# 2023

# PACIFIC NORTHWEST WATER YEAR

## IMPACTS ASSESSMENT

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Supported by the NOAA National Drought Information System

ON THE COVER: Cascade Mountains in Bend, Oregon.

ON THE BACK: Three Sisters mountains, Oregon.

Credit: Wasim/Adobe Stock

## Executive Summary

Aerial view of the Owyhee river, Lake and Reservoir near Adrian, Oregon, Credit: Bob/Adobe Stock

# EXECUTIVE SUMMARY

## Regional Water Year Conditions

- Over the 2023 water year (October 1, 2022-September 30, 2023), drought worsened across most of Washington, the Idaho panhandle, and northwestern Oregon. In contrast, drought improved or was eliminated in southern Idaho, southeastern Oregon, and south central Oregon (*Figure ES1*).
- Averaged across Idaho, Oregon, and Washington (the Pacific Northwest; PNW), the 2023 water year average temperatures were near the 1991-2020 normal and total precipitation was slightly below normal. Precipitation was below normal in the northwestern PNW and above normal in the southeastern PNW. These sub-regional differences aligned with the areas of worsening and improving drought, respectively.
- Summer of 2022 extended well into the start of the 2023 water year. Across the PNW, October ranked as the 3rd warmest and tied as the 32nd driest since records began in 1895.
- Regional temperatures were well below normal from February through April (tied 1956 as the 14th coolest), but well above normal in May.
- Across the PNW, May 2023 ranked as the 3rd warmest since records began in 1895 (*Figure ES2*), which caused snowpack to melt rapidly and earlier than usual across Washington and the Idaho panhandle.
- At the end of August, remnants of Tropical Storm Hilary brought unseasonably heavy precipitation across southern Idaho and eastern Oregon, filling reservoirs, increasing streamflows, and temporarily reducing evapotranspiration.

## Impacts

- Water supply, irrigation, and hydropower generation during May were affected by high temperatures mid-month and the associated rapid snowmelt. In western Washington and Oregon, these early season conditions and impacts worsened over the course of summer.
- High temperatures and dry conditions in May, followed by above normal temperatures throughout summer, required some agricultural producers to adjust the timing of irrigation or stop irrigation prematurely. Agricultural producers of hay, apples, and vegetables reported reductions in crop quantity or quality, and livestock producers reported reductions in the quantity or quality of forage.
- Drought in the northwestern PNW substantially reduced water supply for many drinking water providers, especially those in western Washington, who responded primarily with voluntary water restrictions. Only a few providers experienced conditions that required mandatory water restrictions.
- The combination of a colder than average winter, rapid spring snowmelt, and dry summer caused lower than normal hydropower production in portions of the PNW, particularly in Washington, where some reservoirs did not refill.
- Runoff from the above normal snowpack in southern Idaho together with the heavy precipitation associated with the remnants of Tropical Storm Hilary refilled reservoirs and reduced irrigation demand during the cooler and wetter parts of the irrigation season.

## Response Actions

- Drought declarations were issued from February 2023 through November 2023 for 13 Oregon counties. Washington issued a statewide drought advisory and a drought declaration for parts of 12 counties in July. Idaho did not declare drought.

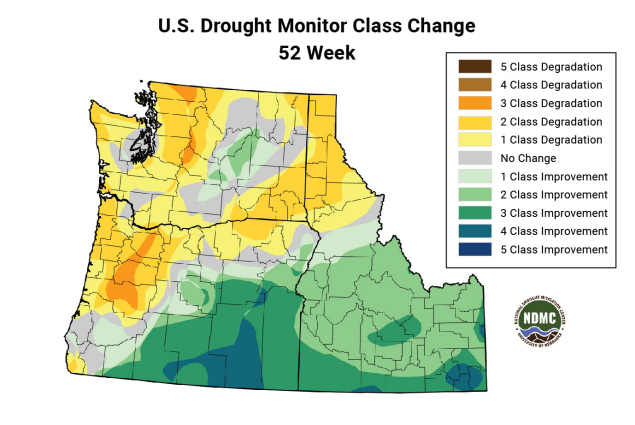



**Figure ES1: Change in U.S. Drought Monitor classifications from the beginning of the 2023 water year (October 4, 2022) to the end of the water year (October 3, 2023). Source: *U.S. Drought Monitor*.**

