



Baseflow in Oregon

Monitoring to better understand our integrated water supply

Monitoring stream baseflow can provide insight into groundwater contributions to streamflow, aquifer recharge, and long-term groundwater variability and trends. As part of ongoing efforts to study Oregon's water resources, OWRD has partnered with the U.S. Geological Survey to estimate baseflow at stream gages statewide. Initial estimates were published in 2025 (Maher and others, 2025), with additional data collection and refined estimates planned for completion in 2026.

What is baseflow?

How do streams continue to flow when it is not raining? Where does the water in streams come from during summer? The flow that sustains streams between runoff events (storms and snowmelt)—including during the long, dry summers that are typical in Oregon—is called **baseflow**. Baseflow comes from groundwater and other subsurface sources discharging to the stream. Because water moves through the ground much more slowly than across the surface, baseflow acts to “smooth out” the delivery of water to streams across the year, providing flow that supports aquatic ecosystems and water supply during long, dry summers and drought (Figure 1). Globally, it is estimated that between 50 and 60% of streamflow is sustained by groundwater (Winter and others 1998; Xie et al. 2024). In the volcanic regions of the Pacific Northwest, it has been estimated that groundwater supports as much as 64% of streamflow (Curtis, 2019; Curtis and others, 2020).

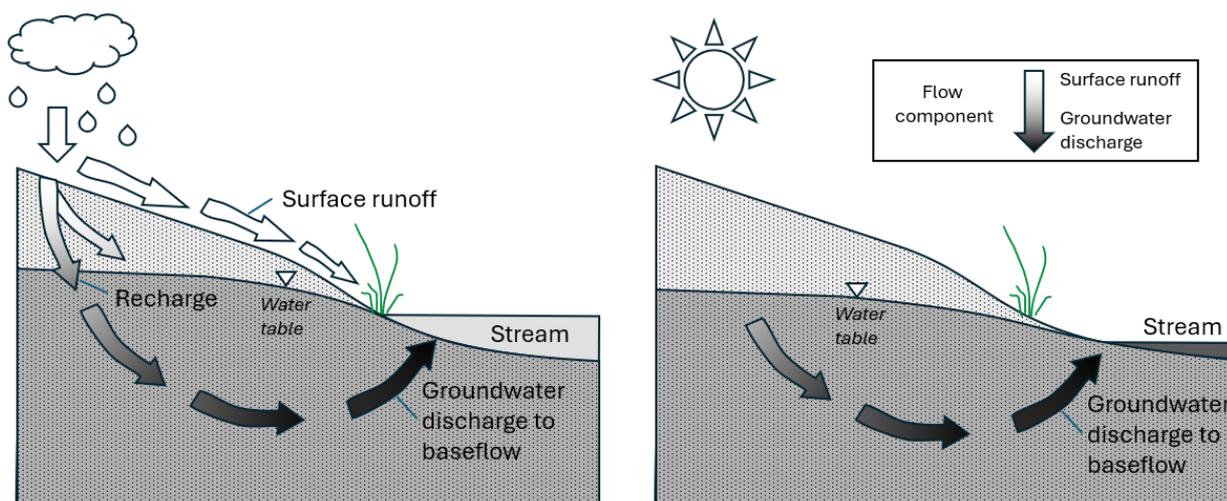


Figure 1: The source of flow to a stream varies with the weather and across seasons. The left diagram shows a rainy period where surface runoff and groundwater discharge are delivering water to the stream. The right shows a dry period where streamflow is relying entirely on groundwater.

Although baseflow estimates may include other subsurface inputs (like drainage from soils), most scientists agree that baseflow estimates can be reasonably interpreted as approximating **groundwater discharge** to the stream. With some caveats, baseflow can thus also serve as a useful estimate of groundwater **recharge**, the flow that replenishes an aquifer (Bredehoeft, 2007). Groundwater recharge varies widely in space and time and there are many pathways that water can

take to reach an aquifer. As a result, it is very difficult to estimate. By using baseflow estimates to refine models that estimate recharge and other water budget parameters, scientists can develop a better understanding of recharge, discharge, and groundwater flow through a basin.

