Urban Water Use and Pricing

Water in urban areas is put to residential, commercial, and industrial uses. The amount used depends on a range of factors, including population, price of water, income, population density, and the use of water-conserving technologies such as low-flow toilets. Many empirical studies based on household, city-level, or national data have estimated urban water demand and identified the most important factors affecting municipal water use (see Appendix).

The WW2100 model's water demand relationships are used to generate estimates of the quantity of water expected to be used in each urban area in future decades. It is important to recognize that these results reflect underlying assumptions about population, income, and water price trends. Because multiple changes may affect the economics and demographics of urban water demand, these projections can be interpreted only as suggestive of a plausible future path. For example, if urban water prices rise faster than model assumptions, urban water use will be lower than the model predicts. In this case, water supply capacity might be more than sufficient to meet demand.

Urban water pricing

Unlike competitive markets, urban water prices are regulated by local governments. Urban water utilities set water prices to achieve multiple goals. These goals include generating revenue to cover costs, assuring affordability, providing stability in revenue, and achieving an allocation of cost that is considered "fair" to various types of ratepayers. Utilities may wish to fully cover all costs, while at the same time providing customers with efficient and transparent incentives to conserve water.

Urban water delivery systems are highly capital intensive, with a need for large investments in infrastructure (building, maintenance, or replacement) on an intermittent basis, sometimes decades apart. In a typical year, customers may not be aware of these capital costs, making it difficult to set prices so that long-term costs are covered. As a result, water

prices tend to be somewhat lower than long-run average or marginal costs, leading to financial deficits and delays in infrastructure investment, repair, and replacement.

This situation is well documented in historical data, surveys, and engineering analyses. U.S. Environmental Protection Agency (EPA) survey data, for example, indicate that average water prices are frequently more than 20 percent below long-run average cost (USEPA, 2009). The gap between average price and average cost has fluctuated over time and across cities and states.

Water prices in major U.S. cities have at times risen more slowly than inflation. In the past 20 years, however, they have risen faster than inflation. Nationwide, an extended period of declining urban water prices (inflation-adjusted) lasted until about the 1980s. Since that time, rising urban water prices have been observed.

Since 2010, urban water prices have increased in the WRB. Increases have been due in part to the need to expand or upgrade infrastructure. In some cases, utilities face new requirements to implement seismic risk reduction upgrades. As a result, urban water prices in some parts of the Basin increased more than 30 percent between 2010 and 2015.

In a separate survey, the EPA has documented the backlog of infrastructure needs for drinking water systems nationwide (USEPA, 2013). Nationwide, the "20-year need" totaled $376 billion in 2011. This backlog has fluctuated, but has been rising, from $843 per person in 1995 to $1,205 per person in 2011.

The backlog of infrastructure needs in Oregon has generally been higher than the national average, rising from $1,108 per person in 1995 to $1,442 in 2011.[8] The exception was in 2007, when Oregon's per-capita need was $845, compared to the national average of $1,220. The reduced backlog of infrastructure needs in Oregon between 2003 and 2007 followed a 53 percent increase in average prices in Portland between 1999 and 2007, which likely financed significant infrastructure improvements.

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[8] Since most urban populations in Oregon live in the WRB, the model uses Oregon-wide data as a reasonable indicator of the situation in the Basin.

Predicting urban water price trajectories is complicated not only by long-term infrastructure investment costs, but also by the regulatory and political factors involved in setting water prices, which often cause price increases to lag behind cost increases. Furthermore, when prices are raised to cover higher costs, the effect can be counterproductive to some extent; higher prices may lead to reduced water use, thus reducing the anticipated increase in revenues.

Our reference scenario assumes initial prices that reflect prices in the Basin's major cities in 2010. Future price trends reflect observed recent price increases in many cities (as of 2015), as well as the fact that the backlog of infrastructure needs in Oregon is relatively high. To represent observed price increases, the model implements annual price increases of 6 percent from 2011 to 2015 (in real, inflation-adjusted dollars). To reduce estimated system needs over the next 20 years, from $1,442 per person to $1,050 (the national average observed since 1995), annual per-person revenues would have to increase by an additional $40, or more than 25 percent. Thus, average water prices are assumed to increase 1.5 percent per year from 2016 to 2025. The result is a cumulative price increase between 2010 and 2025 of 55 percent. After 2025, urban water prices (in inflation-adjusted dollars) are assumed to change only in proportion to changing costs. Figure 17 (p. 25) shows these price trends for the nine largest urban areas.

The high infrastructure costs associated with water delivery produce significant "economies of scale." In other words, the average cost of water delivery per household is somewhat lower for large population areas than for small ones (see, for example, USEPA, 2009). The model takes account of the fact that as cities grow, the average cost per household will decline slightly.

The effect of price increases on total household expenditures will be small, as spending on water represents only one-third of 1 percent of household income, and price increases will be offset by reduced consumption of other goods and services. As incomes rise, the share of household income spent on water is expected to decline to less than half the current level (Figure 18, p. 25; and Figure 19, p. 26). For low-income households, however, the cost of water will represent a more significant share of income.

Total urban water use

Population growth is one of the main drivers of increasing urban water use. Another factor that affects urban water use is income growth. As incomes rise, people tend to use somewhat more water (e.g., with bigger houses, yards, and gardens).[9]

Although it is sometimes thought that urban water use is not responsive to changes in price, dozens of economic studies have shown that long-run responsiveness to price is substantial. Indeed, on average, a 40 percent increase in the price of water can be expected to result in approximately a 24 percent decrease in water consumption. See the Appendix for more detail on the impact of price and other factors on water demand.

For four major urban areas (Portland Metro, Salem, Corvallis, and Eugene-Springfield), the WW2100 model consists of separate models for residential and nonresidential urban water demand. For other cities, residential and nonresidential demand are combined.

Per-capita consumption has been declining for the past 20 years, due to price increases and a range of urban water conservation programs (see Appendix for discussion). Model results indicate that per-capita water use (withdrawals) will stabilize at 80 to 100 gallons per person per day, before rising very gradually due to projected growth in per-capita income (Figure 20, p. 26).

For 2015, the model estimates total annual urban water withdrawals of about 330,000 ccf/day (272 million gallons), or 305,000 acre-feet/year. Our projections show this total rising in coming decades for the Basin as a whole, especially for the Portland Metro area, mainly due to population growth (Figures 21 and 22, p. 27; and Figure 23, p. 28).