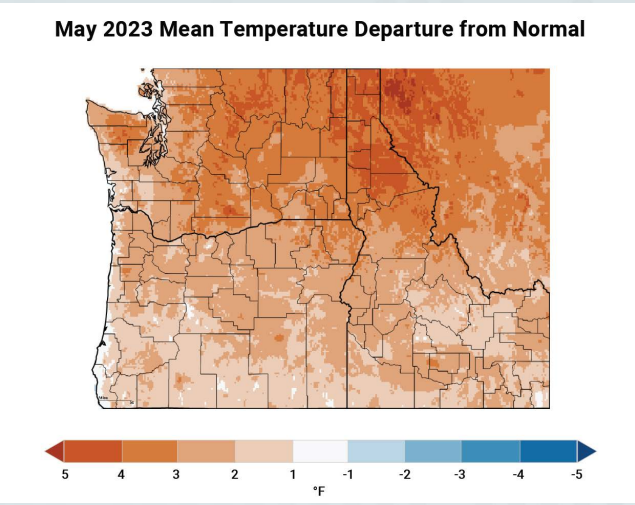



**Figure ES2: May 2023 average temperature departures from the 1991-2020 normal. Source: PRISM data through the *WestWide Drought Tracker*.**

- Responses to the annual Pacific Northwest Water Year Impacts Survey showed that 50% or more of respondents across all sectors are changing their long-term operations in response to trends in seasonal conditions. Fewer respondents are proactively changing operations on the basis of outlooks and forecasts, but several respondents are changing their communications and outreach when drought conditions are anticipated.

# 1 PURPOSE

The purpose of the fourth Pacific Northwest (PNW) Impacts Assessment is to summarize the water year[1] conditions and sector impacts as a resource for future management of drought and other climate extremes. We gathered the information presented in this assessment in three main ways. First, we held two separate but similar annual Water Year Recap and Outlook meetings, one focused on Washington and Oregon and one on Idaho. The meeting objectives were to summarize the climate during the previous water year and to review climate and weather-related impacts of drought and other extremes on various sectors. Second, the University of Washington Climate Impacts Group distributed the Annual Pacific Northwest Water Year Impacts Survey. Third, we summarized Condition Monitoring Reports from Community, Collaborative Rain, Hail, and Snow Network volunteers and Condition Monitoring Observer Reports (CMOR) submitted to the National Drought Mitigation Center (NDMC) during the 2023 water year.

**The purpose of this assessment is to summarize the water year conditions and sector impacts as a resource for future management of drought and other climate extremes.**

The assessment primarily reflects the information from the meeting discussions, surveys, and the authors' expertise. We focus on the warm and dry start to the water year, the relatively dry and cold winter, record warm May and associated rapid snowmelt, heavy precipitation from the remnants of Tropical Storm Hilary, and their associated impacts.

1 A water year is defined as the 12 months beginning on October 1 of the previous year and ending on September 30.

# 2 LESSONS LEARNED

**Lesson 1: Seasonal temperature anomalies had a greater effect than precipitation on water supply during two key portions of the water year.** Below normal temperatures in February through April, which ensured that precipitation fell as snow at high elevations, were critical for building snowpack despite drier than normal conditions in Washington, the Idaho panhandle, parts of the northern Cascade Mountains in Oregon, and parts of southern Idaho. In contrast, above normal May temperatures that included a heat wave mid-month caused the snowpack to melt rapidly and altered the water supply situation, particularly in western Washington, the Idaho panhandle, and northwestern Oregon, where summer precipitation was also below normal. These conditions illustrate the extent to which temperature alone can drive water supply impacts. This result is relevant to the region because projections of future warming are certain but projections of precipitation are less certain. The temperature-driven water supply conditions negatively affected all sectors, yet response actions among those sectors also showed how the region is building resilience.