The influence of baseflow on streams can be illustrated by comparing the flow at two different stream gages in the Willamette Basin. The Middle Fork Willamette River near Oakridge (Gage ID 14144800) and the Luckiamute River at Suver (Gage ID 14190500) have similar watershed size and average annual flow, yet very different patterns of flow. The Middle Fork Willamette River near Oakridge (blue in Figure 2) drains gently sloping, highly permeable volcanic rocks that readily absorb precipitation and route it to groundwater (Conlon and others, 2005). As a result, storm peaks are relatively small and summer flows are relatively high. In contrast, the Luckiamute River near Suver (orange in Figure 2) drains steep, relatively impermeable sedimentary rocks in the Coast Range, which limits groundwater infiltration, produces larger storm runoff peaks, and lowers summer streamflow compared to the Middle Fork Willamette River near Oakridge (Conlon and others, 2005).

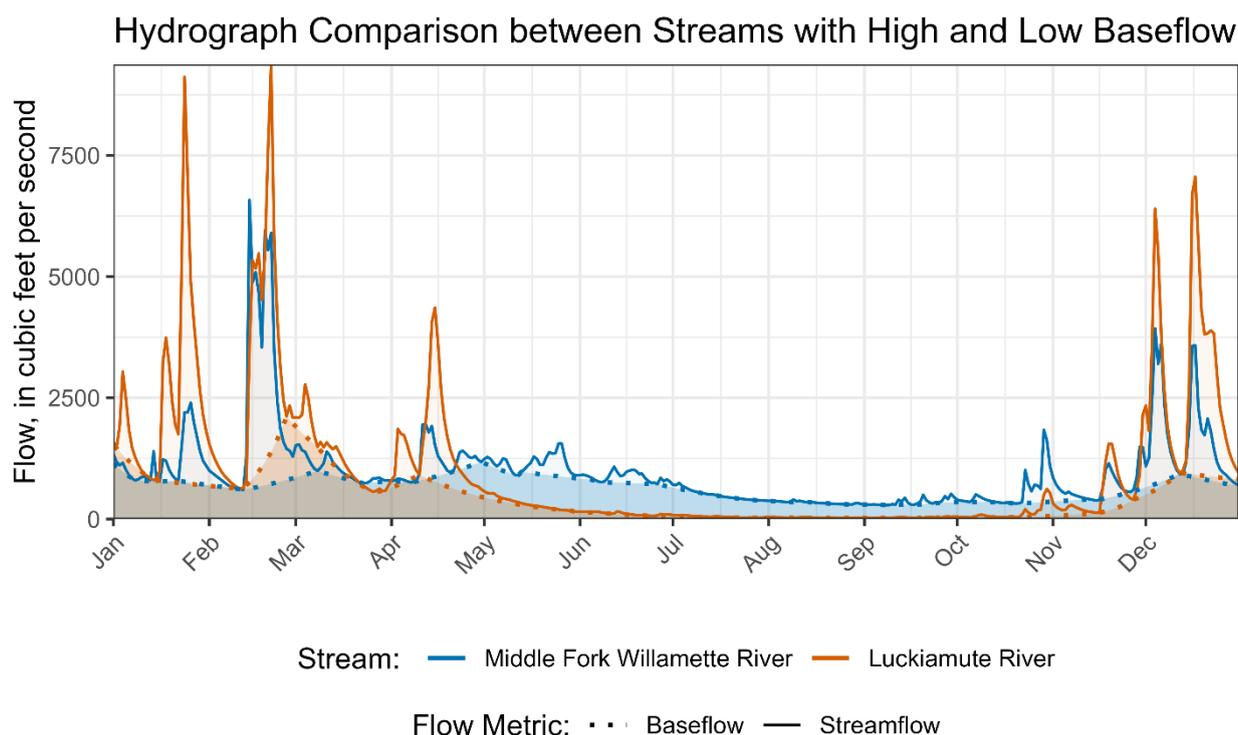


Figure 2: Annual hydrograph showing streamflow (solid line with lighter shading below) and baseflow volume (dotted line with darker shading below) in cubic feet per second throughout a year for the Middle Fork Willamette River near Oakridge (Gage ID 14144800; blue) and the Luckiamute River near Suver (Gage ID 14190500; orange). Data from Maher and others (2025).