Given the uncertainty about future urban water prices, the model projects urban water demand under a range of price trajectories. This sensitivity analysis makes it possible to evaluate how different price paths would affect the level of water use in the Portland Metro area and other cities. Basin-wide, if urban water prices were 25 percent higher than those projected

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[9] The model's water demand relationships are based on peer-reviewed economics research, including more than 100 published studies of urban water demand.

in our reference scenario, urban water use would be 12 percent lower than in the reference scenario. With a 50 or 75 percent price hike, the reduction would be 25 percent and 37 percent, respectively (Figure 24, p. 28; Figures 25 and 26, p. 29). Under these scenarios, per-person water consumption in the Portland Metro area would be expected to decline to about 70, 62, and 55 gallons per day, respectively.
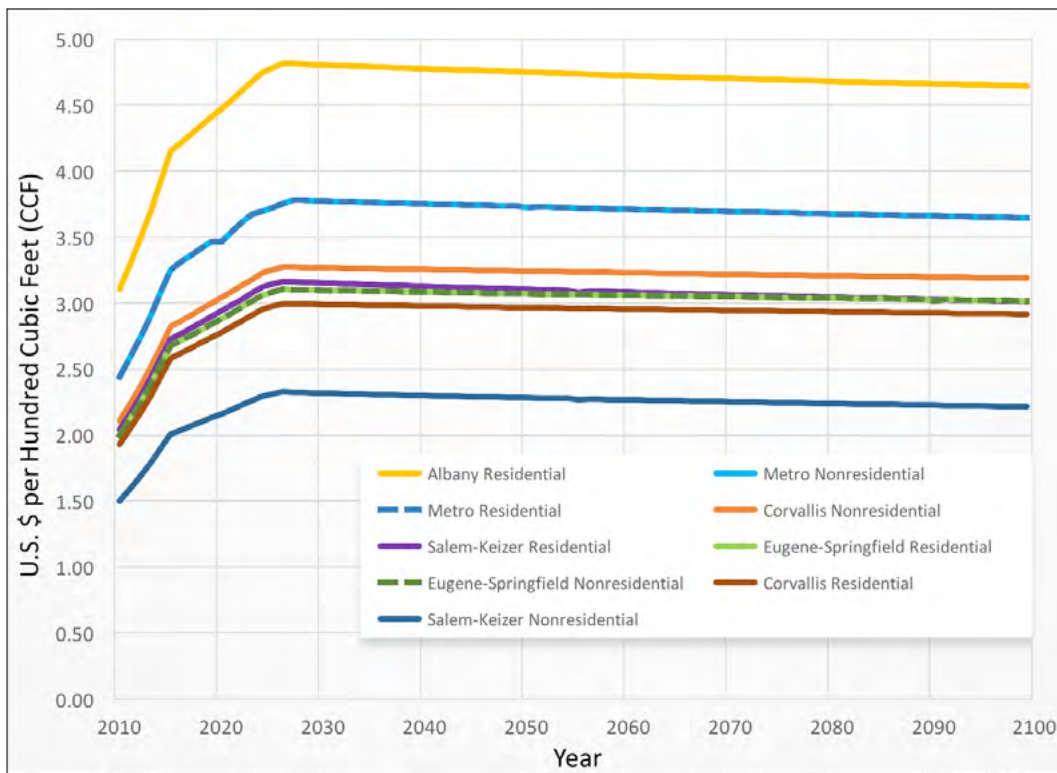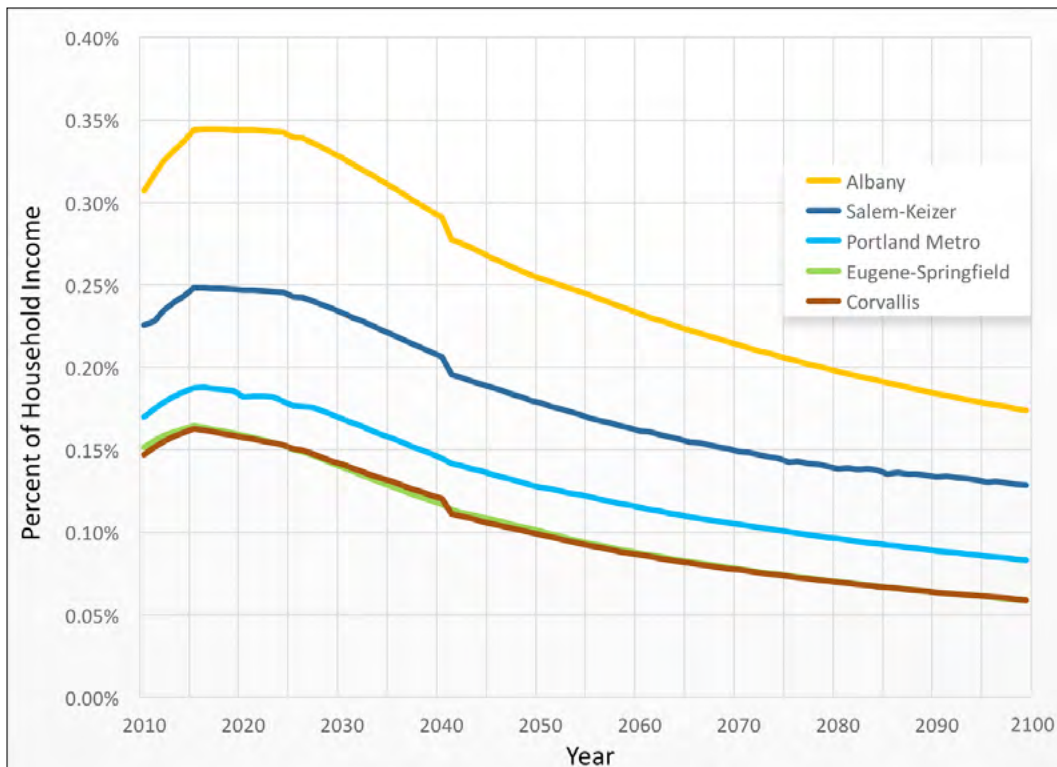

