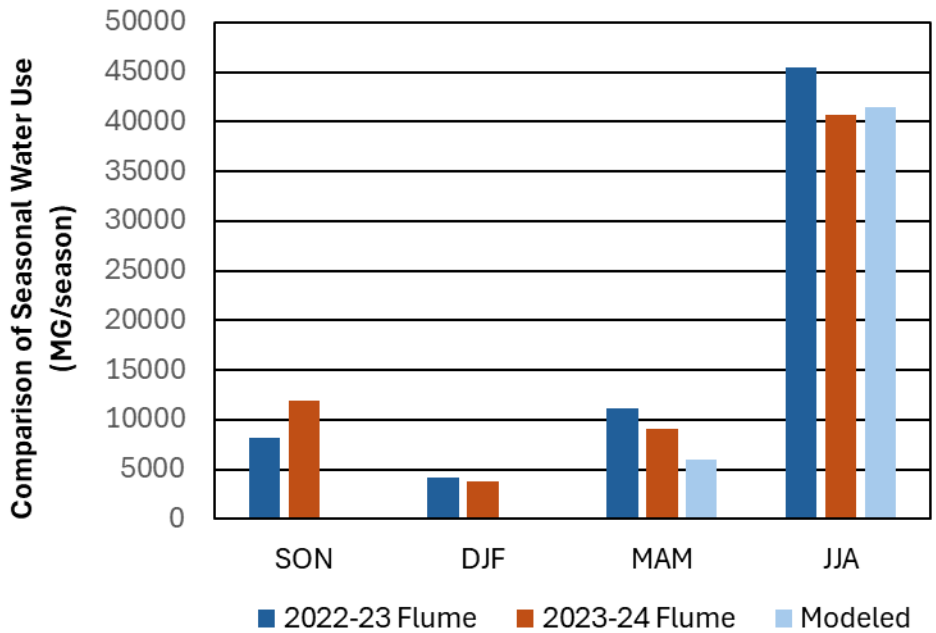

Figure 9. Comparison of Flume-based outdoor use estimates to modeled data. (SON (Sept-Oct-Nov); DJF (Dec-Jan-Feb); MAM (Mar-Apr-May); JJA (Jun-Jul-Aug)) Note: SON 2022-23 Flume estimates only include data from October and November.

Modeled June-July-August (JJA) outdoor water use was within two percent of the Flume estimates in 2024 and within nine percent in 2023. Precipitation in the summer of 2023 was approximately 50 percent of normal and preceded by an abnormally dry May (Figure 10) (NOAA Northwest River Forecast Center 2025). Precipitation in the summer of 2024 was above normal in May, Jun, and Aug. These differences are also reflected in the Flume outdoor use data with higher outdoor use in the drier 2023 summer (Figure 10). These observations also provide insights into how household’s outdoor water use may shift in response to changing summer weather.

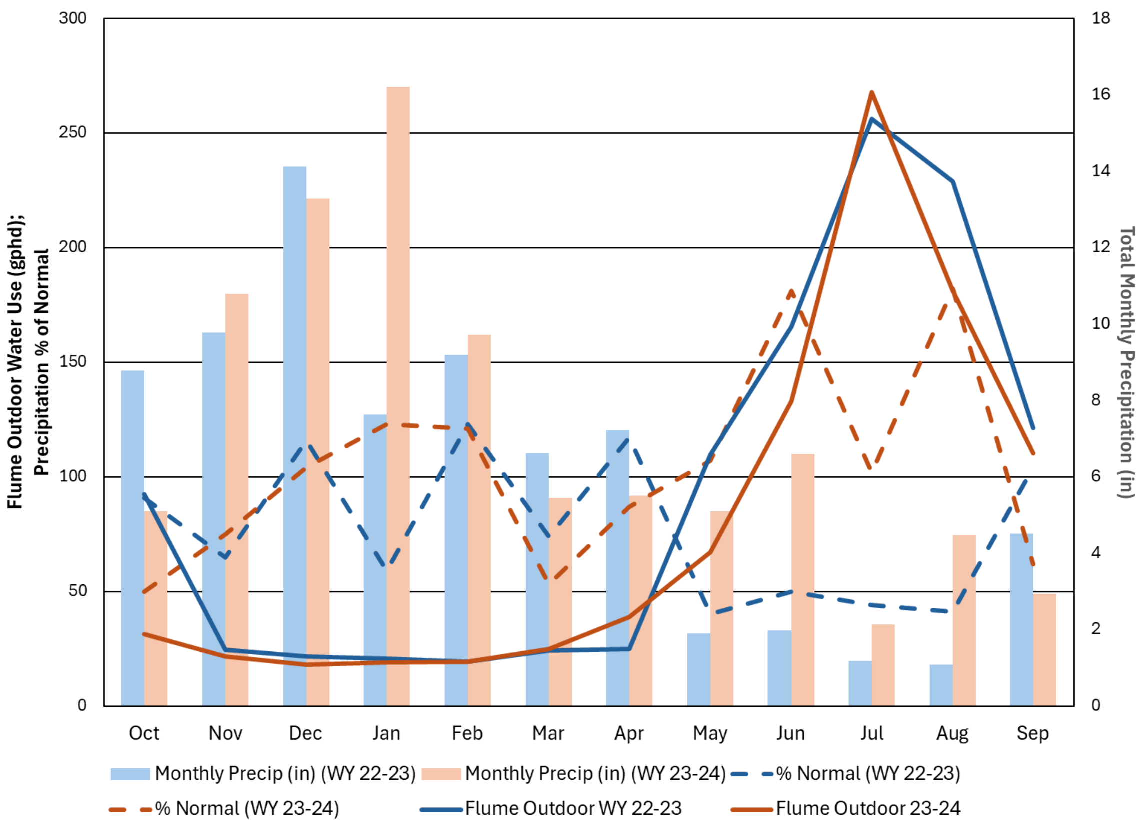

Figure 10. Monthly precipitation, percent of normal precipitation, and Flume outdoor water use data (gal/hh/mo) for 2022-23 and 2023-24 water years. Precipitation and precipitation normals data from NOAA Northwest River Forecast Center (mean across Northwest Washington River Basins; 1991-2020 averages). Flume data from Flume data dashboard (Flume Utility and Business Solutions 2024).

Modeled outdoor water demand in the other seasons is substantially different than estimates from the Flume data. The mean of models precipitation and evapotranspiration data used in this analysis were available as seasonal totals (i.e., DJF, MAM, JJA, SON[11]) (Hegewisch and Abatzoglou 2024). This level of aggregation has important implications for our estimates of spring and fall outdoor water demand. Specifically, in our calculation of net evapotranspiration in the fall (SON), heavy late fall precipitation cancels out the ET deficit typically present in September resulting in a likely underestimate of fall outdoor water demand (relative to observed outdoor use trends). This behavior is also present in the spring months, but to a lesser degree. Additional details are available in Appendix B. A

[11] Season Abbreviations: MAM – March, April, May; JJA – June, July, Aug; SON – Sept, Oct, Nov; DJF – Dec, Jan, Feb.

forthcoming journal article on this work will unpack these differences using an additional monthly dataset. However, for the purposes of this white paper, we mostly focus on JJA totals in our assessment of the impact of growth, efficiency, and climate scenarios outdoor water demand. While there is some year-to-year variability, roughly 60% of outdoor water use in the region occurs during the summer months (JJA).

Geographic Variation in Outdoor Demand

2080 outdoor demand estimates vary widely across each of the counties[12] in the Puget Sound Region, loosely scaling with population in each county (Figure 11) and clustering around the county size classes used in the landscape area analysis (i.e., King County, large, medium, and small counties) (Appendix B). The plots below show the spread in modeled outdoor demand within each county (Figure 11) and WRIA (Figure 12).

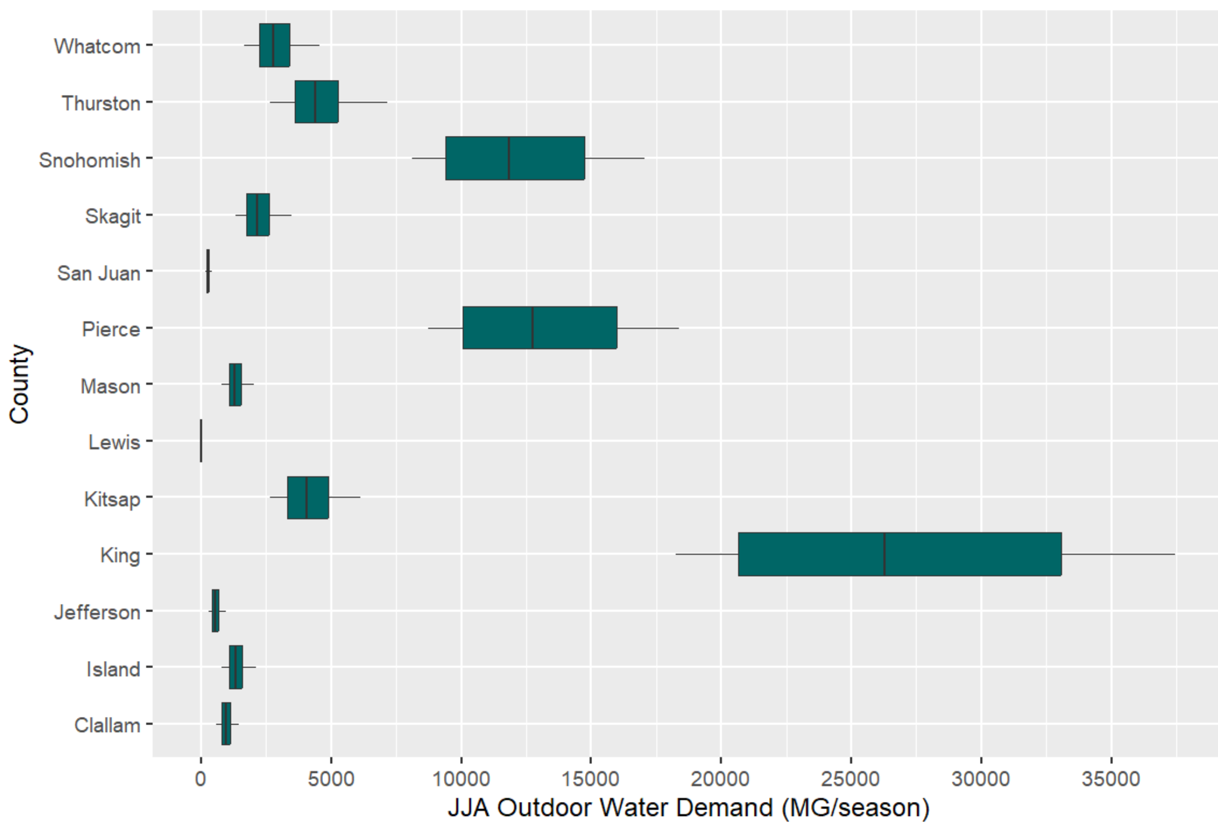

Figure 11. Range in 2080 outdoor water demand estimates across all scenarios evaluated for the portion of each county flowing into Puget Sound.

[12] Outdoor water demand totals for each county only include the portion of the county within the Puget Sound Basin. Portions of Clallam, Jefferson, Mason, Lewis, Thurston, and Pierce counties drain to watersheds outside of the Puget Sound Basin (see Figure 1).

Trends at the WRIA scale (Figure 12) are similar, with greater demand in the most populous WRIAs. However, it is also important to recognize the spread across scenarios within each WRIA. These differences point to the importance of different management strategies in limiting potential population-related increases in outdoor demand.