These differences can be quantified using the baseflow index (BFI), which represents the percentage of streamflow supplied by groundwater. BFI values range from 0%, indicating flow dominated by surface runoff, to 100%, indicating flow entirely supported by groundwater. Typical BFI at a stream gage worldwide ranges from 40% to 90% (Healy, 2010). The long-term average BFI is about 70% for the Middle Fork Willamette River near Oakridge and about 50% for the Luckiamute River near Suver.

How does baseflow vary across Oregon?

Baseflow varies across Oregon, reflecting the diversity of its climate and hydrogeology. Figures 3 and 4 show baseflow metrics at approximately 380 stream gages across Oregon (Maher and others, 2025). The gages included in the study meet a set of data completeness requirements from 1980 to 2021. Additionally, these gages include only those that represent relatively “natural” stream conditions (Andrews and Stratton Garvin, 2025), because gages measuring stream flow with significant upstream damming or diversion would not provide accurate estimates of baseflow at that location.

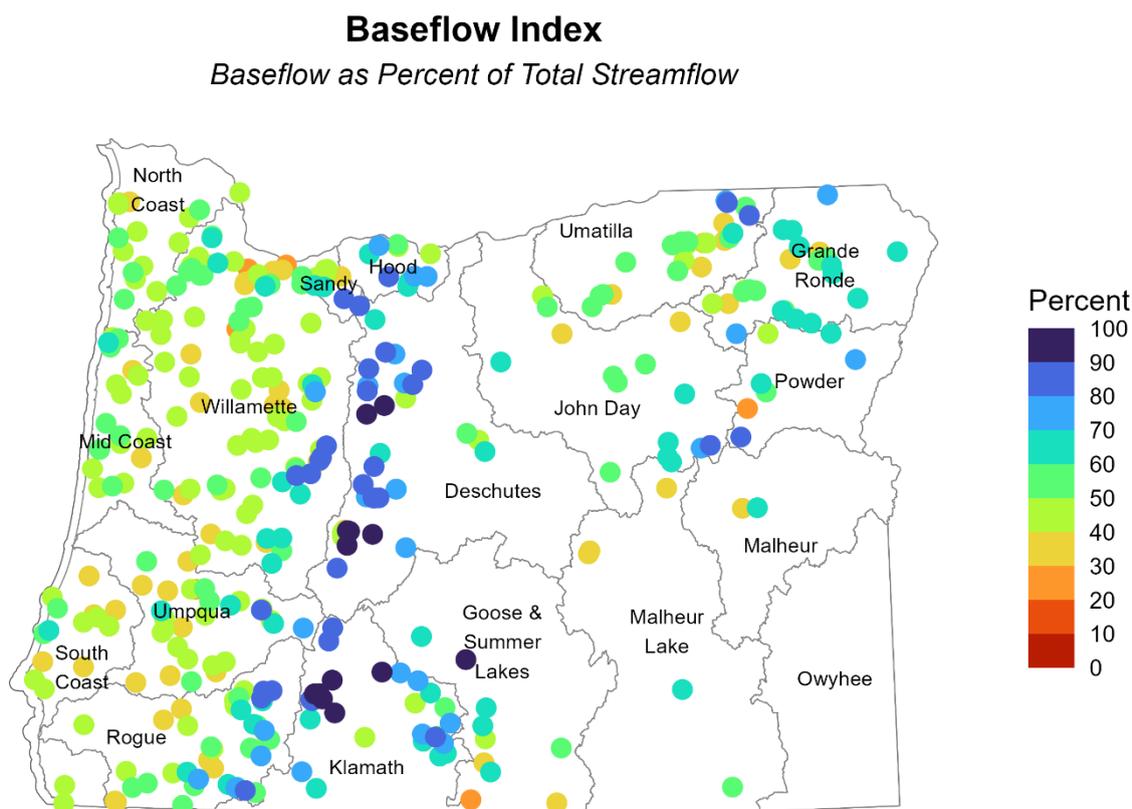


Figure 3: Baseflow Index (BFI), as percent of total streamflow, at 380 gages across Oregon with relatively “natural” streamflow (Maher and others, 2025; Andrews and Stratton Garvin, 2025). Labels and gray boundaries indicate OWRD administrative basins.