Figure 17. Urban water prices, largest cities

Figure 18. Water expenditures as a share of household income.
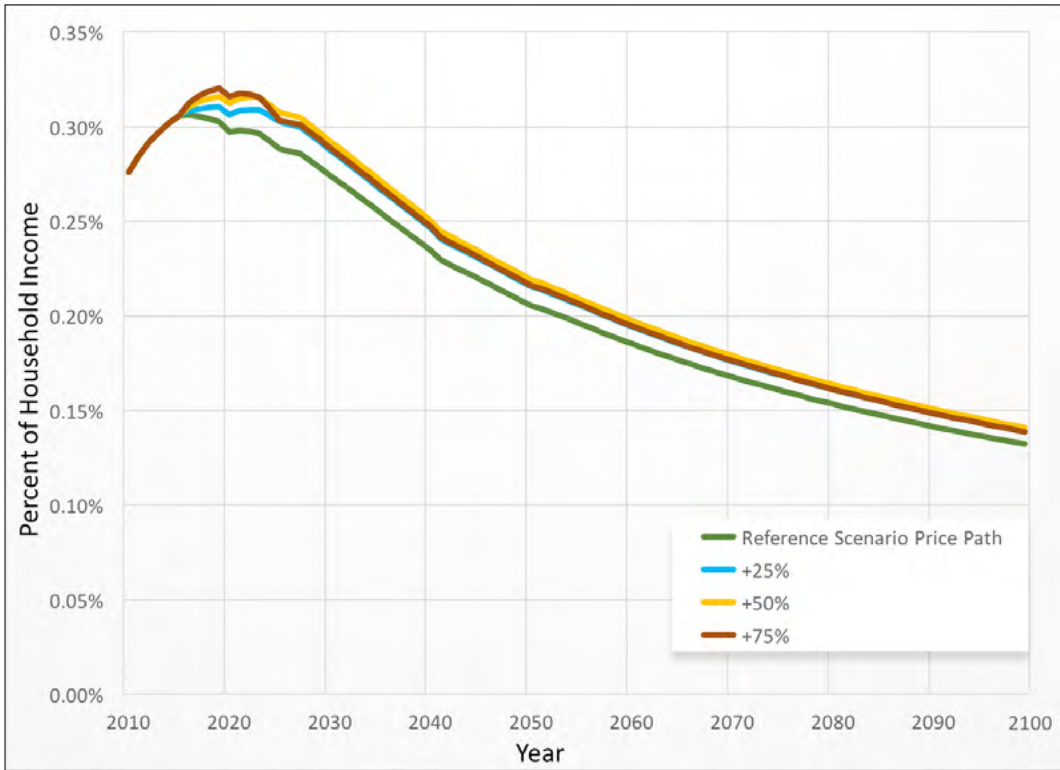
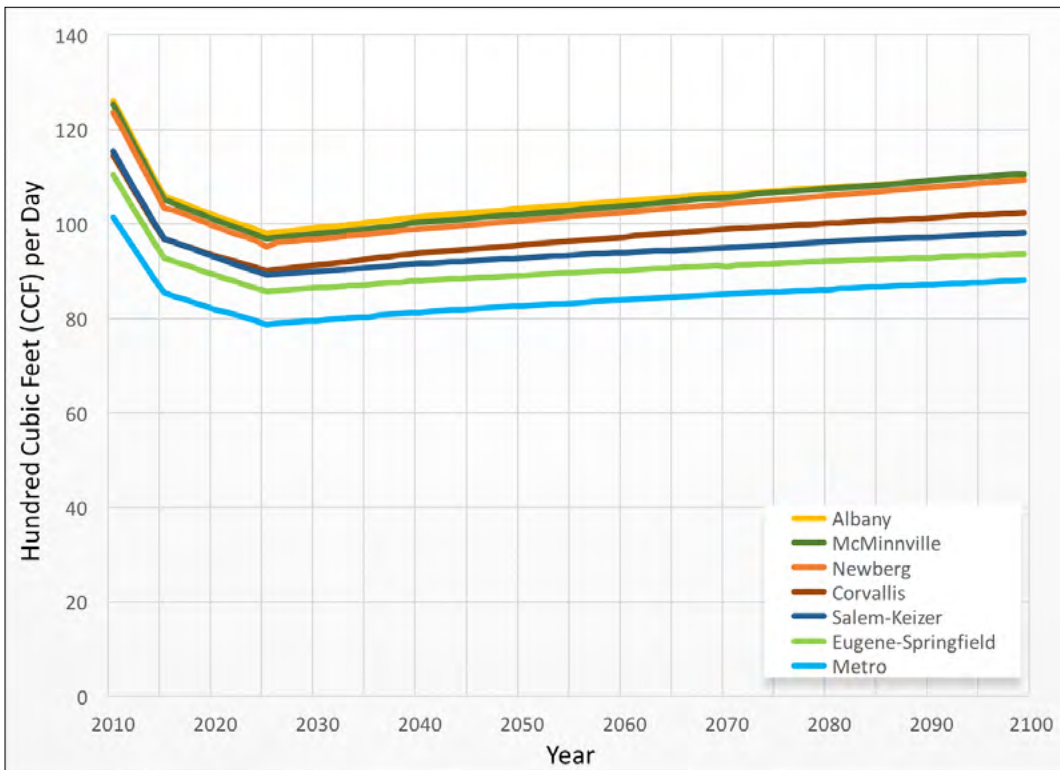Figure 19. Water expenditures as a share of household income, four scenarios.

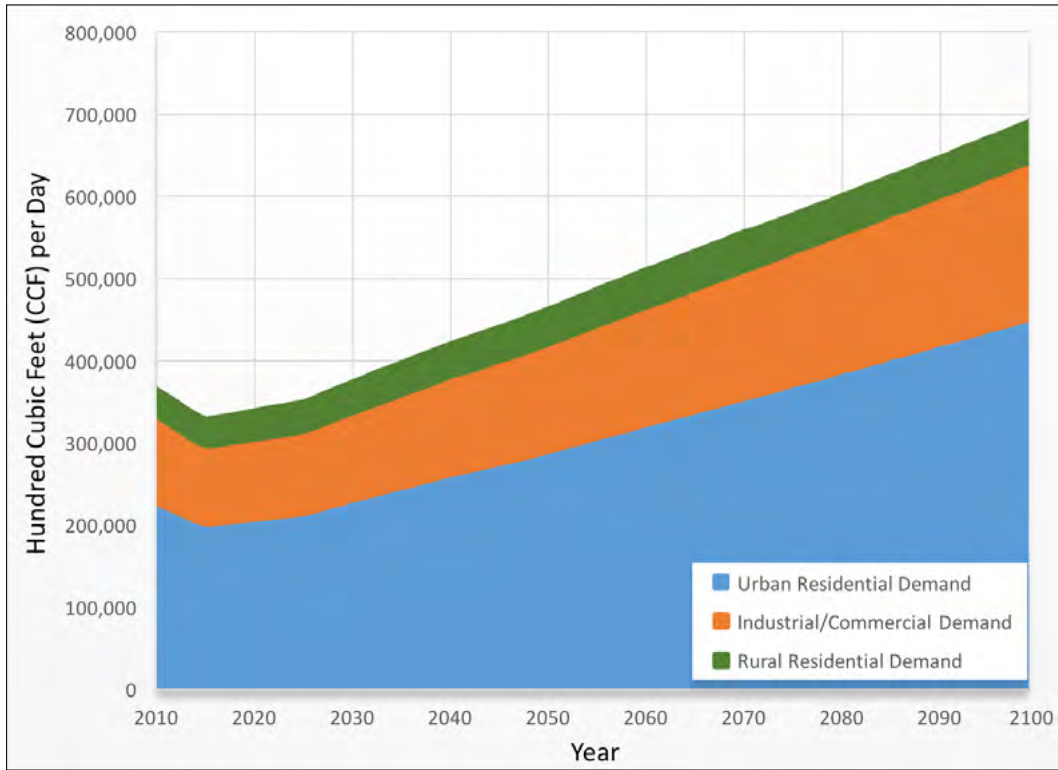Figure 20. Per-capita water use, largest cities.
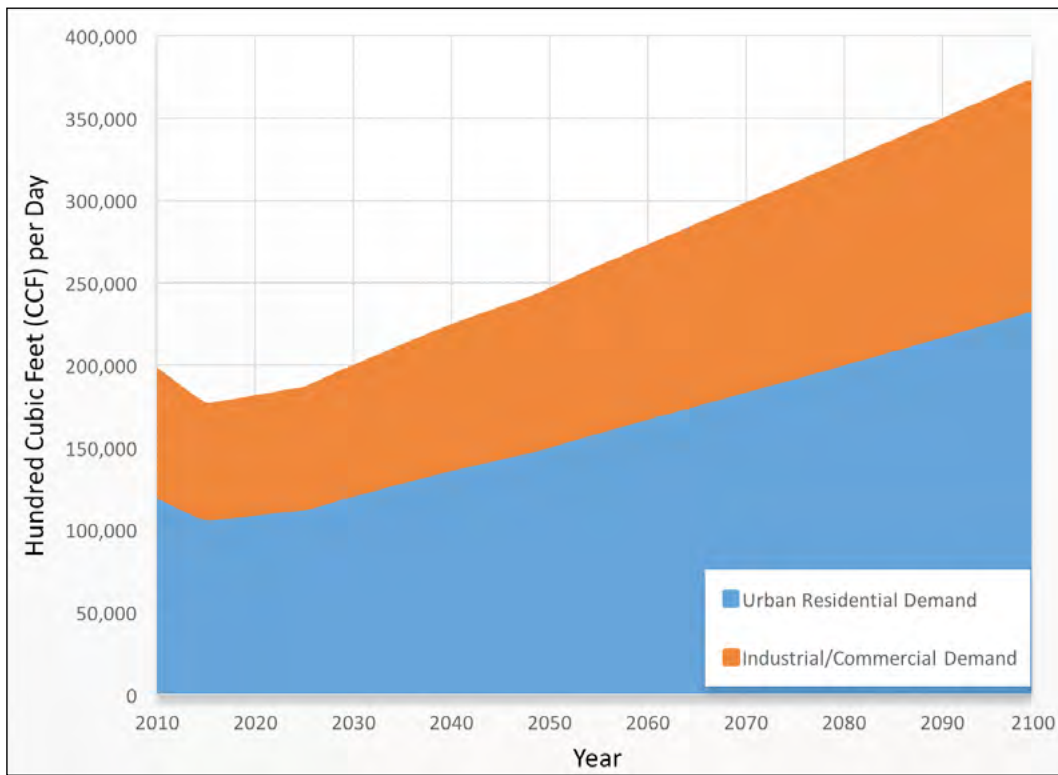
Figure 21. Urban water use, basinwide.