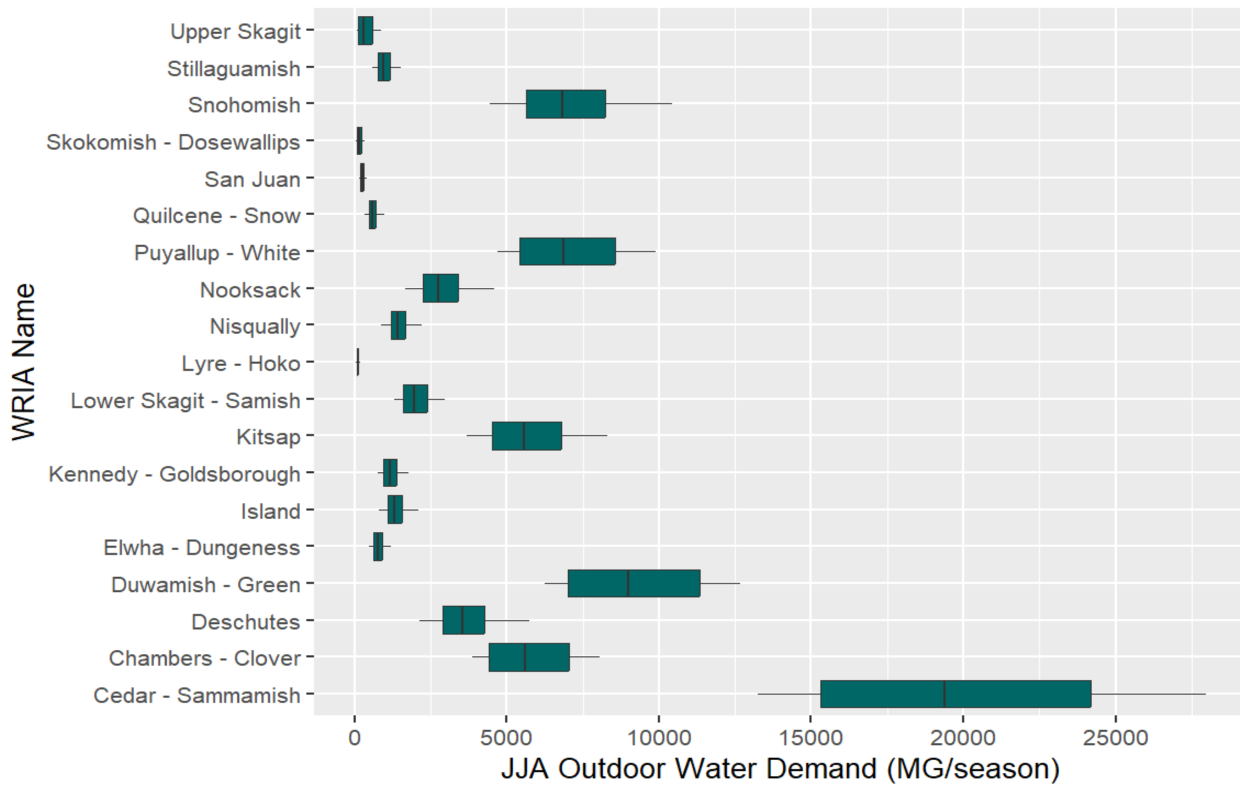

Figure 12. Range in 2080 outdoor water demand estimates across all scenarios for each Puget Sound WRIA.

Regional Impacts of Scenarios on JJA Outdoor Water Demand

A total of twelve outdoor water demand scenarios were evaluated and compared to 2020 baseline values. Relative differences in total JJA outdoor demand across the entire region are compared in Figure 13.

Population and Growth Management

The first two (blue) bars (Figure 13) show the difference in outdoor water demand (BAU and HYB scenarios)[13] relative to the 2020 baseline. In both scenarios, JJA outdoor residential demand increased by more than 40,000 MG/JJA with the BAU scenario increasing by approximately 6000 MG/JJA more than the HYB scenario. These findings suggest that

[13] Under the SQ, RCP 4.5 scenario separate out impacts from water use efficiency gains and limit the influence of climate change impacts.

potential changes in demand associated with increased population could overshadow water savings associated with more compact growth (HYB scenario), though there are locally significant differences between the BAU and HYB scenarios.

Climate Change (RCP 8.5 and RCP 4.5 Scenarios)

The next two (yellow) bars in Figure 13 show the difference in outdoor demand between the RCP 8.5 and RCP 4.5 (high and moderate emissions) scenarios (same status quo efficiency scenario). In that comparison, summer outdoor demand was approximately 9000 MGD greater in the RCP 8.5 scenario with negligible differences between the BAU and HYB scenarios. This estimate only compares differences between the RCP 8.5 and RCP 4.5 scenarios in the summer months. Climate-related changes in outdoor demand associated with differences between historical climate and the RCP 4.5 scenario are embedded in the population and growth management estimates (blue bars). A forthcoming journal article will include additional scenarios that allow deeper investigation into the RCP 4.5 scenario's impact on outdoor demand (versus historical norms). Preliminary results in the next section (parcel-level water demand) incorporated these considerations and suggest that the increase in water demand from current conditions to RCP 4.5 may be greater than the increase from RCP 4.5 to RCP 8.5.

Water Use Efficiency Scenarios

The next four (green) bars in Figure 13 compare differences in summer outdoor demand relative to the 2080 status quo efficiency scenario. The first two bars compare the 'efficient' scenario and the second two (hatched) bars compare the 'highly efficient' scenario. In both cases, differences between the BAU and HYB scenarios are negligible, but there are substantial differences between the water efficiency scenarios. The efficient scenario would save approximately 21,000 MGD per season relative to the status quo while the highly efficient scenario would save an additional 16,000 MGD for a total savings of approximately 38,000 MGD per season. The savings under the highly efficient scenario would offset roughly 70 percent of the anticipated increase in summer outdoor demand while the efficient scenario would offset approximately 40 percent of the anticipated increase. In the modeled scenarios, improvements in outdoor water use efficiency are realized through increased irrigation efficiency and changes in landscape composition (e.g., increased adoption of lower water use plants). A forthcoming journal article will include additional sensitivity testing on the relative significance of different outdoor water use efficiency measures at the regional scale.

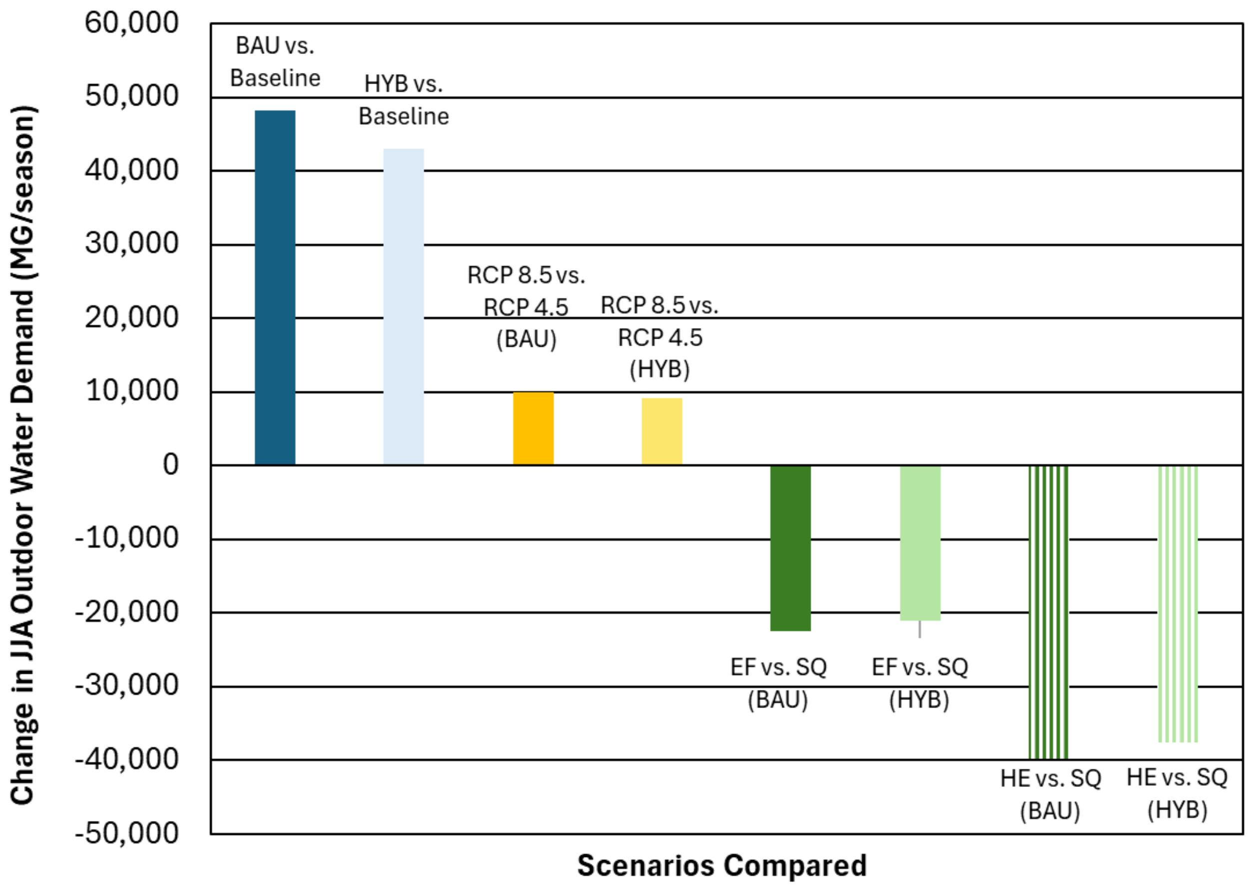

Figure 13. Regional change in JJA outdoor demand associated with growth management, water use efficiency, and climate change.

Outdoor Water Demand by Residential Parcel Class

In this portion of the analysis, we unpack differences in outdoor water demand associated with different types of urban development (Figure 14). Parcels were divided into one of five classes based on county characteristics[14] and land use intensity[15]. Parcel-level outdoor demand was estimated across each of the water use efficiency and climate scenarios described earlier. For the climate scenarios we used minimum, maximum, and median net evapotranspiration values from the RCP 4.5 and RCP 8.5 scenarios. The bars in Figure 14 show the median and range of values across the eighteen scenarios considered for each type of residential development.

[14] Counties were grouped based on population (King; Large (Snohomish and Pierce); Medium (Whatcom, Thurston, Skagit); and Small (all remaining (e.g., San Juan, Clallam)) to capture intra-regional differences in the characteristics of housing stock within land use intensity classes.

[15] High, Medium, Low development intensity from Future Scenarios Project (derived from NOAA CCAP data)

Within each county class (large, medium, small), parcel-level water demand generally increases with decreasing density (Figure 14). For example, in King county parcels, average outdoor demand in low density parcels is 1.8x greater than high density parcels. High density urban parcels are typically home to many more people than lower density parcels–making differences in per capita outdoor demand even more pronounced in these areas.

Within each land use intensity class, median landscaped area per parcel varied across county classes (e.g., 2700 ft^2/parcel for a medium density parcel in King County vs. 4700 ft^2/parcel counties with smaller populations such as Mason and Clallam). This leads to substantive differences in outdoor demand across parcels within the same land use intensity class (Figure 14). For example, median outdoor demand of a high-density parcel in a lower population county is 2.0x greater than demand in a high-density King County parcel. Water demand from high intensity parcels in medium population counties (e.g., Whatcom, Thurston) is an outlier but appears to be a product of the limited number of high-density parcels in these counties and their typical location in downtown areas (e.g., Olympia, Bellingham).