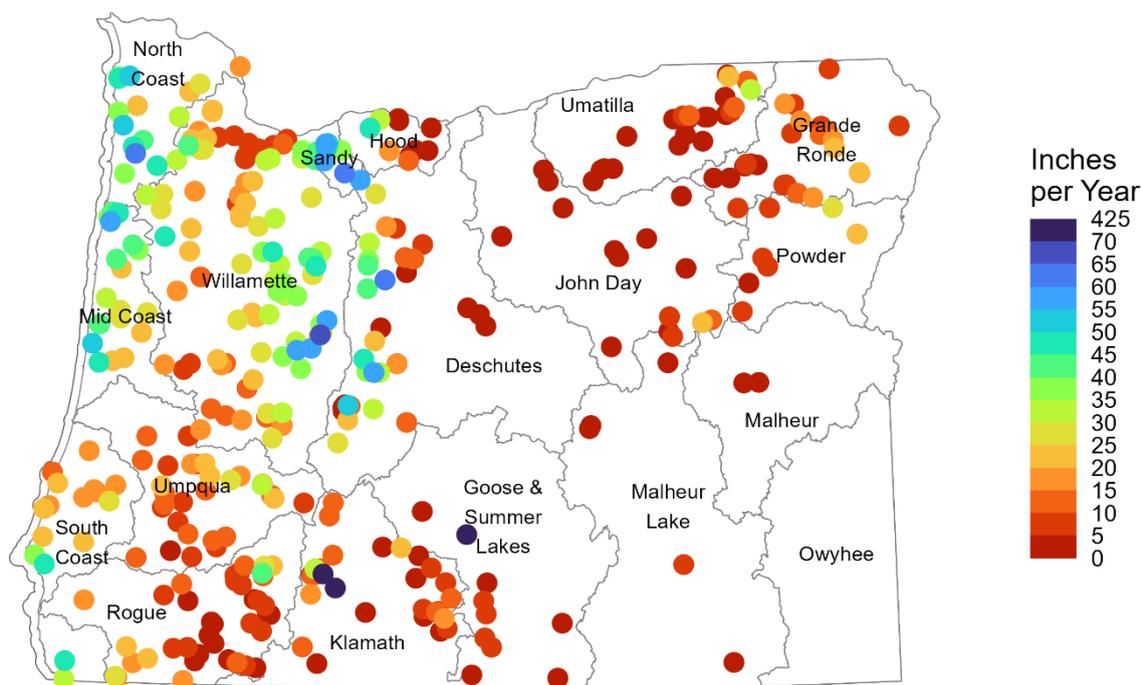
The BFI at measured gages in Oregon ranges from as little as 21% on Dog Creek near Lakeview (Gage ID 11337950) to nearly 100% at springs, such as Browns Creek near La Pine (Gage ID 14054500) or Wood River below Sun Creek near Fort Klamath (gage ID 11502980). The median BFI statewide is 52%.

Locations with high BFI are mostly located along the crest of the Cascade Mountains and in the Blue Mountains of northeastern Oregon. This is likely due to both the prevailing geology in these regions (for example, the Cascade crest is characterized by highly permeable young lavas that promote extensive groundwater recharge) and the high snowpack in these regions, which tends to be lumped with groundwater discharge when using the smoothed-minima method of baseflow estimation.

Gages with low BFI occur throughout the state; in particular, the western third of the state, including the western portions of the Willamette, Umpqua, and Rogue basins, is frequently characterized by lower BFI. Lower BFI is also evident in some parts of northeastern Oregon, including many gages in the Umatilla Basin. These gages likely are characterized by low-permeability watersheds receiving relatively little snow.

Baseflow Yield

Baseflow volume divided by watershed area



Note upper break in scale

Figure 4: Baseflow yield (the area-normalized volume of baseflow) at 380 gages across Oregon with relatively "natural" streamflow, measured in inches per year (Maher and others, 2025; Andrews and Stratton Garvin, 2025). Labels and gray boundaries indicate OWRD administrative basins.

Another way to compare baseflow across the state is to consider the **baseflow yield**, the volume of baseflow estimated at a gage divided by its watershed area. Whereas BFI considers only the percentage of stream flow attributable to baseflow, baseflow yield also varies with total streamflow. Baseflow yield quantity can be measured in depth-equivalent units (inches per year), which how precipitation is usually reported. Normalizing for drainage area allows for comparison between gages measuring vastly different drainage areas.