**Lesson 2: Monthly and seasonal forecasts showed skill during at least one critical period during the 2023 water year, but still more could be gained from better sub-seasonal forecasts.** The NOAA Climate Prediction Center's monthly May outlook accurately forecasted the warmer than normal May temperatures across the northern tier of the PNW. Monthly and seasonal outlooks earlier in the water year were calling for below normal temperatures, so the May forecast released in April 2023 was able to capture that shift in anomalies. Still, within season fluctuations in spring temperatures and precipitation affected agriculture, hydropower generation, and perhaps other sectors.

**Lesson 3: Within season fluctuations in weather require more intensive monitoring of water conditions such as soil moisture and well water levels.** For example, a shift from warmer than normal May temperatures to colder than normal temperatures later in June caused the irrigation system of one agricultural producer to apply more water than was optimal for their apple, cherry, and pear orchards. More-frequent sampling or better spatially distributed monitoring networks could have helped reduce water consumption and mitigate impacts to agriculture, drinking water, and fisheries.

**Spring orchard near Hood River, Oregon with Mt. Adams in Washington in background. Credit: Jim Choate/Creative Commons**

# 3 WATER YEAR EVOLUTION

## WATER YEAR 2023 AT A GLANCE*


**42nd** warmest (tied with 1968, 2001); -0.6°F

**40th** driest; –2.59" (92% of normal)


**23rd** warmest (tied with 1961, 2006); +0.2°F

**20th** driest; -6.72" (84% of normal)


**60th** warmest (tied with 1914, 1989); -1.1°F

**58th** wettest; +0.54" (102% of normal)

*Anomalies relative to 1991–2020 normal; records since 1895 (Source: NOAA NCEI 2023)

## Water Year Summary

**The PNW 2023 water year temperatures were near-normal and total precipitation was below normal. The 2023 water year tied three water years as the 40th warmest and was the 35th driest.**

The PNW 2023 water year temperatures were near-normal and total precipitation was below normal.[2] Averaged across the PNW, the 2023 water year tied three water years (1959, 1978, and 2002) as the 40th warmest (-0.6°F) and, with 92% of normal precipitation, was the 35th driest.[3]

2 Unless otherwise noted, this assessment uses 1991-2020 as the baseline and ranks each water year relative to the full historical record, beginning with 1896.

3 NOAA National Centers for Environmental Information (NCEI). Climate-at-a-Glance: Statewide Time Series. Published December 2023. Retrieved in December 2023 from: https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance. All monthly and seasonal rankings in this assessment are from this source.