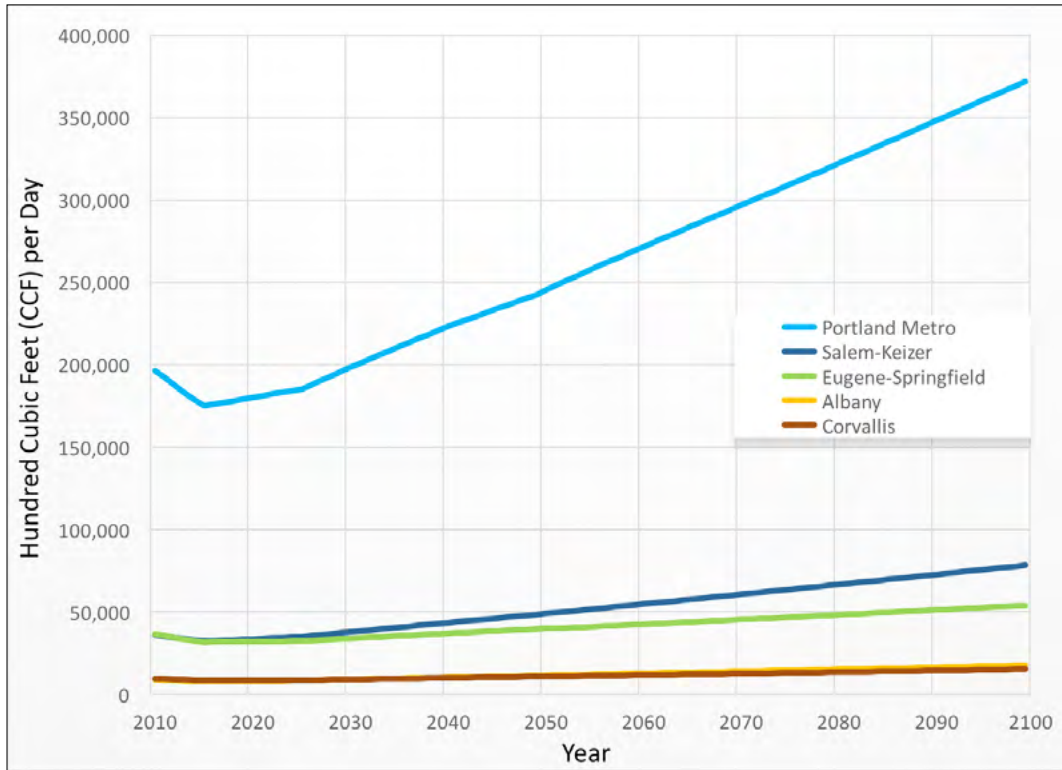

Figure 22. Urban water use, Portland Metro.
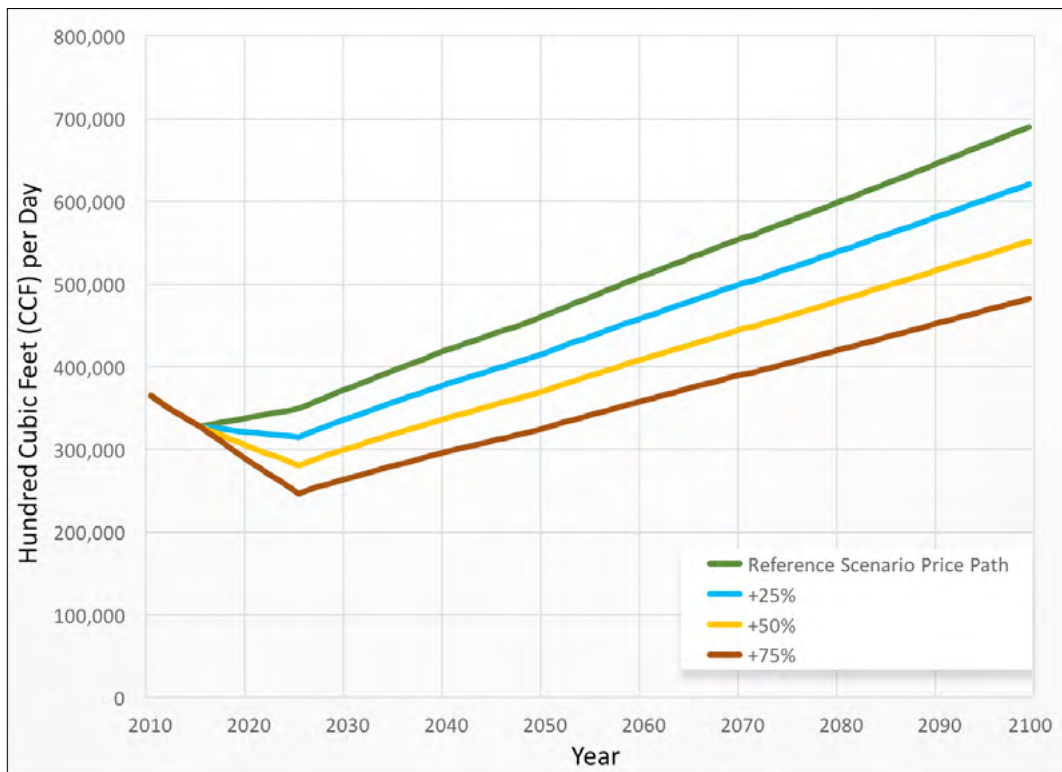
Figure 23. Urban water use, largest cities.