The distribution of baseflow yield across Oregon is different compared to the BFI. High baseflow yields are concentrated in the Willamette Valley, the Sandy Basin, and the coast (Figure 4). The Rogue and Umpqua Basins, in contrast, have relatively low baseflow yields despite the high BFI observed in their upper basins. Similarly, much of northeastern Oregon shows low baseflow yields. These patterns reflect the distribution of precipitation statewide as well as local basin characteristics such as temperature, topography, and land cover. Some gages in the Goose and Summer Lakes and the Klamath Basins show very high (several hundreds of inches) baseflow yield. This is likely an indication that the "ground-watershed," the area from which groundwater recharge is routed to surface water as stream discharge, is much larger than the mapped surface watershed.

Because gages are typically installed to support specific water management decisions rather than to represent overall basin conditions, extrapolating gage-based baseflow estimates to basin-wide or regional scales may be inappropriate. In particular, fewer gages in eastern Oregon mean a more incomplete understanding of these basins. The Malheur Basin, for example, had only two gages appropriate for baseflow analysis (in contrast to 90 in the Willamette Basin). This gap reflects a real limit in our understanding, but also likely suggests generally low baseflows, as non-perennial streams (streams that do not flow year-round) are less likely to be gaged.

What are we doing to learn more?

Current Limitations

Many approaches to quantifying baseflow have been developed and refined over the past century. Scientists continue to debate which methods are most accurate and appropriate for different applications. As a result, it is common to calculate baseflow using multiple methods to help identify the most suitable approach for a given location.

The baseflow estimates published by the USGS for stream gages across Oregon include results from eight different methods. In general, these are **graphical hydrograph separation** methods that rely on the shape of the hydrograph to separate flow into different components. For example, the “smoothed minima” method used in Figure 2 connects low points in the hydrograph between storm events. Flow below this line is considered baseflow and flow above the line is considered surface runoff (Institute of Hydrology (1980a, b; Wahl and Wahl, 1995; Barlow and others, 2014).

Most scientists agree that graphical hydrograph separation is reasonable in watersheds where precipitation falls primarily as rain. In snow-dominated watersheds, however, graphical baseflow methods tend to include seasonal snowmelt in their estimates of baseflow. As a result, these methods can overestimate groundwater discharge. This limitation makes graphical baseflow estimates in snow-dominated regions less useful and complicates comparisons with baseflow estimates from rain-dominated areas.

New Methods: Chemical Hydrograph Separation

A newer but more data-intensive method to estimate baseflow is called “chemical hydrograph separation,” which uses differences between the chemical signature of groundwater and surface runoff to separate flow into different components (Miller and others, 2014; 2015). Rain and snowmelt tend to have very low specific conductance (the ability of water to conduct electricity). In contrast, groundwater usually has higher specific conductance due to its prolonged contact with rocks and minerals in the subsurface. If these differences are mathematically compared, scientists can determine the amount of flow in a stream that is from surface runoff vs. groundwater.



Figure 5: Water samples ready to be analyzed for specific conductance. Photo credit OWRD.

Many scientists consider chemical hydrograph separation to be more accurate than the older graphical methods because it is based on physical differences as opposed to the plotted shape of a hydrograph. Additionally, unlike the older graphical methods, chemical hydrograph separation can properly separate snowmelt from groundwater.

From 2022 through 2025, OWRD and USGS collected nearly 10,000 discrete specific conductance samples at active stream gages across Oregon (Figure 5). Once completed in 2026, this dataset will be used to develop refined estimates of baseflow at active stream gages across the state. These new estimates will help OWRD refine its understanding of baseflow and recharge statewide, particularly in snow-dominated basins across the state.

Contact

For more information on baseflow or OWRD's efforts to better understand recharge and groundwater discharge statewide, contact Laurel Stratton Garvin, laurel.e.strattongarvin@water.oregon.gov.