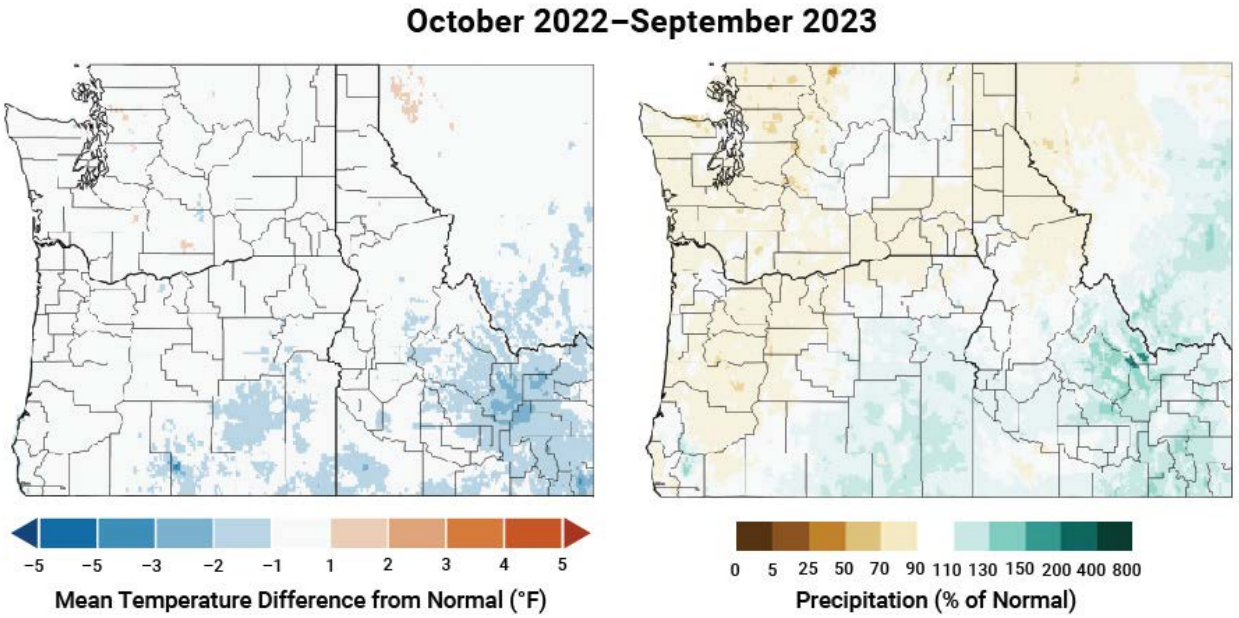


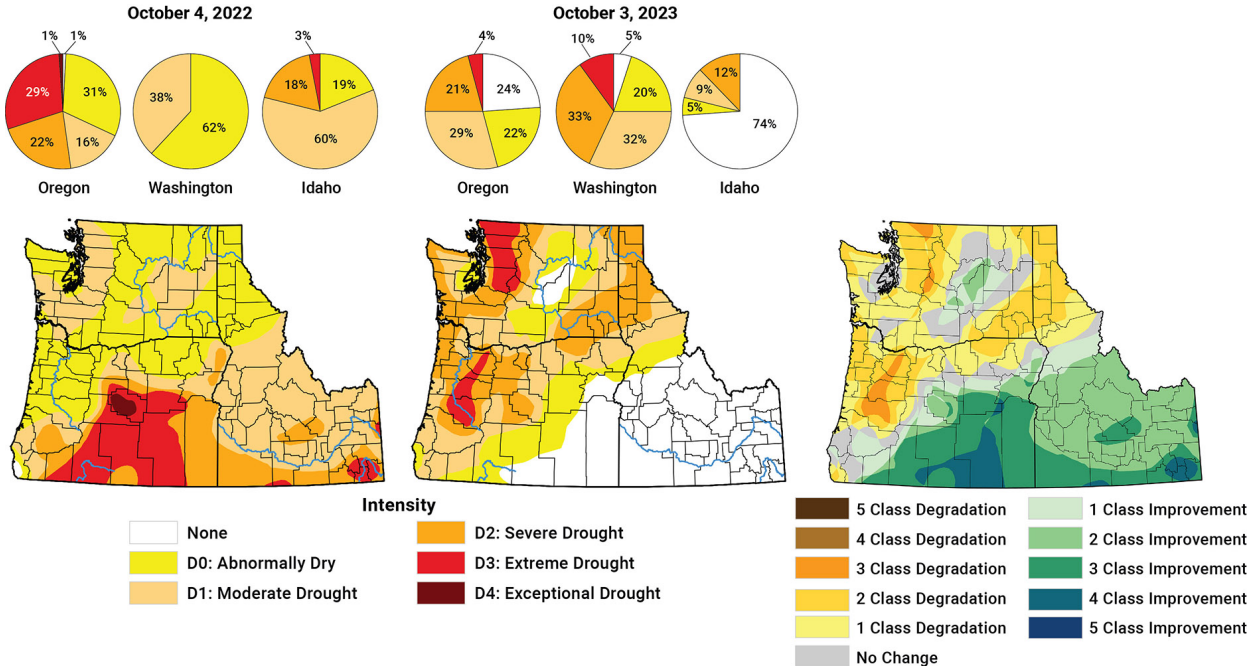

**Figure 1: October 2022-September 2023 average temperature departures and precipitation percent of normal. The normal period is 1991-2020. Source: PRISM data through the *WestWide Drought Tracker*.**

Also across the PNW, the 2023 water year was cooler than nearly all of the last 11 water years, and had the same average temperature as the 2019 water year. The 2023 water year was drier than the 2022 water year, during which precipitation was 102% of normal, and wetter than 2020 (83% of normal) and 2021 (86% of normal).