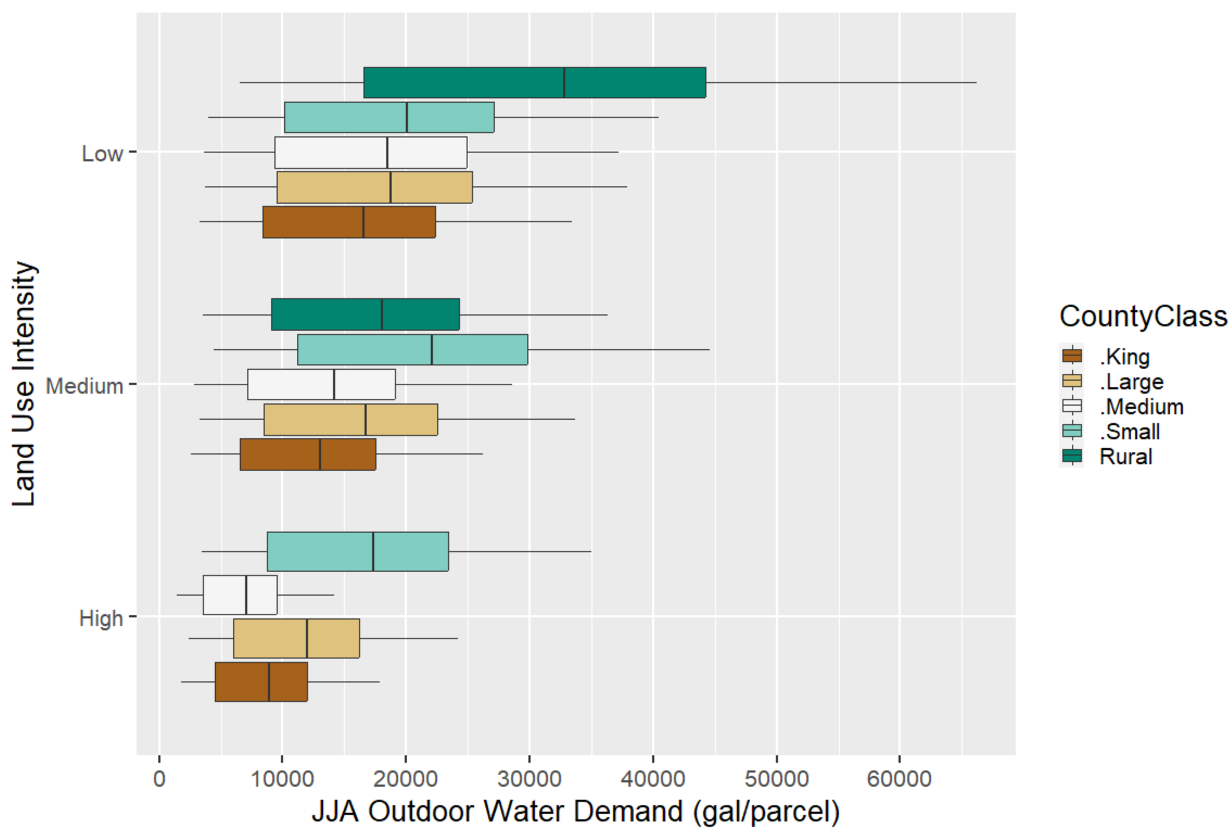

Figure 14. Range of parcel level outdoor water demand by land use intensity and county population classes.

Changes in Parcel-Level Water Demand Associated with Climate Scenarios

In Figure 15, median outdoor demand (based on historical norms) was subtracted from projected demand under RCP 4.5 (RCP4.5-HIST) to understand the impact of a transition from historical norms to RCP 4.5 on outdoor demand. Similarly, demand under RCP 8.5 was subtracted from RCP 4.5 estimates (RCP8.5-RCP4.5) to better understand the impact of a transition from RCP 4.5 to RCP 8.5 on outdoor demand. These comparisons assume no improvements in outdoor water use efficiency (i.e., status quo efficiency scenario).

Similar methods were used to produce the parcel-level estimates of water savings via different water use efficiency scenarios (Figure 15). SQ-EF is the difference between the status quo and efficient scenarios while EF-HE is the difference between the efficient and highly efficient scenarios. These comparisons assume no changes in demand due to climate change (i.e., historical climate norms).

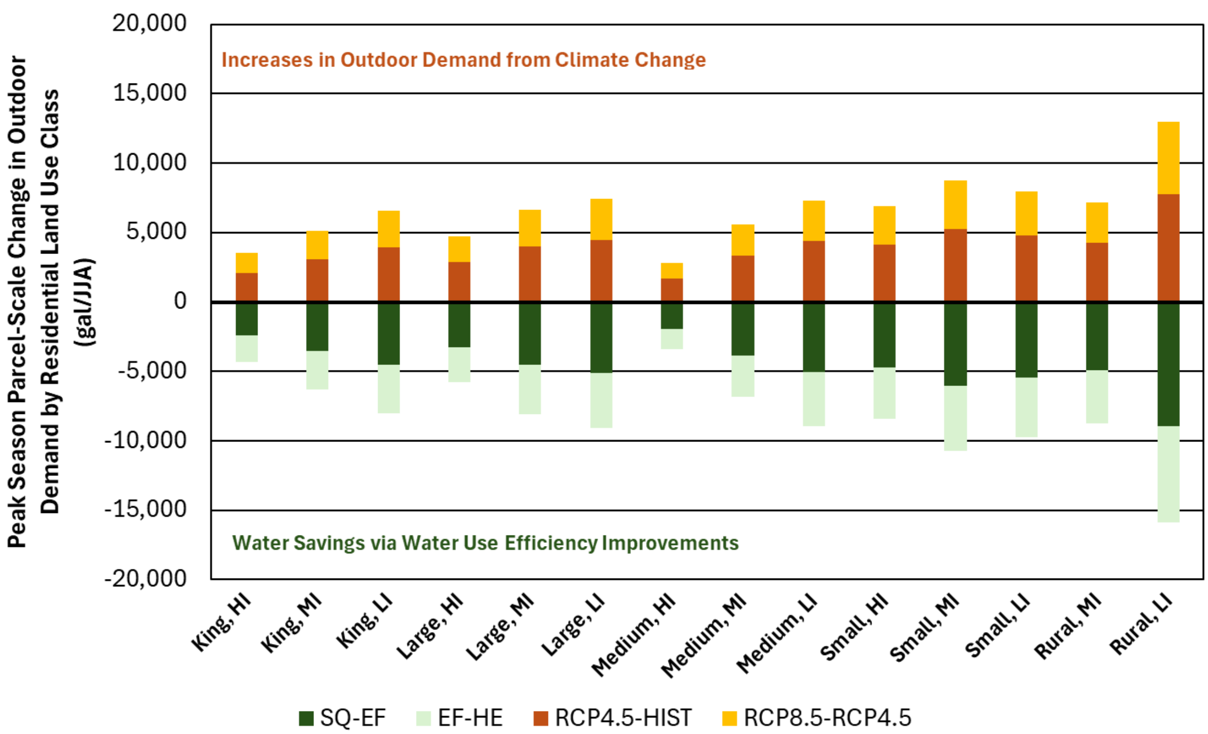

Figure 15. Parcel-level changes in median outdoor water demand associated with climate transitions and water use efficiency improvements across and different classes of residential land use. (Low intensity (LI); Medium intensity (MI); High intensity (HI)).

The difference in water demand associated with a transition from historical norms to RCP 4.5 was consistently higher than the transition from RCP 4.5 to RCP 8.5. With median precipitation and evapotranspiration estimates under each scenario, the RCP 4.5 to 8.5 transition was 67 percent of the increase in demand associated with the transition from historical norms to RCP 4.5. Water savings via water use efficiency were greatest in the transition between the status quo and efficient scenarios (approximately 78 percent of savings, assuming median historical precipitation and evapotranspiration values). Changes in residential outdoor demand were amplified in less dense land use classes due to larger landscaped (and irrigated) areas.

Notably, water savings via efficiency at the parcel level were approximately 1.2X the increase in demand associated with the climate change scenarios. This suggests that, at the parcel level, water use efficiency improvements can be an effective climate resilience strategy.

TOTAL RESIDENTIAL WATER DEMAND ESTIMATES

TOTAL RESIDENTIAL WATER DEMAND

Figure 16 shares modeled total (indoor+outdoor) annual water demand at the regional scale for each of the scenarios considered. Population growth is the biggest driver of changes in water demand between the baseline and 2080 status quo scenarios (135-140,000 MGY). However, similar to indoor and outdoor demand estimates, total demand under the 2080 highly efficient scenario was close to current baseline demand across all urban growth and climate scenarios (Figures 16, dashed line). Differences between the 2080 BAU and HYB scenarios (2900-6100 MGY) and climate scenarios (6100-12,000 MGY) are relatively small, compared to population-related changes. Annual outdoor demand ranged from 36-41 percent of total demand in the future scenarios considered, a slight increase over the baseline percentage of 33 percent. Water savings from indoor efficiency account for 61-65 percent of total efficiency savings in the highly efficient scenario and 59-63 percent of savings in the efficient scenario.

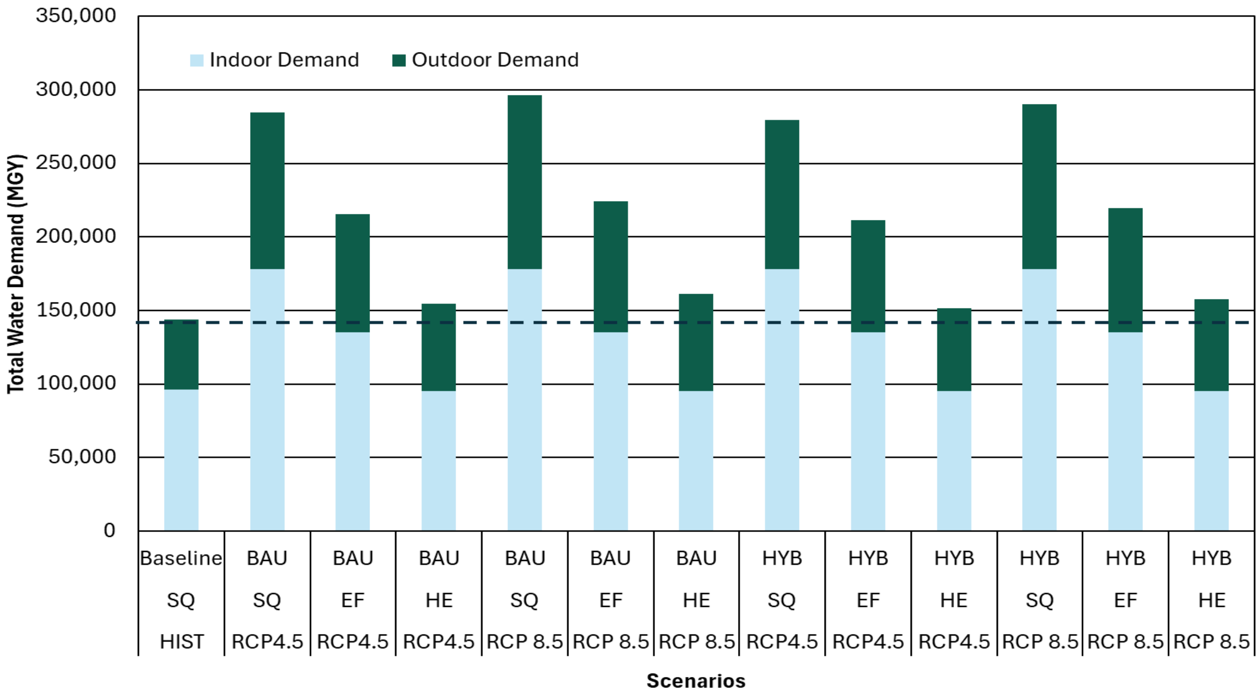

Figure 16. Total (indoor+outdoor) annual water demand by scenario. Dashed line is modeled 2020 baseline water demand.

In the second portion of this analysis, we looked at total demand in the peak demand summer months (Figure 17). In the future scenarios considered, outdoor demand was roughly 65-70 percent of total water demand in the summer months, slightly higher than baseline estimates (63%). Efficiency gains in the summer months could reduce projected summer demand by roughly 44 percent. These months are often when water systems face the greatest supply availability challenges due to decreases in water supply in the dry summer months and seasonal increases in demand.