Figure 24. Urban water use for a range of price trajectories (or equivalent regulatory conservation programs), basinwide.
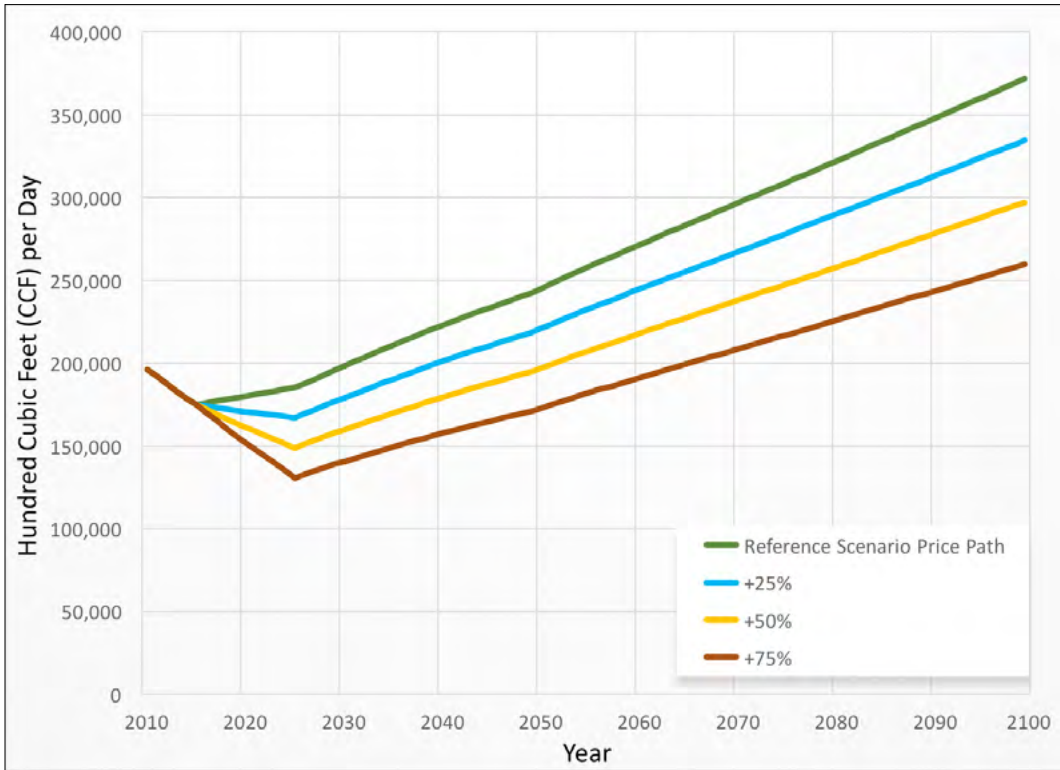
Figure 25. Urban water use for a range of price trajectories (or equivalent regulatory conservation programs), Portland Metro.
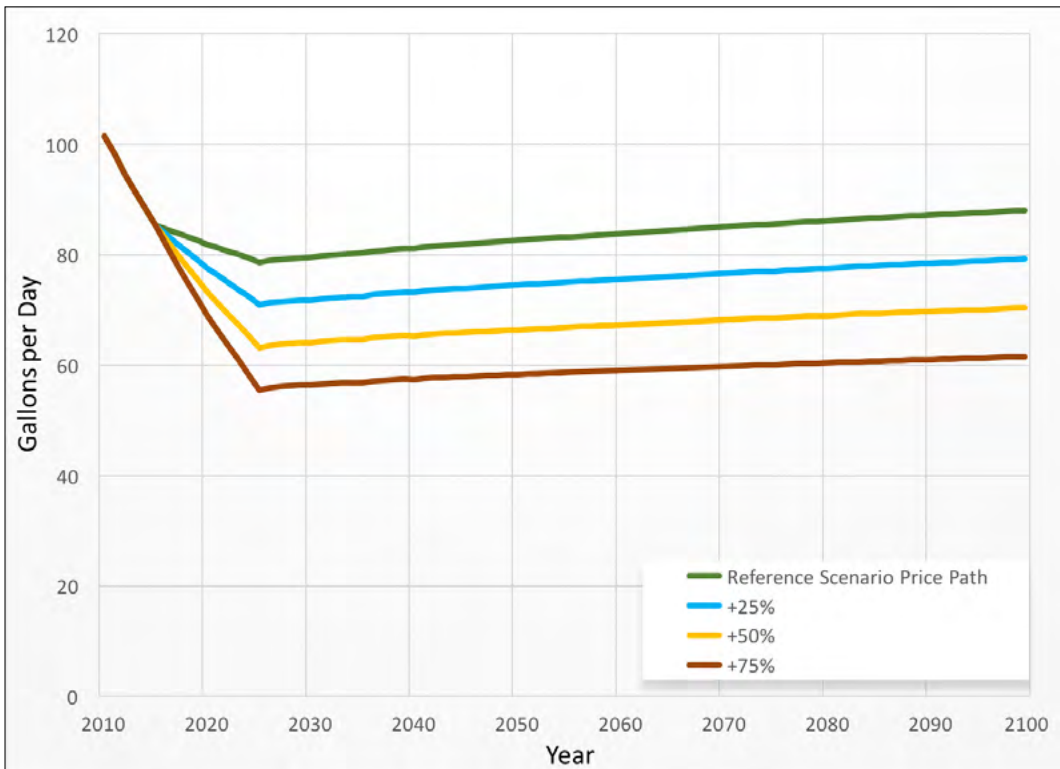

Figure 26. Per-capita urban water use for a range of price trajectories (or equivalent regulatory conservation programs), Portland Metro.

Consumptive use of WRB surface water

Consumptive use of surface water refers to water that is not returned to its source; it is lost to ET, evaporation, or groundwater. In contrast, nonconsumptive use refers to water that is returned via wastewater treatment facilities to streams. Three important factors affect urban consumptive use of surface water in the WRB.

First, urban water use varies significantly between indoor and outdoor uses. Outdoor use is largely consumptive. By contrast, indoor water use is mostly nonconsumptive; the amount of water returned to streams is roughly equal to the amount diverted. Thus, the net use of water in urban areas is significantly less than total diversions (Figure 27, p. 31).