Water year temperatures were consistent throughout the region (*Figure 1*), and largely within 1°F of normal. Southeastern Oregon and parts of southern Idaho were cooler than normal, which reduced the state-level water year average temperatures. Spatial differences in water year precipitation within each state were more marked. Southern Idaho and southeastern Oregon had normal to above normal precipitation, with water year totals 90 to 200% of normal. Despite near-normal precipitation in the northern and central parts of eastern Washington, Washington was the driest of the three states relative to its normal. Elsewhere in Washington, and in western and northwestern Oregon and the Idaho panhandle, total water year precipitation was 70 to 90% of normal. At the state level, Oregon was drier than normal and Idaho wetter than normal.

Drought improved in the southeastern PNW and worsened in the northwestern PNW over the course of the water year, consistent with the water year precipitation anomalies. According to the U.S. Drought Monitor (*Figure 2*), Idaho saw the most improvement. At the start of the water year, 81% of Idaho was in moderate to extreme drought, and that percentage was reduced to 21% by the end of the water year. By the end of the water year, 74% of Idaho was drought-free, and reservoirs had substantial carryover from both the above normal snowpack and the heavy precipitation from the remnants of Tropical Storm Hilary in late August.

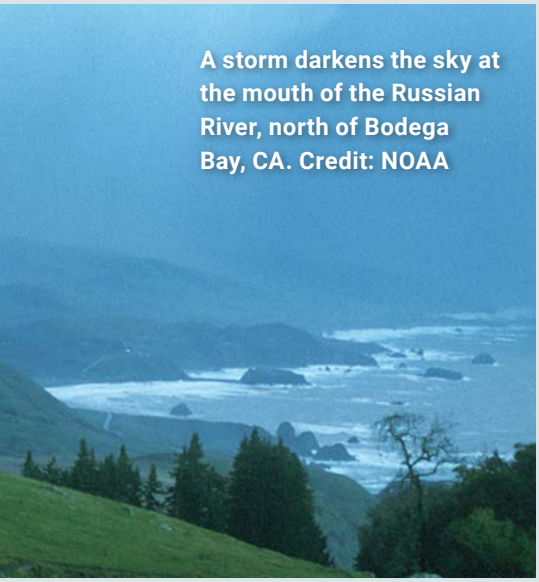
Drought in Oregon also improved over the water year. At the start of the water year, 68% of Oregon was in moderate to exceptional




drought compared to 54% at the end of the water year. Importantly, the area of drought in Oregon changed throughout the water year, with large drought improvements in central and southeastern Oregon and drought development in northwestern Oregon.

Washington drought worsened in all but east central Washington. At the start of the water year, 38% of Washington was in moderate drought; by the end of the water year, 75% was in moderate to extreme drought. The *Seasonal Progression* section describes in more detail the weather conditions that led to drought improvement in some areas and drought development in others.

**Figure 2: Pie charts and maps of drought conditions as characterized by the U.S. Drought Monitor on October 4, 2022 (*left*) and October 3, 2023 (*center*), the beginning and end of the 2023 water year, respectively. The changes in the *U.S. Drought Monitor* classifications from the start to the end of the water year are also shown (*right*).**



**A storm darkens the sky at the mouth of the Russian River, north of Bodega Bay, CA. Credit: NOAA**

## Atmospheric Rivers

Atmospheric Rivers (ARs) - bands in the atmosphere associated with enhanced water vapor transports - can account for a large percentage of total winter precipitation across the western coast of the U.S. According to the ***Center for Western Weather and Water Extremes*** at UC San Diego's Scripps Institution of Oceanography, water year 2023 had a total of 46 ARs, 15 less than the 2022 water year total of 61. Moreover, in a reversal from the 2022 water year, more 2023 ARs were directed at California than the PNW, which resulted in above normal water year precipitation in California and Nevada. The precipitation variability across the PNW, with the southeastern PNW receiving above normal water year precipitation, can also be partially explained by this variation in storm track. Overall, the 2023 water year storm track was displaced to the south of its counterpart during the 2022 water year.