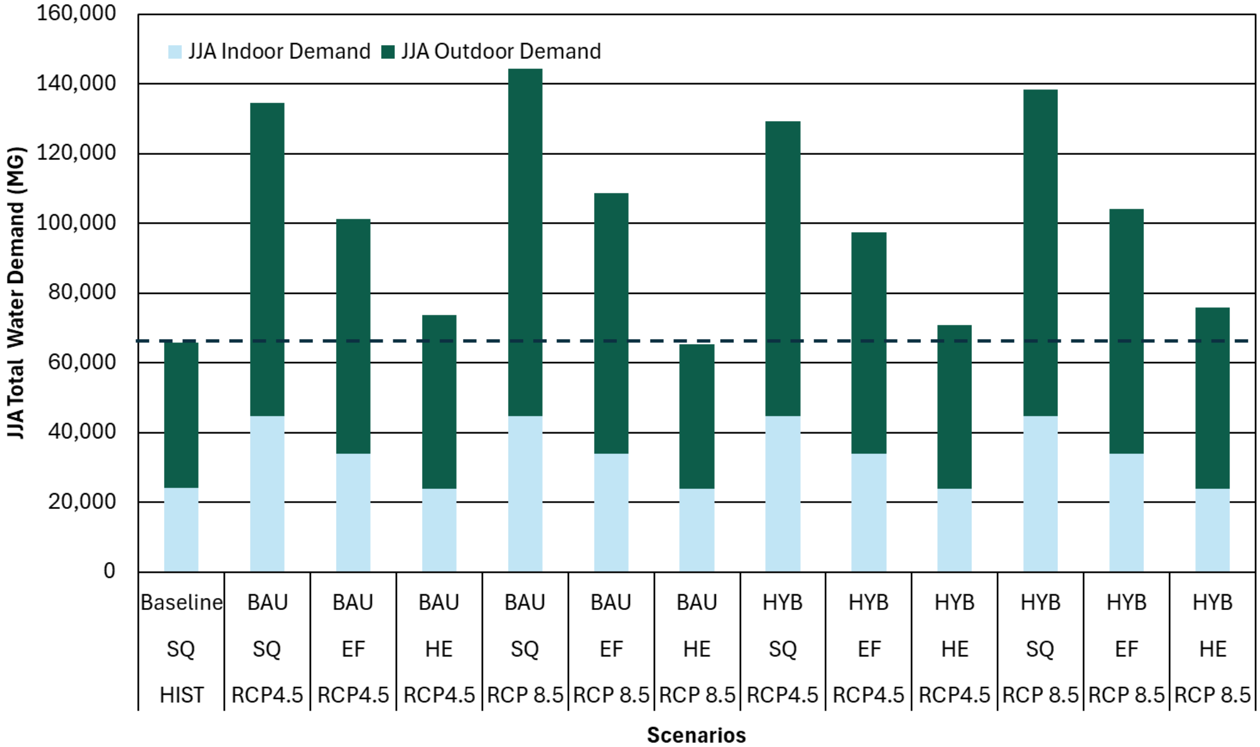

Figure 17. Total (indoor+outdoor) annual (a) and summer (JJA) (b) water demand by scenario. Dashed line is modeled 2020 baseline water demand.

COMPARISON OF MODELED DEMAND TO OBSERVED DATA

In the following two figures we compare our modeled baseline water demand (per household) to observed data from Flume, DOH Water System Plans (WSP), and SPU wholesale customer data. Figure 18 compares modeled data to average annual consumption data from wholesale customers and total gphd (Flume and WSP). In that comparison we found that our modeled demand value (173 gphd) was nearly identical to the weighted wholesale average (173 gphd) and within about 3 percent of Flume (168 gphd) and WSP averages (169 gphd) data. This suggests that despite concerns about outdoor water use projections, our total household usage estimates are actually very close to observed values.

In Figure 19, we compare our modeled (total) peak season demand to peak season consumption data from wholesale customers and average JJA use (Flume). Our baseline peak season demand (314 gphd) was about 35 percent higher than the wholesale average (233 gphd) and five percent higher than the Flume data (298 gphd). The relationship between annual household demand (Figure 18) and peak season demand (Figure 19) suggests that our higher (modeled) peak season estimates may be compensating for lower-than-expected fall outdoor demand in our models.

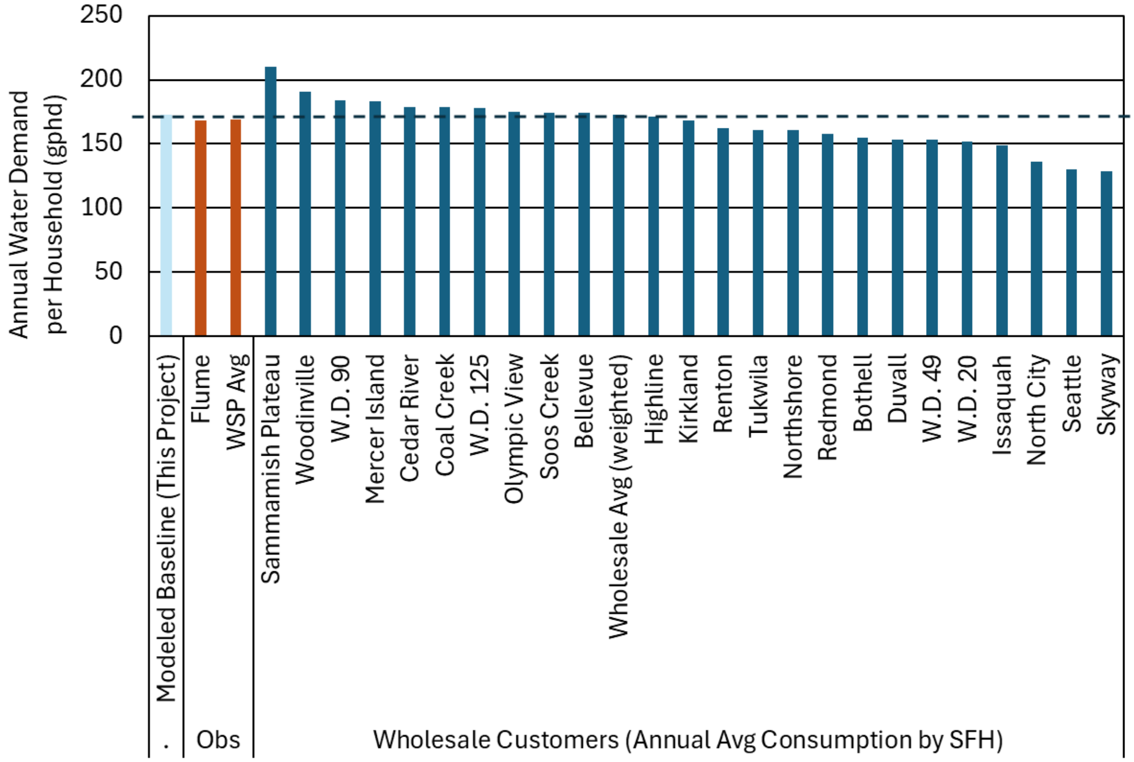

Figure 18. Modeled annual baseline household demand (gphd) relative to observed data from Flume, WSP, and SPU wholesale customers.

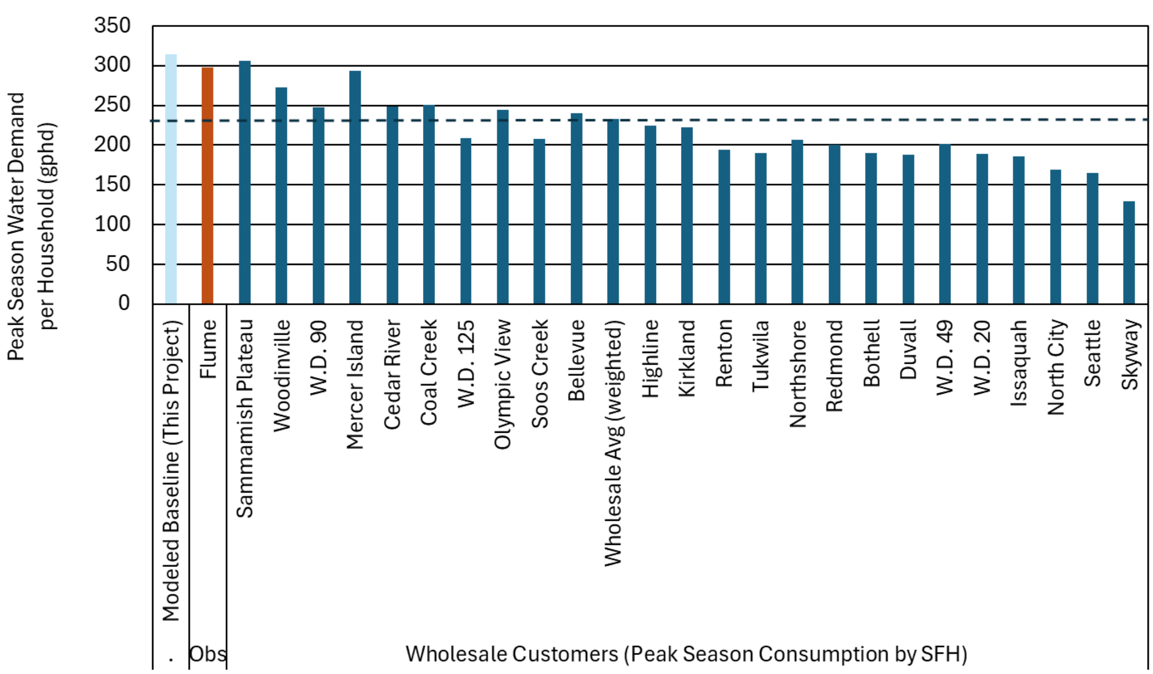

Figure 19. Modeled peak season household demand (gphd) relative to observed data from Flume, WSP, and SPU wholesale customers.

GEOGRAPHIC VARIATION IN TOTAL WATER DEMAND

Total water demand varies substantially across WRIAs. In Figure 20, we show total baseline water demand and the percent change associated with each urban growth and water use efficiency scenario (under the RCP 4.5 climate scenario). For most WRIAs, the percent change in total demand was lower under the HYB scenario than the BAU scenario. Trends are similar looking at differences across the status quo, efficient, and highly efficient scenarios, with the highly efficient scenarios showing the smallest increases in demand (or even decreases in demand relative to the 2020 baseline, in some WRIAs). The Upper Skagit (WRIA 4) is an outlier in the BAU scenario due to a substantial (percentage-based) increase in demand associated with an increase of approximately 46,000 additional residents in the BAU versus HYB scenarios.

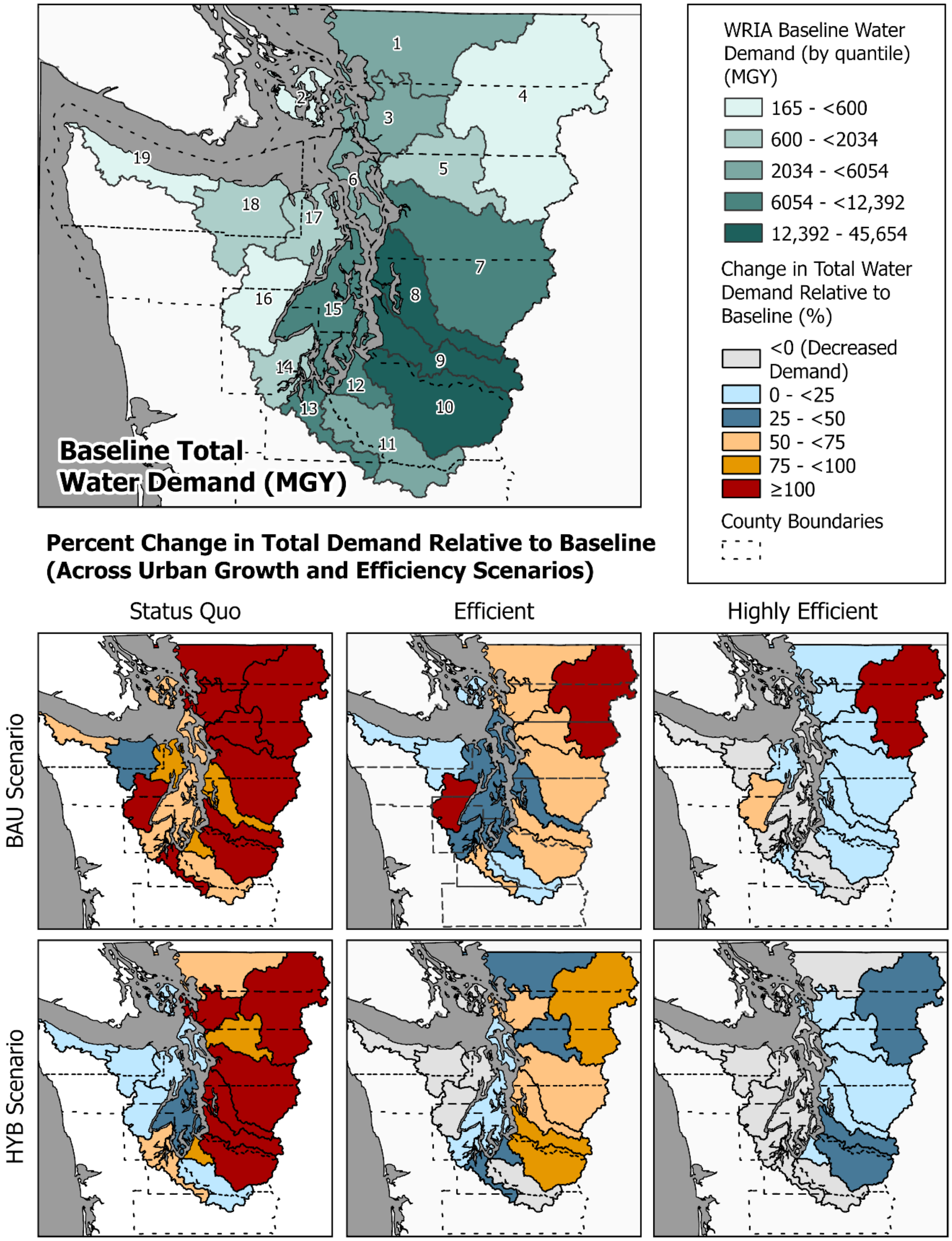

Figure 20. Baseline water demand by WRIA and percent change associated with each urban growth (BAU and HYB) and water use efficiency scenario. All future projections use the RCP 4.5 climate scenario.