References

- Andrews, R., and Stratton Garvin, L.E., 2025. Development of a flow management index for gaged watersheds in Oregon. Oregon Water Resources Department Open-File Report 2025-01, 26 p. [Available at [https://www.oregon.gov/owrd/publicationsandreports/Pages/default.aspx?wp899=so:\[\[79318,0\]\]](https://www.oregon.gov/owrd/publicationsandreports/Pages/default.aspx?wp899=so:[[79318,0]])]
- Barlow, P.M., Cunningham, W.L., Zhai, T., and Gray, M., 2014. U.S. Geological Survey groundwater toolbox, a graphical and mapping interface for analysis of hydrologic data (version 1.0)—User guide for estimation of base flow, runoff, and groundwater recharge from streamflow data: U.S. Geological Survey Techniques and Methods 3–B10, 27 p., <https://doi.org/10.3133/tm3B10>
- Bredehoeft, J., 2007. It is the discharge. *Groundwater* 45(5), 523. <https://doi.org/10.1111/j.1745-6584.2007.00305.x>
- Conlon T.D., Wozniak, K.C., Woodcock, D., Herrera, N.B., Fisher, B.J., Morgan, D.S., Lee, K.K., and Hinkle, S.R., 2005, Ground-Water Hydrology of the Willamette Basin, Oregon: U.S. Geological Survey Scientific Investigations Report 2005–5168, 83 p. [Available at <https://pubs.usgs.gov/sir/2005/5168/>]
- Curtis, J.A., 2019, Streamflow, Runoff and Baseflow Estimates for Gaged Basins in the Northwest Volcanic Aquifer Study Area, USA, 1904 to 2015: U.S. Geological Survey data release, <https://doi.org/10.5066/P9WWKST1>
- Curtis, J.A., Burns, E.R., and Sando, R., 2020. Regional patterns in hydrologic response, a new three-component metric for hydrograph analysis and implications for ecohydrology, Northwest Volcanic Aquifer Study Area, USA. *Journal of Hydrology: Regional Studies* (30), 100698, <https://doi.org/10.1016/j.ejrh.2020.100698>
- Healy, R.W., with contributions by Scanlon, B.R. 2010. Estimating groundwater recharge. New York, New York: Cambridge University Press, 245 p.
- Institute of Hydrology, 1980a, Research report, v. 1 of Low flow studies: Wallingford, United Kingdom, Institute of Hydrology, 42 p.
- Institute of Hydrology, 1980b, Catchment characteristic estimation manual, v. 3 of Low flow studies: Wallingford, United Kingdom, Institute of Hydrology, 27 p.
- Maher, A., Gingerich, S.B., Grabowski, J.D., Johnson, H.M., and Garcia, C.A., 2025, Statewide base-flow estimates for Oregon, water years 1980–2023: U.S. Geological Survey data release, <https://doi.org/10.5066/P17DGTTB>
- Miller, M.P., Susong, D.D., Shope, C.L., Heilweil, V.M., and Stolp, B.J., 2014. Continuous estimation of baseflow in snowmelt-dominated streams and rivers in the Upper Colorado Basin: A chemical hydrograph separation approach. *Water Resources Research* 50(8), 6986-6999. <https://doi.org/10.1002/2013WR014939>
- Miller, M.P., Johnson, H.M., Susong, D.D., and Wolock, D.M., 2015. A new approach for continuous estimation of baseflow using discrete water quality data: Method description and comparison with baseflow estimates from two existing approaches. *Journal of Hydrology* 522, 203-210. <https://doi.org/10.1016/j.jhydrol.2014.12.039>
- Wahl, K.L., and Wahl, T.L., 1995, Determining the flow of Comal Springs at New Braunfels, Texas, in Proceedings of Texas Water 95, August 16–17, 1995, San Antonio, Tex.: American Society of Civil Engineers, p. 77–86
- Winter, T.C., Harvey, J.W., Franke, O.L., and Alley, W.M., 1998. Ground water and surface water: a single resource. U. S. Geological Survey Circular 1139, 79 p. [Available at <https://pubs.usgs.gov/circ/circ1139/>]
- Xie, J., Liu, X., Jasechko, S., Berghuijs, W. R., Wang K., Liu, C., Reichstein, M., Jung, M., and Koirala, S., 2024. Majority of global river flow sustained by groundwater. *Nature Geoscience* 17, 770–777. <https://doi.org/10.1038/s41561-024-01483-5>