Second, urban water use shows seasonal patterns that reflect the rise and decline of outdoor water use. Whereas indoor water use is assumed to be evenly distributed throughout the year, outdoor water use is assumed to begin at low levels in April, peak in July, and decline to zero in October (Figure 28, p. 31; Figures 29 and 30, p. 32). In the summer, about 40 percent of urban water use is outdoors (consumptive).[10] It is assumed that the seasonal distribution of total demand will not change in future years. For the six largest metropolitan areas in the Basin, our model predicts an increase of 36,800 acre-feet per year in summer outdoor (consumptive) use (Table 1).

Finally, it is important to recognize that nearly half of urban water demand in the WRB is met by water imported from out-of-basin surface-water sources. Most of this water comes from the Bull Run Watershed, located 25 miles east of downtown Portland in the Sandy River Basin on the Mt. Hood National Forest. Bull Run supplies all of the drinking water for the City of Portland and some water to other cities in the Portland Metro area. From June through October, additional water is supplied to the western Metro area from two other out-of-basin sources, Barney Reservoir and Scoggins Reservoir, both on the western side of the Coast Range.[11] As a result, consumptive urban water use from in-basin surface-water sources is less than 10 percent of total urban water deliveries. These different measures of urban water use are reflected in Figures 27 through 30.

Table 1. Change in urban consumptive water use, total and net of displaced irrigation, 2010–2100.

	Change in urban consumptive water use (acre-ft/yr)	Net of displaced surface irrigation (acre-ft/yr)	Net of reduced surface and ground-water irrigation (acre-ft/yr)
Portland Metro area	25,028	17,532	5,833
McMinnville	1,181	(664)	(1,239)
Salem-Keizer	5,992	3,742	802
Albany	1,224	979	318
Corvallis	814	394	(126)
Eugene-Springfield	2,560	2,037	501
Total	36,800	24,021	6,090

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[10] The seasonal pattern of urban outdoor water use is based on 24 years of data from the Portland Water Bureau.

[11] The WW2100 model does not include the climate and hydrology of these out-of-basin areas. Our implicit assumption is that these sources will continue to provide the quantities of water authorized by the corresponding municipal water rights.
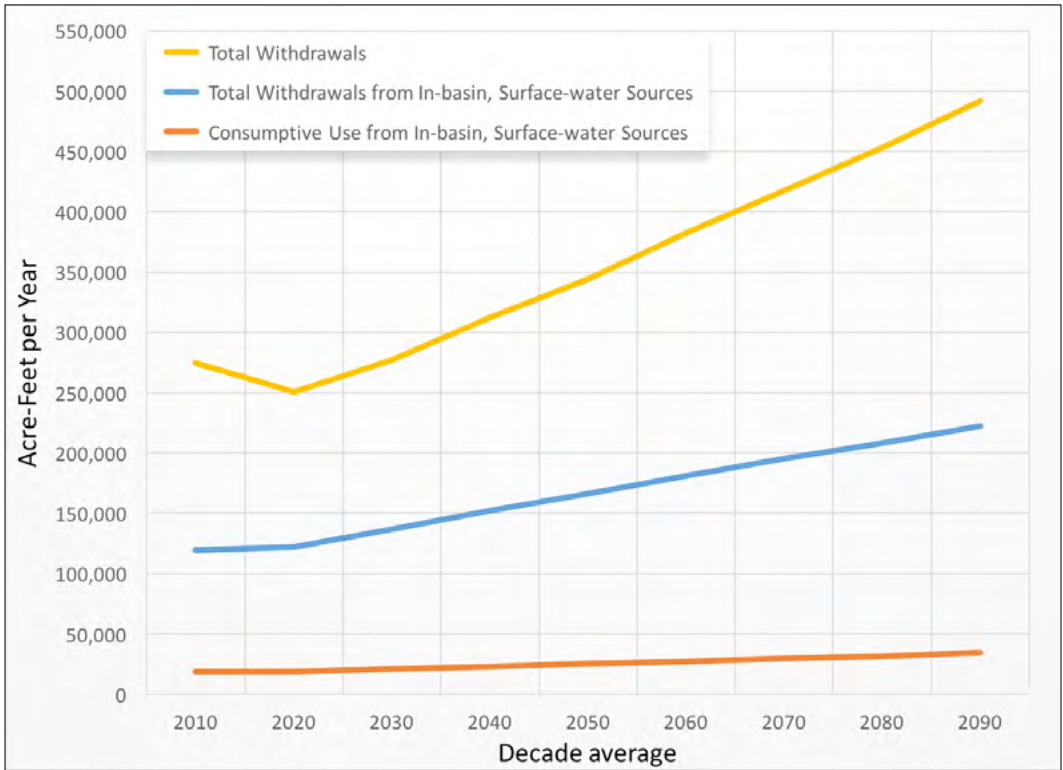
Figure 27. Urban water use, total and from in-basin surface-water sources.
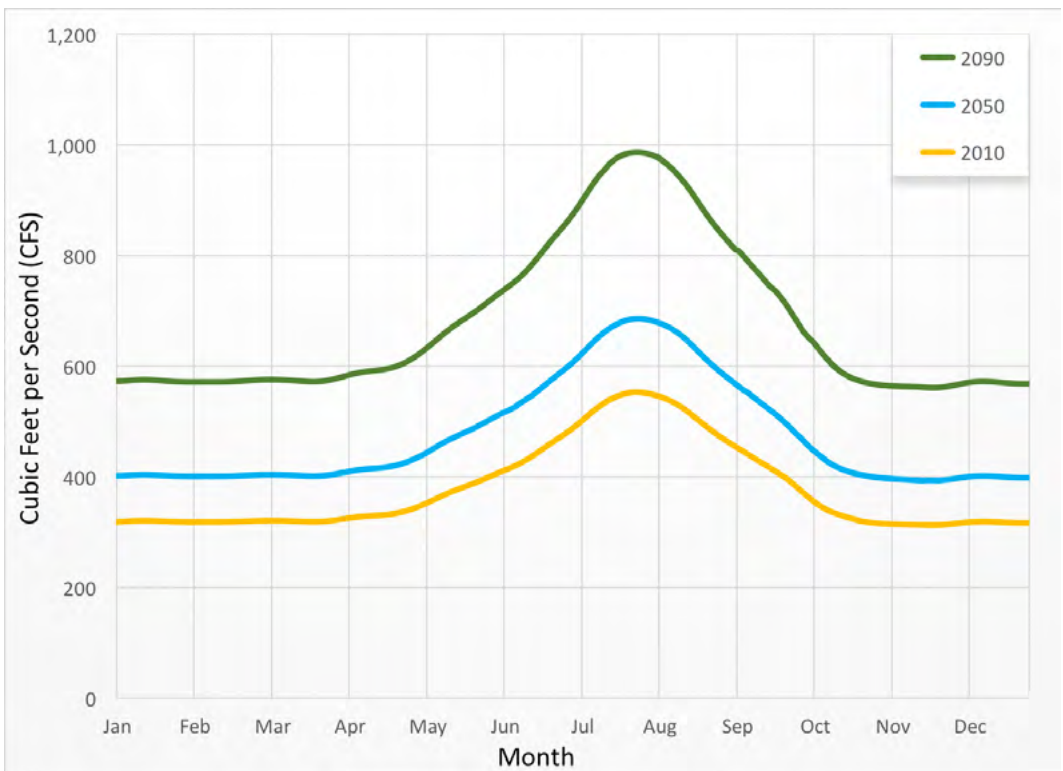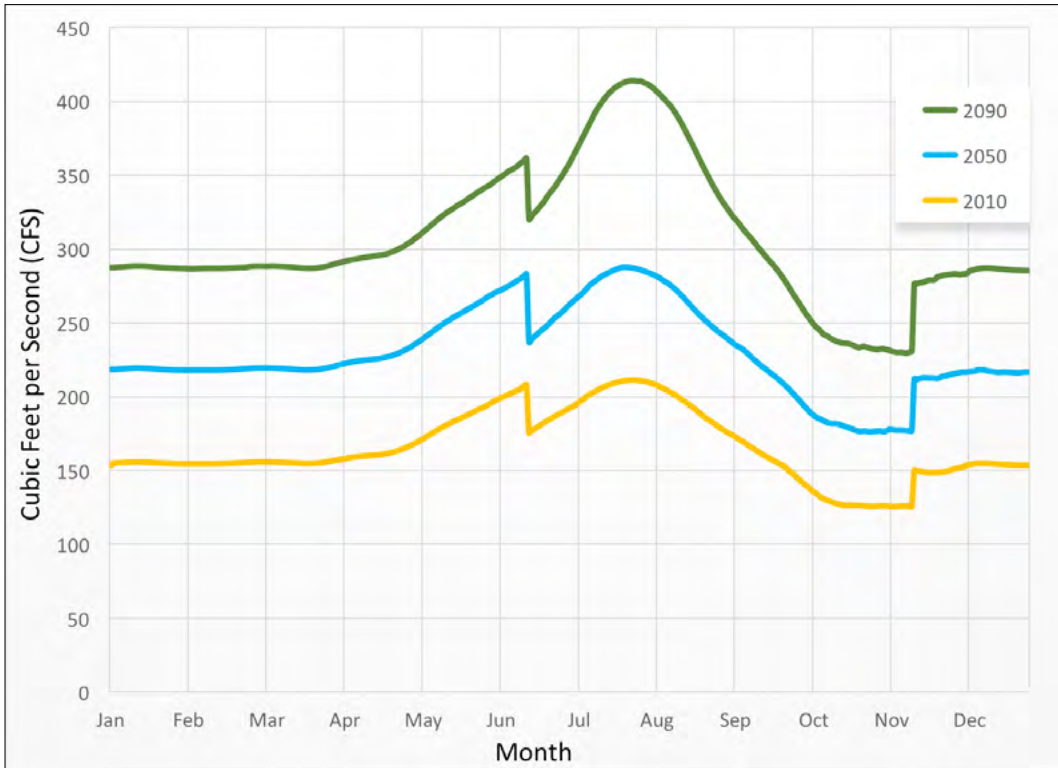