POPULATION GROWTH AND TOTAL RESIDENTIAL WATER DEMAND

While population is a key driver of water demand, the exact relationship varies across water use efficiency scenarios. To explore these differences, we performed simple linear regressions across each class of efficiency scenario, comparing the percent change in population with the percent change in residential water demand at the WRIA scale. Figure 21 shows a scatter plot of these relationships, with each point representing an individual model result for a specific WRIA and scenario combination (e.g., growth, efficiency, climate). Linear trendlines—shown by scenario—illustrate how the dynamics of the population-demand relationship shifts across different levels of water use efficiency.

Practically speaking, these regression equations provide basic, quantitative estimates of how residential water demand may respond to population growth and different levels of water efficiency across the region. In the status quo scenario, a one percent increase in population corresponds with a 1.19 percent increase in water demand. Under the highly efficient scenario, a one percent increase in population corresponds to a 0.65 percent increase in water demand. The efficient scenario lies between the two, with an estimated 0.78 percent increase in demand for each one percent increase in population (Figure 21).

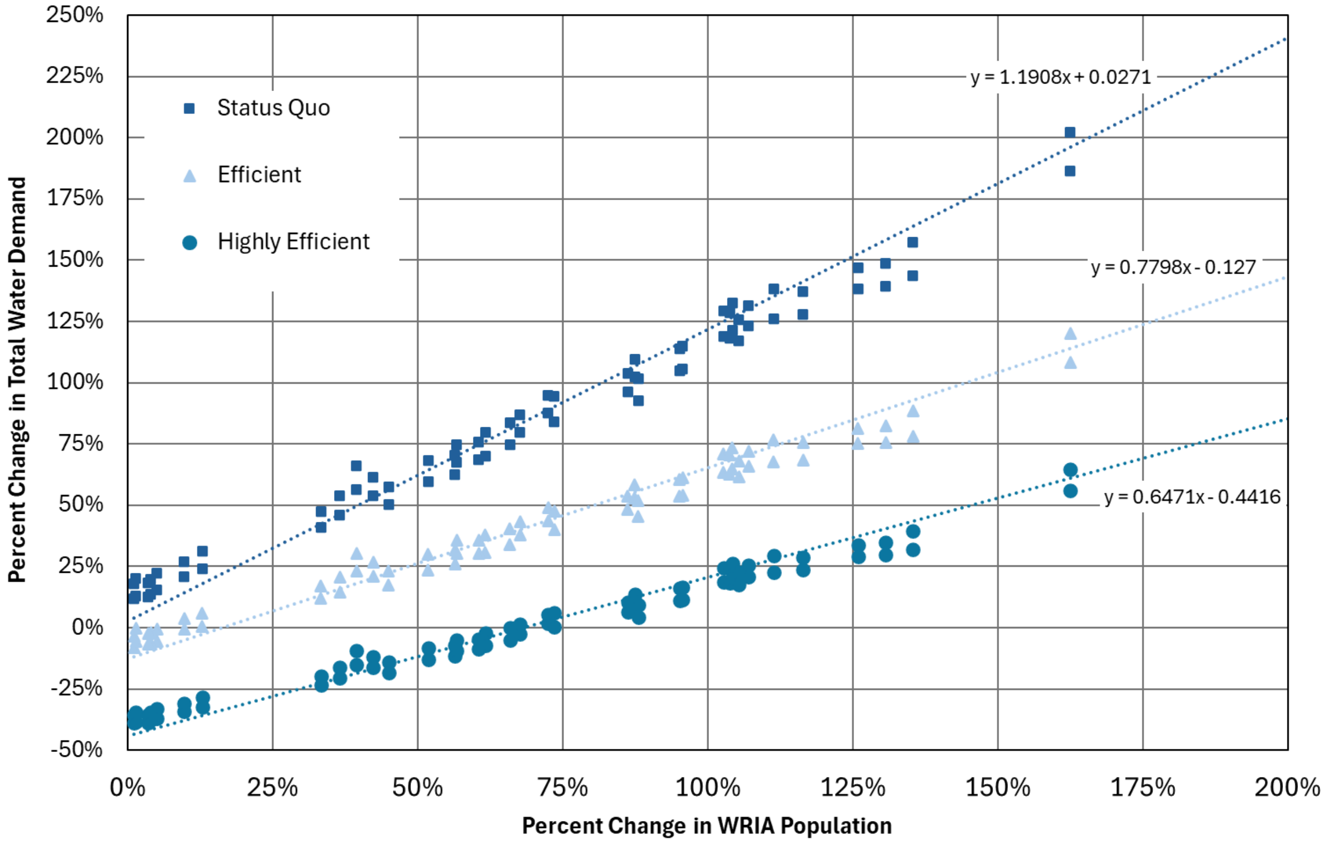

Figure 21. Relationship between the percent change in WRIA population and total water demand (by WRIA) within each water use efficiency scenario.

WATER DEMAND OUTSIDE OF PUBLIC WATER SYSTEM BOUNDARIES

This analysis also developed rough estimates of total demand within and outside of areas currently served by public water systems. To make this assessment, we overlaid current public water system and IDU boundaries to classify IDUs as 1) within or intersecting a current public water system (PWS) boundary; or 2) outside of a current PWS boundary. IDU boundaries were based on a combination of administrative boundaries and areas of homogenous land use (Puget Sound Future Scenarios Project 2024), leading to reasonable (but imperfect) matches with water system boundaries. While this approach provides general estimates, it also has limitations. First, this approach likely assigns demand from IDUs on the periphery of PWS to these systems when, in practice, some of these users may be served by private wells. Second, we did not attempt to estimate future water system boundaries which may lead to overestimates in future non-PWS demand in areas where systems may eventually expand their service areas.

Total water demand across WRIAs mirrors trends in indoor and outdoor demand—the majority of demand occurs in the most populous WRIAs (Figure 22). Across all WRIAs, 93 (BAU) and 96 (HYB) percent of demand[16] occurs near or within existing public water system boundaries.

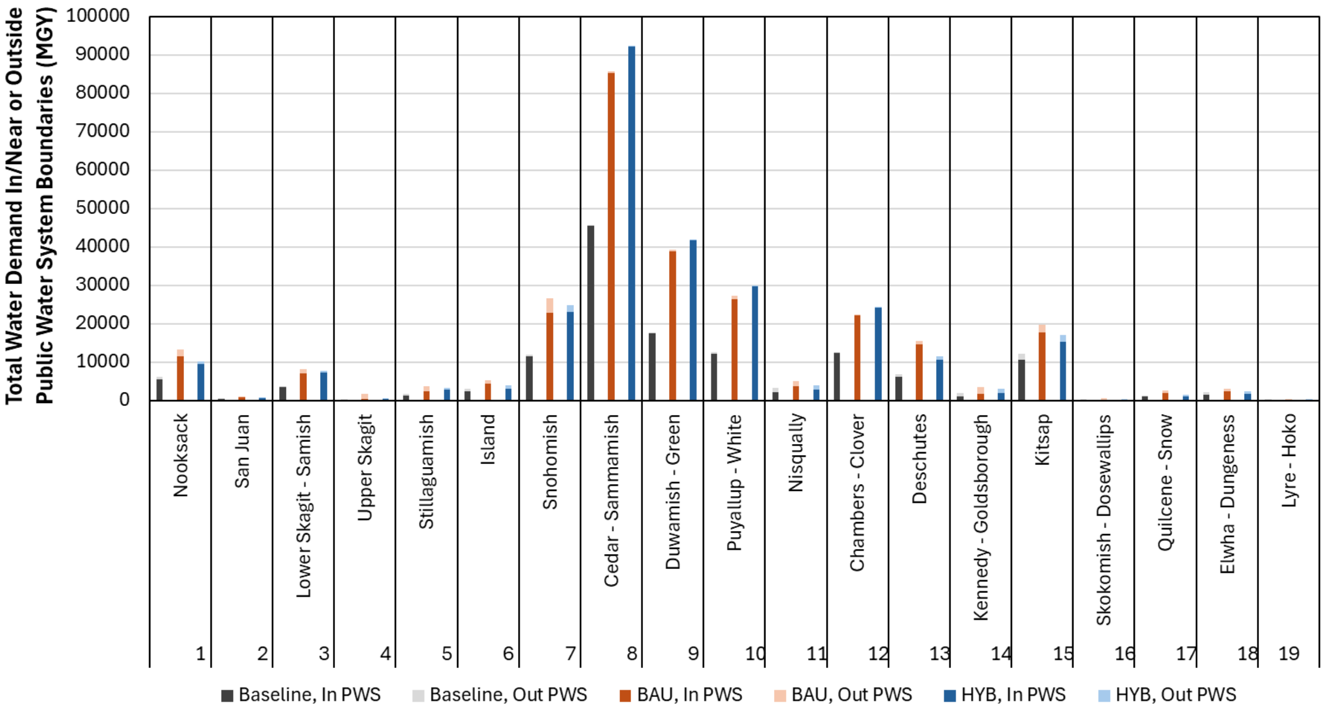

Figure 22. Total annual water demand occurring within/near or outside of current public water system (PWS) boundaries (baseline, BAU and HYB scenarios).

Looking at regional totals provides useful insights into regional trends, but masks changes that may be locally significant in watersheds with relatively low total water demand. To look at these differences, we also looked at the proportion of water demand occurring near/within or outside a PWS by WRIA (Figure 23). In WRIAs such as the Cedar-Sammamish and Duwamish-Green, where 99-100 percent of demand occurs in IDUs within a PWS boundary, nearly all demand continues to occur within PWS boundaries under both the BAU and HYB scenarios.

The impacts of growth management policies are clearer in WRIAs with a lower portion of the population served by PWS. For example, in the Stillaguamish, 66 percent of demand occurs within a PWS boundary in the BAU scenario, but 86 percent of demand occurs within a PWS boundary in the HYB scenario. Similar trends are present in WRIAs 4, 14, and 16. While these differences are more extreme in rural WRIAs, there are still notable

[16] Under the status quo efficiency scenario.

differences in the distribution of future demand in the more populous Snohomish (7) and Lower Skagit – Samish (3) WRIAs (Figure 23). In the Snohomish, demand within a PWS boundary increases from 86 percent in the BAU scenario to 93 percent in the HYB scenario.