Figure 28. Seasonal urban water use.

Figure 29. Urban water use from in-basin surface-water sources. The jump in water use in June and the corresponding drop in November coincide with the activation and deactivation of water rights for Barney and Scoggins Reservoirs.
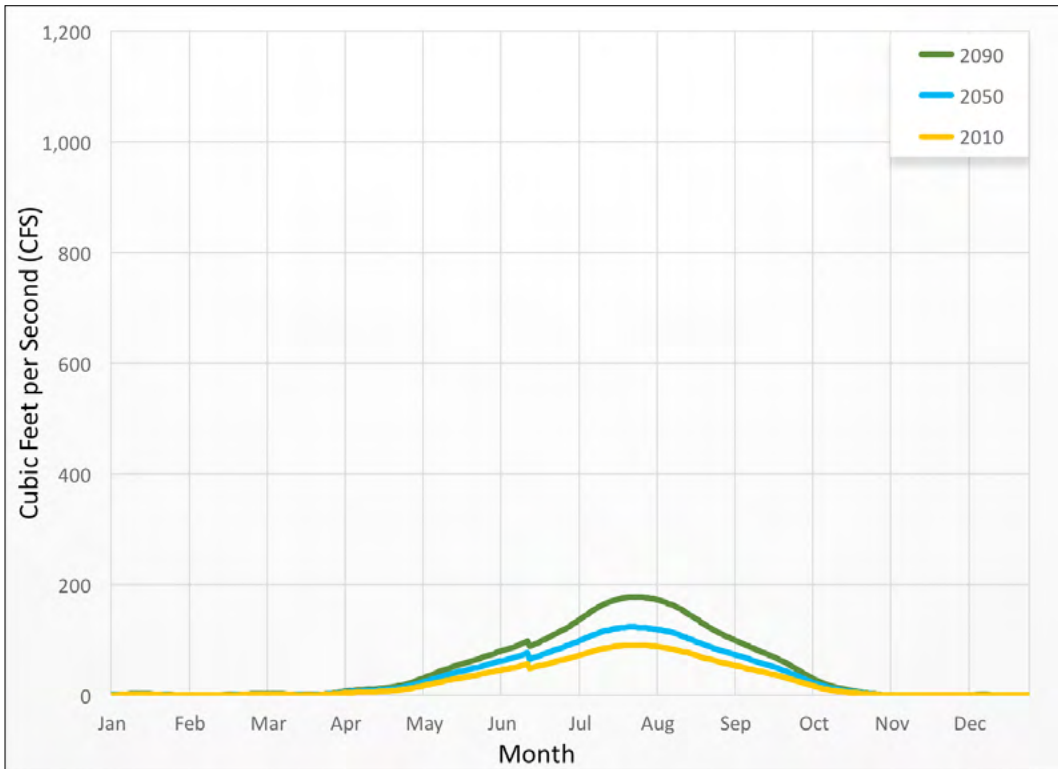

Figure 30. Outdoor (consumptive) urban water use from in-basin surface-water sources.

Effects of climate change on urban water demand

Climate change could affect urban water demand, primarily due to the effects of changing temperatures and precipitation on lawn and garden irrigation, as warmer temperatures may increase the ET rate of grass, flowers, and trees.

Our urban water demand model does not include any adjustment for the direct impacts of climate change on urban vegetation and outdoor water use. However, the agricultural growing season (March–September) corresponds to the seasonal increase in urban water use; thus, we can make inferences based on the effects of climate change on agricultural ET and water use. The model includes ET for grass seed; orchards, vineyards and tree crops; and a broad category of "other crops."

In the reference scenario, the trend in "maximum ET" (the total seasonal ET that occurs if plants always have adequate soil moisture) for agricultural crops is flat, fluctuating slightly around an average of 425 mm (16.7 inches). In the high climate change scenario, maximum ET for agriculture increases about 2 percent between the beginning and end of the century. For grass seed and "other crops," maximum ET decreases slightly. By contrast, the model shows a 24 percent increase in maximum ET for orchards, vineyards, and tree crops.