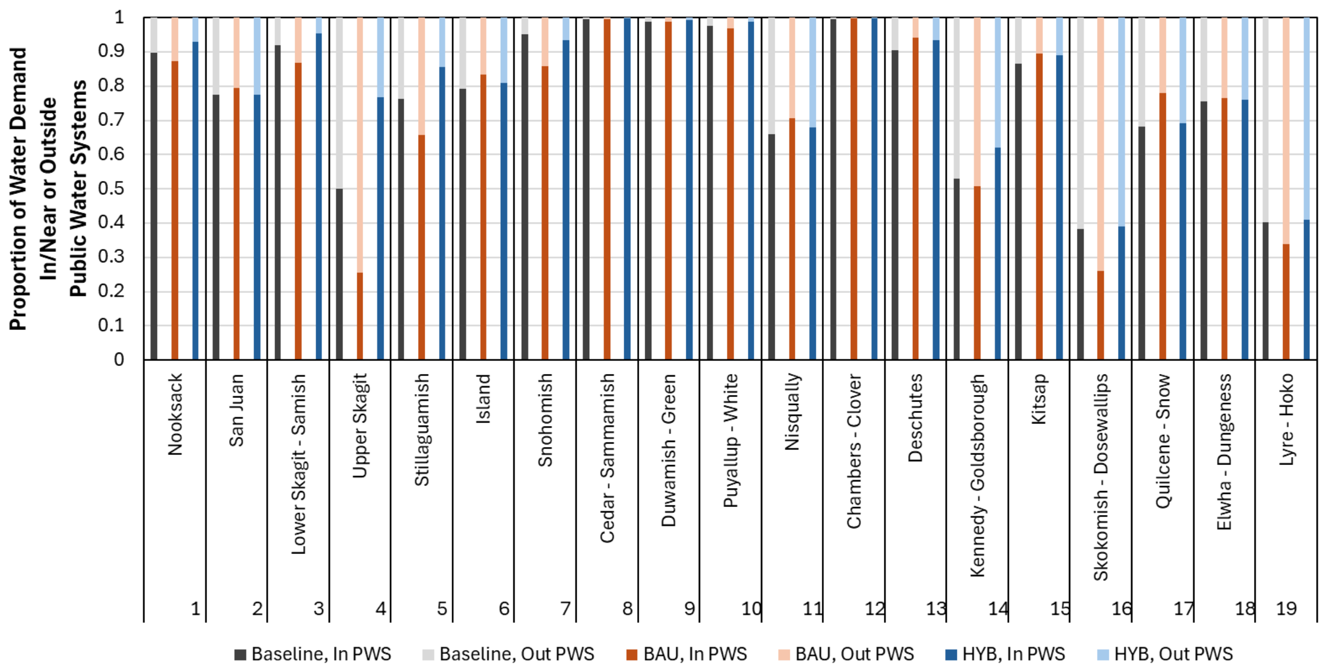

Figure 23. Proportion of total annual water demand occurring within/near or outside of current public water system (PWS) boundaries (baseline, BAU and HYB scenarios).

Given ongoing questions around permit exempt wells, it is important to consider not just the total change in water demand, but also the implications of different urban growth scenarios on the distribution of demand within sensitive environments. Likewise, planning for urban growth should also consider whether local water systems have the supply available to support projected changes in population.

DISCUSSION AND FUTURE WORK

LOCALLY SIGNIFICANT IMPACTS OF CHANGES IN DEMAND

While the focus of our analysis was regional, many of our findings are shared at the WRIA and/or county level. At the regional level, the largest potential increases in demand and water savings from efficiency occur in the most populous counties and WRIAs, but this can mask locally significant changes in smaller or less populous areas. For example, in WRIA 16 (Skokomish-Dosewallips) current residential demand is relatively low. However, projected growth in the BAU scenario would increase demand by roughly 186 percent compared to

18 percent in the HYB scenario. Our preliminary analysis of the distribution of water demand between public water systems and private wells builds on this finding, identifying increases in demand outside of current public water system boundaries in the BAU scenario. Whether these changes—and the difference between the BAU and HYB scenarios—are significant depends on local context. For example, can local water sources support increased withdrawals, and do local water systems hold sufficient water rights? Local context is an important determinant of the relative significance of changes in demand. The findings from this project are not a substitute for local demand forecasting and planning efforts. Rather, they are intended to provide high-level insight into the broader regional context water systems operate within.

RELATIVE WATER SAVINGS FROM INDOOR AND OUTDOOR EFFICIENCY IMPROVEMENTS

On an annual basis, projected residential water savings via indoor efficiency improvements account for roughly 60-65 percent of total savings. However, during the dry summer months, the pattern reverses—outdoor efficiency improvements account for roughly 64-70 percent of total savings. Overall, nearly half of all projected water savings from efficiency measures occur in the summer months. Seasonal differences in when efficiency gains are realized have important implications for water supply management and the design of water conservation and efficiency programs.

Residential water demand typically peaks in the summer months, coinciding with periods of low streamflow and declining groundwater levels. As such, the relative benefits and costs of different conservation and efficiency measures will vary widely across water systems—with the greatest gains realized where the marginal cost of additional supply (annually or during peak months) is highest.

EQUITY AND AFFORDABILITY CONSIDERATIONS

While water use efficiency is often viewed as a cost-effective demand management strategy, its benefits and burdens are not always distributed evenly. Households with the resources to invest in upgrades—such as high-efficiency appliances or landscape retrofits—may realize greater savings, while lower-income households may face barriers to participation. Similarly, smaller or rural water systems may have limited capacity to fund or implement conservation programs. Future work should explore how efficiency and reuse strategies can be designed to promote equitable outcomes, minimize unintended rate impacts, and ensure that all communities—regardless of income or service area size—can benefit from investments in demand management.

URBAN GROWTH AND OUTDOOR WATER DEMAND

While the impacts of population growth on water demand were a significant factor in our models, the differences between the 2080 BAU and HYB scenarios were relatively small. Our outdoor demand analysis focused on transitions in zoning and land use classes between the baseline and BAU/HYB future scenarios. However, while the population increased in many IDUs, it was not always enough to trigger a transition in zoning or land use class. In practical terms, this meant that, in some IDUs, per-parcel landscape area remained unchanged between 2020 and 2080 if zoning or land use designations stayed the same.

We modeled changes in landscape area by multiplying the number of different types of housing units within an IDU by the typical irrigated landscape area associated with that class of residential development (see Appendix B for additional details), and we assumed that the relative proportions of different types of dwelling units (e.g., single family homes, 3-4 unit multi-family) remained constant from 2020 and 2080. We felt this was the most defensible approach within the scope of this analysis, but future work could conduct additional sensitivity tests examining the impact of more substantial shifts in housing type (e.g., higher proportion of multi-family housing units in the HYB scenario).

The findings from our parcel analysis—showing substantial differences in outdoor water use across different types of residential development—suggest that additional sensitivity testing could yield more targeted insights into how growth management strategies may reduce residential demand. Because multi-family developments generally have less irrigated landscape area per household, we anticipate that differences in outdoor water demand between urban growth scenarios would become more pronounced with increasing proportions of multi-family units.

CLIMATE CHANGE IMPACTS ON OUTDOOR DEMAND

Climate change is expected to lead to increased summer temperatures and reduced summer precipitation in the Puget Sound region. Predicted changes in evapotranspiration are more uncertain (Milly and Dunne 2017), but could significantly influence outdoor water demand. In our regional scenarios we examined the effects of transitioning from RCP 4.5 to RCP 8.5, finding that anticipated changes increased potential outdoor demand by roughly 9000 MG during the summer months.

Additional climate-related impacts, associated with the change from current climate normals to RCP 4.5 are embedded in the increase in demand between baseline and the 2080 status quo scenario. Our simple parcel-level analysis suggests that the increase in outdoor demand from historical climate norms to RCP 4.5 may be larger than the subsequent increase from RCP 4.5 to RCP 8.5. These initial findings suggest that deeper exploration of the potential impacts of climate change on outdoor water demand would be valuable in future work.

CONSIDERING OTHER SOURCES OF DEMAND

While our analysis focused on residential demand—the largest source of demand at the regional level—commercial, industrial, and institutional (CII) demand, along with agricultural demand, can be locally significant across many areas of the Puget Sound Region. The drivers of demand in these sectors are diverse. CII demand varies widely by industry type. Other analyses found that regional shifts from manufacturing and heavy industry to service- and information-based economies have led to reductions in water use (Chinnasamy et al. 2021). Water efficiency improvements are possible in the CII sector but can differ substantially by facility. Many CII sites also maintain significant landscaped areas, creating additional opportunities for outdoor efficiency gains. Similar to outdoor residential demand, agricultural water demand is highly seasonal—concentrated in the growing season—and depends on crop types, local weather, and irrigation practices. Agricultural demand in the Puget Sound Region can be locally significant, with operations ranging from small urban farms through large industrial producers. Future work should include additional analysis to quantify future demand in non-residential sectors and integrate these insights with this study's residential demand findings.

DEMAND HARDENING

Demand hardening is the concept that long-term improvements in water use efficiency can reduce a utility's operational flexibility—limiting their ability to respond to drought or other shortages through short-term conservation measures. In essence, inefficiencies in a water system can provide a buffer during supply disruptions by creating space for rapid reductions in demand. While the Puget Sound Region already uses water relatively efficiently, current usage remains well above what could be achieved using current best available technologies and practices. Maintaining some level of system flexibility can be a valid adaptation strategy—but may come with tradeoffs, such as overbuilt infrastructure and reduced flows available for ecosystems.

At a broader scale, and given the population growth projected within the region, the central question is really: What level of demand can future supplies and ecosystems sustainably support? From a practical standpoint, efficiency improvements may be essential to extend limited supplies and reduce environmental impacts. Future work is needed to better understand the balance between projected supply and demand at the regional scale.

WATER SUPPLY AND DEMAND

Water supply and demand are closely interconnected—both are essential to understanding how changes in water availability affect utilities, communities, and ecosystems. While this analysis focused on residential demand, current models project substantial declines in summer streamflow across many Puget Sound watersheds (Pytlak et al. 2018). This is especially true for many of the headwater streams and rivers feeding the region's reservoirs. Many water systems also rely on groundwater sources that are hydrologically connected to these same rivers and streams. When considering supply projections and current water rights, the potential demand increases projected under the status quo scenario are likely to place additional stress on some water systems. However, our findings also suggest that substantial water savings remain achievable through residential water efficiency improvements that could help offset demand associated with regional population increases.

CROSS-SECTOR AND INTERJURISDICTIONAL COORDINATION

Projected changes in residential water demand are shaped not only by population growth, but by land use policy, zoning, infrastructure planning, and watershed management—each typically governed by different agencies or jurisdictions. Coordinating across sectors and scales is essential to ensure that water demand strategies align with transportation, housing, and ecosystem recovery goals. Many WRIAs span multiple counties and utility service areas, increasing the importance of shared planning frameworks and data. Future work should explore institutional approaches to better integrate water demand forecasting with local comprehensive plans, salmon recovery strategies, and wastewater planning, supporting more efficient, resilient, and ecologically informed decision-making across the region.

CONCLUSION

This analysis explored future residential water demand in the Puget Sound Region under a range of scenarios, including more compact urban growth (hybrid scenario), varying levels of water efficiency, and climate change impacts on local precipitation and evapotranspiration. These were compared to a 'do-nothing' scenario—business-as-usual patterns of growth and status quo efficiency scenarios—and a 2020 baseline.

Without changes, residential water demand could nearly double by 2080, driven primarily by a projected population increase of 4.8 million people. However, the findings also show that modest but widespread improvements in both indoor and outdoor water efficiency could offset much of this growth, keeping total demand near 2020 levels (Figure 16).

While regional trends are promising, sub-regional results reveal greater variability (Figure 20). The efficacy of efficiency strategies depends on local conditions—such as development patterns, seasonal availability, and existing system constraints. Targeted improvements in indoor and outdoor efficiency can offer significant benefits, but the relative impact will vary.

This project provides initial, high-level insights into how residential demand may evolve in a changing region and identifies several priorities for future research. Although residential demand is the largest source of demand regionally, CII and agricultural water use can be locally significant and merit further analysis. Additionally, projections of future demand must be viewed in the context of supply constraints—particularly in summer months, when climate change is expected to reduce streamflows and increase temperatures. Combined with ecosystem needs and limited water rights, these pressures suggest that improving water use efficiency will not only be beneficial—it may be essential for long-term resilience.

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APPENDIX A. INDOOR RESIDENTIAL WATER DEMAND METHODS

WATER USE EFFICIENCY SCENARIOS AND PER CAPITA DAILY WATER USE

Overview

Per capita water use is the product of:

- Devices within a household (e.g., dishwasher, washing machine);
- People per household;
- Device flow rating (e.g., gal/flush, gpm, gal/cycle);
- Human behavior (e.g., flushes/day, min/person/day, loads/person/day);
- State and federal standards on devices available for purchase; and
- Replacement rates of water-using devices in households.

This section walks through each of these variables and how they come together in our estimates of per capita indoor water use.

Water Use By Device

Federal standards set thresholds on the maximum water use allowable by devices available for purchase. Some states, including Washington, set limits that are more stringent than federal standards (Table A1). The voluntary WaterSense and EnergyStar rating programs aim at supporting consumer identification of low water and energy use products. Washington state water use standards (Washington State Department of Commerce 2022) mostly align with the limits set by the WaterSense (U.S. Environmental Protection Agency 2021; 2023) and EnergyStar (U.S. Department of Energy 2024) programs for device certification. The standards and programs discussed above set maximum limits on use. However, there are many products available for purchase that use less water than these standards. Water use under 'leading edge technology' is use by the most efficient devices currently available (U.S. Environmental Protection Agency 2024).

Table A1. Water use by device under state/federal standards and leading-edge technologies.

Device	Avg Use North America (2016)	Federal Standard	WA Standard	WaterSense / EnergyStar	Leading-Edge Technology	Units	Notes
Toilet	2.6	1.6	1.28*	1.28	0.79	gal/ flush	
Faucet	1.4	2.2	1.5*^	1.5	0.8^^	gal/min	
Shower	2.1	2.5	1.8	2	1	gal/min	
Clothes Washer	31	19.7	15.5*	15.5	10.9	gal/ cycle	
Bath	20	20	20	20	20	gal/ person/ day	Usage is based on behavior; Used NA average for all.
Dishwasher	6.3	5	3.5*	3.5	2	gal/ cycle	
Leak	7.8	7.8	7.8	7.8	7.8	gal/ person/ day	North America average
Source	Feinstein and Thebo (2021); REUW (2016)	77 FR 32307 (2022)	WA Dept of Commerce (2022); Saving Water Partnership (2024).	EPA 2021, 2023	EPA 2024		
* WA Standard references WaterSense/EnergyStar requirements for these devices							
^ As of 2020, Washington requires <1.8 gpm for kitchen faucets and <1.2 gpm for bathroom faucets. Used WaterSense standard to match units of use behavior data (does not separate kitchen vs. bathroom faucet use).							
^^ Appear to be products @0.35 gpm (bathroom faucets), using 0.8 gpm b/c use behavior data includes both kitchen and bathroom faucets							

Water Use Behaviors

Water use is a product of both the device usage (Table A1) and how people use those devices (e.g., shower length, number of loads of laundry per day). In this project, we use data from the Residential End Uses of Water (REUW) v. 2.0 study to estimate human behaviors around indoor water use (Table A2). While the data is from 2016, we would not anticipate significant changes in behavior. Tacoma Water participated in the REUW flow tracing study, supporting the developing local estimates of water use behaviors. Indoor water use behaviors in Tacoma did not deviate substantially from national norms (Table A2).

Table A2. Water use behaviors in western Washington

Device	Average North America (2016)	REUW Tacoma (2016)	Units
Toilet	5.5	5.56	flushes/person/day
Faucet	10.5	10.25	min/person/day
Shower	5.62	5.15	min/person/day
Clothes Washer	0.32	0.33	loads/person/day
Bath	0.07	0.06	bath/person/day
Dishwasher	0.1	0.13	loads/person/day
Other		0.01	
Source	REUW Table 6.22	REUW Tables 6.9 and 6.23 (per capita)	

Per Capita Daily Water Use

Per capita, daily indoor water use (Table A4) was estimated by multiplying device level water use (Table A1) by water use behavior factors (Table A1). Table A3 includes the per capita usage values used in this analysis (see 'Efficiency Scenarios Using') and other estimates of per capita use (e.g., North America (NA) Averages) for comparison.

Table A3. Per capita daily water use (gallons) under each device use and water use behavior scenario and the source of device use and behavior data used to develop each estimate.

Device Use Data	Average Use NA (2016)	Average Use NA (2016)	Federal Standard	Washington State Standard	WaterSense / Energy Star	Leading Edge Technology	Flume Data
Water Use Behavior Data	**Average NA**	**REUW Tacoma**	**REUW Tacoma**	**REUW Tacoma**	**REUW Tacoma**	**REUW Tacoma**	**N/A**
Toilet	14.3	14.5	8.9	7.1	7.1	4.4	-
Faucet	10.5	14.4	22.6	15.4	15.4	8.2	-
Shower	11.8	10.8	12.9	9.3	10.3	5.1	-
Clothes Washer	9.9	10.2	6.5	5.1	5.1	3.6	-
Bath	1.4	1.2	1.2	1.2	1.2	1.2	-
Dishwasher	0.6	0.8	0.7	0.5	0.5	0.3	-
Other	0	0	0	0	0	0	-
TOTAL (gpcd)	**48.5**	**51.9**	**52.7**	**38.5**	**39.6**	**22.8**	**34.6 ± 2.9 ***
Leaks (gpcd)	**7.8**	**7.8**		**7.8**		**7.8**	
TOTAL w/Leaks (gpcd)				**46.3**		**30.6**	
Efficiency Scenarios Using				**Baseline/ Status Quo/ Efficient**		**Efficient/ Highly Efficient**	

* *Monthly mean (10/22-9/24)*

Log-Normal Stock Model

This project aims to quantify water savings from water use efficiency not just at the present time but also looking forward to 2080. Water using devices within households have a finite life span and are replaced when they stop functioning or when upgrades are desired. Stock modeling is a common method for projecting what proportion of the 'original' stock of a device is still present in a future year. Table A4 summarizes what percent of the original (2024) stock of devices would remain in service in 2050 and 2080, assuming a log-normal replacement curve. Water conservation rebate programs can expedite adoption of low water use devices. Current per capita indoor water use in the Puget Sound region appears to be close to the 'Washington State Standard' estimates, suggesting that a large proportion of older devices have already been replaced with newer, lower water use devices. This observation motivated our use of the Washington State Standard per capita estimates as our per capita baseline.

Table A4. Stock modeling results by device.

Device	Typical Life Span	Percent of Original Stock Remaining in 2050	Percent of Original Stock Remaining in 2080
Toilet	25	48.4	5.53
Faucet	10	3.05	0
Shower	10	3.05	0
Clothes Washer	11	4.63	0
Bath	N/A	N/A	N/A
Dishwasher	11	4.63	0

Indoor Water Use Efficiency Scenarios

The variables used in each indoor water use efficiency scenario for existing and new housing stock is summarized in Table A5. In the highly efficient scenario, all housing units adopt current leading-edge technologies by 2080. In the status quo scenario, all housing units meet current state standards. Climate change is not expected to have significant impacts on indoor water use but may prompt accelerated adoption of water efficient devices in some households.

Table A5. Per capita indoor water use estimates used in each water use efficiency scenario.

	Water Use Efficiency Scenario	Status Quo	Efficient	Highly Efficient
Per Capita Water Use Estimates Used by Housing Type	*Existing Housing Stock*	Washington State Standard	Washington State Standard	Leading Edge Technology
	New Housing Stock	Washington State Standard	Leading Edge Technology	Leading Edge Technology

URBAN GROWTH SCENARIOS

Population data from the Puget Sound Future Scenarios Phase 3 Model Outputs (Puget Sound Future Scenarios Project 2024) were used to estimate baseline (2020) and future (2080) population by IDU for the Business as Usual and Hybrid scenarios.

INDOOR RESIDENTIAL DEMAND ESTIMATES

Spatial Analysis

Indoor residential demand within each IDU was estimated by multiplying the IDU population in each scenario by the relevant per capita use value. In the case of the efficient scenario, we assumed new (2080) housing stock used (current) leading edge technology' while existing housing stock met the Washington State Standard (Table A5). IDU indoor demand totals were summed by WRIA and county to obtain aggregate totals. Urban growth-efficiency pairings for each indoor demand scenario are summarized in Table A6.

Table A6. Summary of Water Use Efficiency and Urban Growth Scenario Pairings.

	Water Use Efficiency Scenario		
Urban Growth Scenarios	*Status Quo*	*Efficient*	*Highly Efficient*
Baseline (2020)	X*		
Business As Usual (2080)	X	X	X
Hybrid (2080)	X	X	X

APPENDIX B. OUTDOOR RESIDENTIAL WATER DEMAND METHODS

OVERVIEW

In this analysis, we used a water budget approach to estimate landscape water requirements (LWR) (United States Environmental Protection Agency 2014). LWR (equation below) is an estimate of the amount of water needed to maintain a healthy landscape and is a function of the irrigated landscape area (A), evapotranspiration and precipitation (ET_{net}), water requirements of the landscape vegetation (K_c), and irrigation efficiency (e). The following section describes how each of these variables was calculated.

$$Landscape\ Water\ Requirement\ (LWR) = \frac{Irrigated\ Area\ (A) * ET_{net} * Plant\ Factor(K_c)}{Irrigation\ System\ Efficiency(e)}$$

In this document we use the term outdoor [residential] water demand synonymously with 'landscape water requirement'. We originally planned to also use data from the 2016 REUW study that suggested typical Tacoma households were deficit irrigating at a rate of 55% of LWR (DeOreo et al. 2016). However, when we compared our outdoor demand estimates to observed outdoor use, we found they aligned well and decided to use the calculated LWR as our estimate of outdoor demand. Our estimates of outdoor demand only include use for irrigation, neglecting other outdoor uses such as car washing and patio cleaning.

PARCEL ANALYSIS AND URBAN GROWTH SCENARIOS

'Irrigated area' is the outdoor demand variable that incorporates the urban growth scenarios. The amount of landscaped (and irrigated) area varies across different types of residential land use. A fundamental question underpinning this portion of the analysis was 'how will irrigated area change over time, given current urban growth projections?'

To answer this question, we first did an analysis to understand landscape characteristics of a typical parcel within different types of residential developments (Task 1). Data on typical landscape characteristics (Task 1) were joined with the IDU data (based on the residential type class of the IDU in a given scenario) and multiplied by the number (and type) of housing units in each IDU under each of the different urban growth scenarios to obtain the residential irrigated landscape area in each IDU (Task 2).

Task 1: Landscape Characteristics

Table B1. Data used in Task 1: Landscape characteristics analysis.

Data	Data/Information/Use	Source
Washington State Parcel Data	Parcel boundaries + whether they contain a building(s) (i.e., building value >0)	WATech GIS (2024)
1-m Impervious Cover	Non-impervious area in each sample parcel	NOAA C-CAP (2021)
Current IDU Zoning, Land Use Classes	Used to filter out likely residential parcels located entirely within the boundary of an IDU (i.e., not splitting across boundaries); Defining residential land use classes	Future Scenarios Phase 3 Model Outputs (2024)
Output 1: *Characteristics of representative parcels within each type of residential development*		

In this portion of the analysis, we aimed to quantify typical landscape and irrigated area across different types residential development. We started with the Washington State 2024 parcel data (WATech GIS 2024), selected parcels that were entirely within the boundary of an IDU, then used the baseline (residential) Zoning ID and (developed) land use classes (high, medium, low intensity development) from the Puget Sound Future Scenarios modeling data (2024) to extract parcels likely to be residential properties. To exclude undeveloped parcels, we only included parcels with an assessed value >0 under the parcel field 'structure'. This resulted in a sample of 955,000 parcels across the region (Table B2). Within each of the (likely) residential parcels, we used 2021 NOAA C-CAP 1-m impervious cover data (NOAA C-CAP 2021) to estimate the current percent and area of each parcel that was impervious (and its inverse, non-impervious cover). At that resolution of data, property features such as sidewalks, driveways, and patios are easily identifiable. That observation and previous studies finding a strong correlation between larger impervious areas and lower outdoor water use (Chang et al. 2017; Blount, Wolfand, et al. 2021) lead to our assumption that non-impervious area is a reasonable proxy for current yard/landscape area.

We explored several different approaches for defining residential land use classes including various combinations of Zoning ID, consolidated Zoning ID, County, land use class, and groups of counties (by population). Consideration was limited to classes included in (or easily derived from) the Future Scenarios data because those classes provide the key to understanding how land use changes in the 2080 BAU and HYB scenarios. After exploring several iterations, we found that a combination of consolidated zoning ID (residential and rural residential), county group, and land use class provided the best fit to observed trends across different types of residential development.