Assuming that ET for urban vegetation is similar to that of crops, these estimates suggest that climate change will not lead to a significant increase in urban water use in the WRB by the year 2100.[13] Furthermore, the increase in ET for orchards and trees, if comparable to urban tree cover, could be partially offset by planting species with lower water requirements.

Effects of reduced agricultural irrigation on urban water supply

Urban growth will to some extent displace agriculture, including some irrigated lands. The model assumes that irrigation water rights are relinquished or converted to municipal water rights when farmland is converted to urban development. These water rights will help meet the growing demand of cities.

The model projects that displacement of surface-irrigated farmland could offset about one-third of the increase in urban consumptive (outdoor) water use, reducing the net increase to an estimated 24,000 acre-feet.

This effect varies significantly among cities, depending on the extent and direction of urban expansion, as well as on the proximity of the city to surface-irrigated farmland. In Albany, for example, the offset is only 20 percent. In McMinnville, reductions in surface irrigation will more than offset increased urban water use (see Table 1).

Scarcity in urban areas

City governments are understandably concerned about how the growing demand for water will be met. "Live" or natural surface-water flows are already fully appropriated, and currently federal reservoir storage can be allocated only to agriculture. Cities will also compete with in-stream water rights and regulatory flows established under the Endangered Species Act. These requirements represent a large proportion of summer flows and may increase (see "In-stream Flows," page 49).

The results presented in Figure 31 (p. 34) suggest that currently utilized municipal water rights may reach capacity in the Metro area in 30 years. Demand (primarily in summer months) may exceed existing capacity by about 12,000 acre-feet annually by the end of the century. Our model suggests that Salem may reach the capacity of currently utilized water rights in 60 years and may require an additional 3,000 acre-feet per year by the end of the century.

Nevertheless, it appears that municipal water rights will be adequate to meet nearly all of the increased water demand expected through the year 2100 (see Appendix for details). One factor is that many cities rely on out-of-basin water and/or have multiple water rights, some of which are not currently utilized. Unutilized or underutilized sources may include surface water, groundwater, and aquifer storage and recovery. (Cities also plan strategically to have extra or redundant water rights for unexpected circumstances). Not all of these water rights are included in our model. Furthermore, the Tualatin

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[13] Chang et al. (2014) analyzed historical data on daily water use in Portland, Oregon, as well as the effects of variations in temperature on monthly and seasonal use. Their analysis suggests that the effects of climate change on urban water use would be no more than 1 or 2 percent by late in the 21st century.

Valley Water District is constructing a large new water supply system, which will draw water from the Willamette mainstem.[14]

Conditions vary across cities and towns in the WRB and will often differ from the overall or average results summarized here.

Alternative scenarios and urban water use

A number of alternative scenarios were assessed to explore how population and income growth might affect urban water use.

In a high population growth scenario, urban water use increases by almost 20 percent by 2030, 36 percent by 2060, and almost 50 percent by the end of the century, relative to the reference scenario. With high population growth, currently utilized water rights may reach capacity in the Metro area somewhat earlier (intermittently starting in 2017 and permanently from 2032 on). Demand (primarily in summer months) may exceed existing capacity by 47,000 acre-feet per year by the end of the century.

Other urban areas reaching capacity for utilized water rights are Salem (by 2046) and Albany (by 2058), with demand exceeding capacity by roughly 27,000 and 2,800 acre-feet per year by the end of the century, respectively. Conversely, in a scenario in which no population growth is assumed, basinwide urban water use decreases by almost 21 percent by 2030, 38 percent by 2060, and 52 percent by the end of the century, relative to the reference scenario.

In order to assess the importance of income growth, a scenario is included in which income does not change (in real, inflation-adjusted terms). In this scenario, basinwide urban water use is 4 percent lower than in the reference scenario by 2030, 9 percent lower by 2060, and 13 percent lower by the end of the century.

Finally, a scenario is included in which both income and population are kept constant. In this case, basinwide urban water use is 24 percent lower than in the reference scenario by 2030, 44 percent lower by 2060, and 58 percent lower by the end of the century.
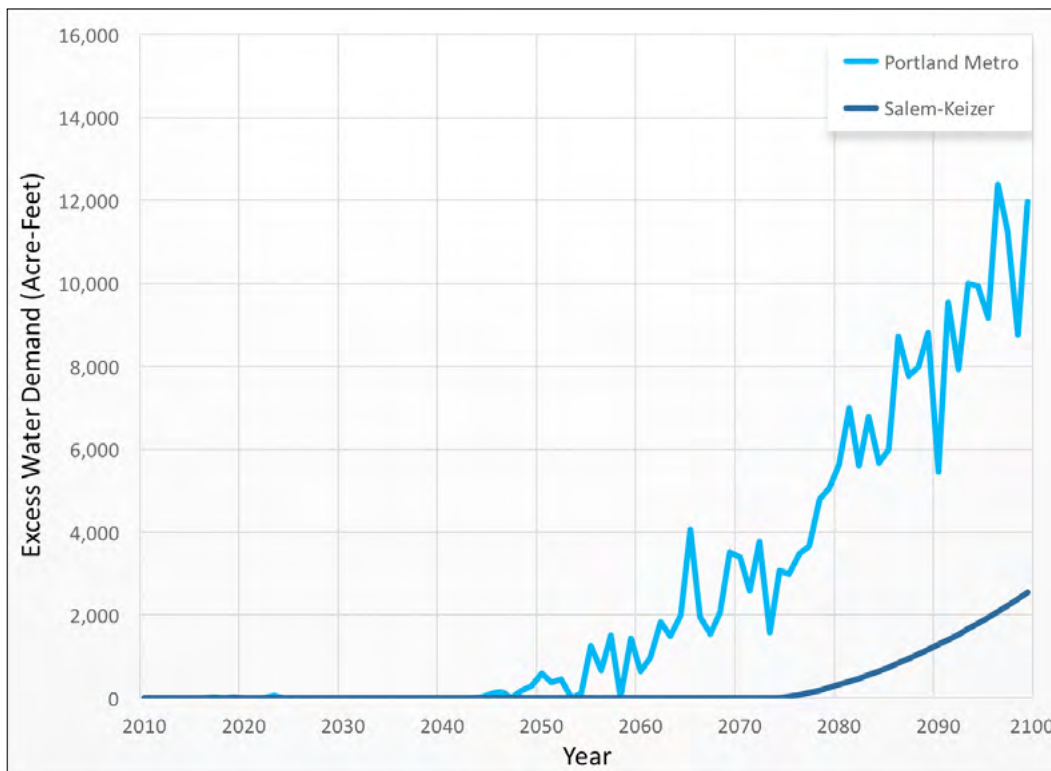

Figure 31. Urban water demand not satisfied by modeled municipal water rights.

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[14] This water right is not included in our model. Scheduled to be completed in 2026, this source will be able to deliver 100 million gallons (more than 36,000 acre-feet) per day during the four peak summer months. It is designed to serve more than 300,000 residents in Beaverton, Hillsboro, and Tigard.