As we looked at what different types of residential development looked like in communities, there were clear differences in, for example, high intensity residential development in King County vs. Thurston County or even Snohomish County. To account for these differences, we developed a series of five secondary 'county classes' based on the county's 2020 population (e.g., King, large (Snohomish, Pierce); medium (Whatcom, Thurston, Skagit); small (all remaining (e.g., Mason, San Juan)). Land use class was derived from the Future Scenarios IDU data which was based on the 2016 NOAA CCAP data. Residential land use classes included three classes – developed (high intensity); developed (medium intensity); and developed (low intensity). For parcels within each of the final residential land use classes, we calculated summary statistics (mean, median, standard deviation, etc.) across all parcels falling within that class (Table B2). Since our goal was to identify 'typical' parcels, we ended up using median landscape area in subsequent calculations due to skew in the mean caused by some outlier parcels.

Table B2. Typical landscape characteristics across different types of residential development.

Consolidated Zoning ID	County Size Class	Development Intensity	# Parcels in Estimates	Typical Parcel Landscape Area (LA)					
				Mean	Median	Std Dev	Mean	Median	Std Dev
				%	%	%	ft²	ft²	ft²
Residential	King	High Intensity	4504	0.68	0.69	0.24	2719	1405	8283
		Medium Intensity	117,819	0.49	0.47	0.18	3248	2756	4645
		Low Intensity	225,565	0.38	0.36	0.16	6732	5274	7994
	Large	High Intensity	7350	0.72	0.77	0.25	4910	1905	17,975
		Medium Intensity	106,917	0.49	0.46	0.19	5804	3541	18,328
		Low Intensity	167,568	0.39	0.37	0.18	8140	5974	12,090
	Medium	High Intensity	4804	0.77	0.87	0.24	2863	1119	6594
		Medium Intensity	37,135	0.52	0.49	0.21	3794	3003	5608
		Low Intensity	80,404	0.39	0.36	0.20	7591	5866	9456
	Small	High Intensity	874	0.69	0.75	0.27	4071	2761	6249
		Medium Intensity	737	0.45	0.42	0.18	7220	4682	12,332
		Low Intensity	928	0.37	0.34	0.19	8497	6383	10,081
Rural Residential	All Counties	Medium Intensity	3406	0.50	0.48	0.20	6123	3821	10,420
		Low Intensity	69,945	0.28	0.25	0.17	17,477	10,430	22,007

Task 2. Irrigated Area Analysis

Task 2a. Number and Type of Housing Units by IDU

Table B3. Data used in the housing characteristics analysis.

Data	Data/Information/Use	Source
Population by IDU (current/2080)	Change in population by IDU	Future Scenarios Phase 3 Model Outputs (2024)
Population and number of people per occupied housing unit (by census tract)	Calculated average household size by county; Divided by population in each IDU to get number of households/IDU in each scenario	American Community Survey Housing Characteristics Data
Housing units by housing type (census tract)	Proportion of housing by type (e.g., % SF, 15-19 unit MF); Joined with IDU boundaries (tract IDU centroid was located in) to estimate proportion of housing units by type	American Community Survey Housing Characteristics Data
Output 2a: *Number of housing units in each IDU by type in baseline, BAU, and HYB scenarios*		

Task 1 identified typical landscaped area within parcels from different types of residential development. However, there are often multiple residential units in a single parcel (when multifamily housing is present) and it would be inaccurate to apply the entire parcel landscape area to each household within the IDU. The Future Scenarios model outputs did not provide information on the types of residential dwellings present within an IDU so we completed a secondary analysis using data the American Community Survey (ACS) 'housing characteristics' data from 2020 (U.S. Census Bureau 2020). First, we used the ACS data to calculate the current average household size by county. The IDU population in each scenario was divided by this number to get the total number of housing units in each IDU.

Next we used the ACS housing characteristics data to calculate the percent of occupied housing units within each census tract belonging to each of the census specified 'number of units in structure' classes (i.e., 1-unit detached, 1-unit attached, 2 units, 3 or 4 units, 5 to 9 units, 10 to 19 units, 20 or more units, mobile home, and boat/RV/van/etc.). IDUs were joined to the census tract their centroid was located within and census tract attributes on the percent of different classes of housing structures was transferred over to the IDU data layer. Each housing class percentage from the ACS data was multiplied by the number of housing units in the IDU (for each scenario) to estimate the number of housing units within each IDU by housing size class (e.g., 1-unit attached, 3 or 4 units).

Task 2b. Irrigated Area by IDU

Table B4. Data used in IDU irrigated areas estimates.

Data	Data/Information/Use	Source
Representative parcel characteristics	Typical landscape area characteristics by residential type	Output 1
IDU housing units by ACS housing class	Number of housing units/IDU by ACS housing class	Output 2a
IDU Zoning Class (baseline, 2080 for BAU and HYB scenarios)	Which IDUs change zoning classes/stay the same relative to baseline in BAU and HYB scenarios	Future Scenarios Phase 3 Model Outputs (2024) (Future Scenarios baseline compiled from local/county records)
Land use class	Which IDUs transitioned between land use classes (land use intensity, specifically)	Future Scenarios Phase 3 Model Outputs (2024) (baseline from NOAA CCAP data)
Output 2b: *Total landscape and irrigated area of all residential units within IDU under baseline, BAU, and HYB scenarios*		

Task 2b brings together outputs from Tasks 1 and 2a with data from the Future Scenarios Phase 3 Model Outputs to estimate changes in landscape (and irrigated area) between the 2020 baseline and 2080 BAU and HYB urban growth scenarios. Parcel characteristics data were sequentially joined to the IDU data using the combined 'residential type' classes (Table B2) based on an IDU's class in each scenario. The following equation shows how we calculated residential landscape area within each IDU for each scenario.

$$LA_{S,IDU} = (N_{HU1D} * LA_{PC}) + (N_{HU1A} * LA_{PC}) + \left(N_{HU2} * \frac{LA_{PC}}{2}\right) + \left(N_{HU34} * \frac{LA_{PC}}{3.5}\right) + \left(N_{HU59} * \frac{LA_{PC}}{7}\right) + \left(N_{HU1019} * \frac{LA_{PC}}{15}\right) + \left(N_{HUGT20} * \frac{LA_{PC}}{20}\right)$$

$LA_{S,IDU}$ is the total estimated residential landscape area within each IDU, for each scenario. Total landscape area in the IDU is the sum of the landscape area associated with different types of housing.

$N_{HU(n)}$ is the estimated number of housing units by type of housing (e.g., 1-unit attached, 3 or 4 units)

LA_{PC} is the landscape area associated with a typical parcel within each 'residential type' class (e.g., King-Medium Intensity, Rural Residential)

To distribute the parcel landscape area across multiple households in multifamily developments, we divided the typical parcel landscape area (LA_{PC}) by the midpoint of the number of housing units in that size class (e.g., 15 in the 10 to 19 units class) or 20, in the case of the '20 or more units' class and one, in the case of single family homes.

For our estimates of outdoor demand, we needed to know the percent of the landscape area that is irrigated. Data on typical irrigated area per parcel is relatively limited and, where there is data, it is often from areas that have different climates and landscaping practices than the Puget Sound Region (Gober et al. 2016; Blount, Abdi, et al. 2021; Chang et al. 2017). A regression analysis of parcel irrigated areas in the 2016 REUW study (DeOreo et al. 2016) fit the following equation to data from study cities.

$$Irrigated\ Area = (0.337 * Parcel\ Area) + 449.45$$

We used the findings from previous studies to make basic assumptions about the percent of landscape area likely to be irrigated then applied the REUW equation to our parcel sample to evaluate those assumptions. For high intensity residential development, we assumed that 100 percent of the landscape area was irrigated. This class includes a higher proportion of multi-family housing, which typically has professionally managed and irrigated landscapes. Medium intensity development is primarily urban and suburban single-family housing. We assumed 75 percent of the landscape area was irrigated in this class. The low intensity residential development class is primarily large-lot single family housing. Given the larger lot sizes, we conservatively assumed 50 percent was irrigated. The total landscape area in each IDU was multiplied by the irrigated area percent (i.e., 1.0, 0.75, 0.5) matching the development intensity to estimate irrigated area within each IDU.

OUTDOOR WATER USE EFFICIENCY SCENARIOS

Task 3. Landscape Transition Analysis

Outdoor water use efficiency was incorporated via assumptions about the types of vegetation present in landscapes (plant factors representing water demand of installed landscaping) and irrigation efficiencies (Table B5).

Table B5. Data used in landscape transition analysis.

Data	Data/Information/Use	Source
Plant factors	Used to adjust reference ET for landscape that is present (e.g., low-water use, turf)	Baum-Haley (2013) and CA Model Water Efficient Landscape Ordinance
Irrigation efficiency	Typical irrigation efficiency of common irrigation methods (i.e., proportion of water that goes to supporting landscaping)	Baum-Haley (2013) and CA Model Water Efficient Landscape Ordinance

Plant factor and irrigation efficiency coefficients (Table B6) were used directly in the landscape water requirement equation at the beginning of this Appendix.

Table B6. Landscape and irrigation efficiency coefficients by outdoor efficiency scenario.

Outdoor Efficiency Scenario	Plant Factor (Kc)	Irrigation Efficiency (e)
Status Quo	0.7	0.7
Efficient	0.6	0.8
Highly Efficient	0.5	0.9

In the highly efficient scenario, we assumed a landscape (K_c = 0.5) roughly in between a low water use landscape (K_c = 0.3) and turf (K_c = 0.8) with an irrigation efficiency of 0.9, typical of drip irrigation or other low water use system. Given the high proportion of landscape plants present in many Puget Sound landscapes, we felt it was more realistic to set our highly efficient scenario a bit above the landscape coefficient expected for a 100% low water need landscape (K_c=0.3). Likewise, coefficients for the status quo scenario were set slightly below the coefficients for a 100% turf landscape (K_c=0.8). Selection of plant factors and irrigation efficiency coefficients were informed by the findings of Baum-Haley (2013) and California's Model Water Efficient Landscape Ordinance (MWELO) (California Department of Water Resources 2015).

CLIMATE CHANGE SCENARIOS

Task 4. Current and Projected Changes in Precipitation and Evapotranspiration

Climate change impacts were incorporated by incorporating at projected differences in seasonal precipitation and evapotranspiration (ET) (Task 4) into estimates of LWR.

Table B7. Data used to evaluate current and future precipitation and evapotranspiration.

Data	Data/Information/Use	Source
Historical norms and future precipitation	Simulated historical seasonal precipitation (1971-2000) and projected future precipitation (2070-99) under RCP 4.5 and RCP 8.5 (multi-model mean derived from 20 downscaled CMIP5 models)	Climate toolbox (MACAv2-METDATA)
Historical norms and projected future potential evapotranspiration (PET)	Simulated historical seasonal PET (1971-2000) and projected future PET (2070-99) under RCP 4.5 and RCP 8.5 (multi-model mean from 20 MWBM runs forced by downscaled CMIP5 models)	Climate toolbox (MACAv2-METDATA)

The Climate Toolbox 'Climate Mapper' web tool (Hegewisch and Abatzoglou 2024) was used to access the precipitation and potential evapotranspiration data cited in Table B7. Data were available as gridded data (roughly 5.5 mi^2 per gridcell). The centroid of each IDU was joined to each of the seasonal (SON, DJF, MAM, JJA) precipitation and PET rasters to estimate current and future conditions within each IDU.

Typically, it is assumed that trace precipitation and the first small portion of any precipitation event does not directly contribute to plant irrigation needs, leading to the concept of 'effective precipitation' (P_{eff}). For basic estimates of P_{eff} , WSU Extension and Farmwest (2025) recommend estimating effective precipitation as 75 percent of the modeled precipitation minus the first 5 mm falling during dry periods. In our analysis, we calculated the ‘effective’ precipitation within each season as $(0.75*(P_{season} – 5\ mm))$.

ET_{net} was estimated by subtracting P_{eff} from modeled PET for each IDU then used directly in the ‘landscape water requirement’ equation at the beginning of this Appendix.