## Seasonal Progression

The seasonal progression of temperature and precipitation characterizes the water year more fully than water year averages and totals. Spatial differences in precipitation across the PNW are apparent from the water year and monthly rankings (*Figure 3*). In Washington, five months ranged between abnormally dry and moderately dry, six months were neutral, and only one month (April) was moderately wet. In contrast, in Oregon and Idaho, four months were abnormally wet or wetter. Despite these differences, January, February, and July were abnormally to extremely dry in all three states. October was abnormally dry in Idaho and Oregon, and abnormally dry to neutral in Washington. November precipitation was neutral in all three states.

Precipitation rankings deviated among the three states at other points in the water year. For example, March was moderately wet in Oregon and Idaho but slightly dry in Washington. May and June were moderately dry in Washington and drier than normal in Oregon, but neutral and abnormally

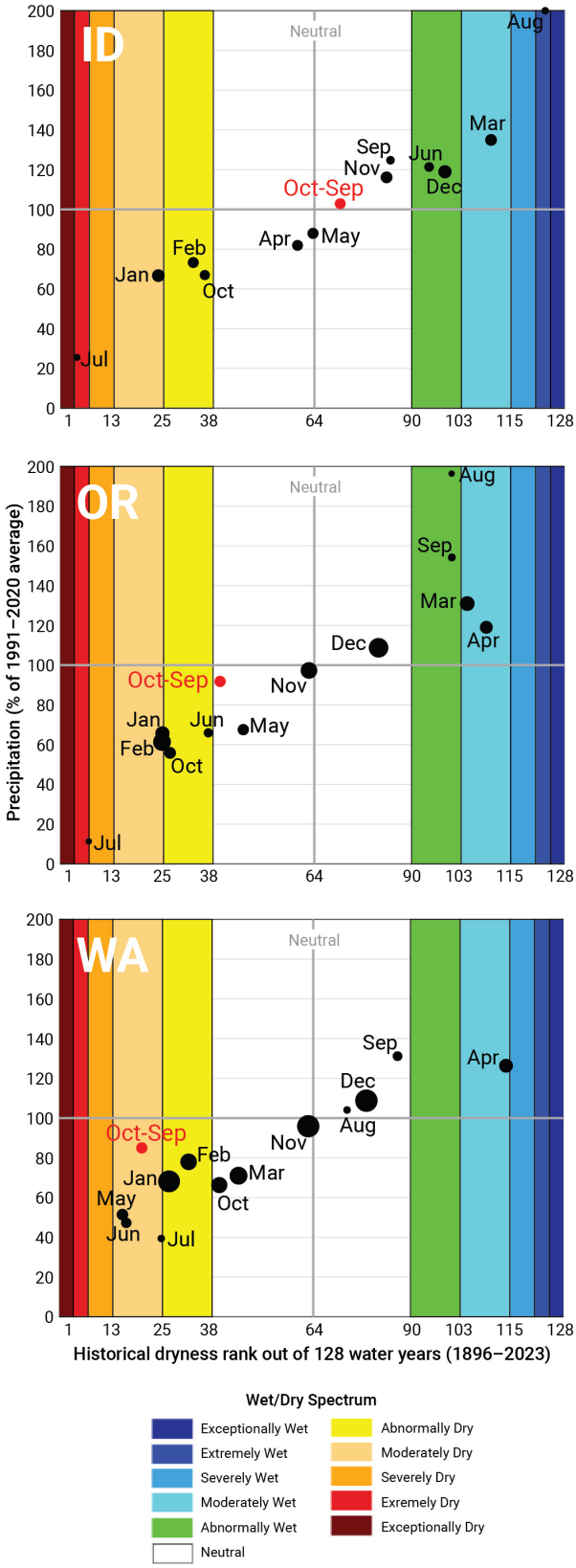



**Figure 3: Monthly percent of normal (compared to 1991-2020 baseline) statewide precipitation compared to the monthly precipitation rank during the last 128 water years for Idaho (*top*), Oregon (*middle*), and Washington (*bottom*). The red point illustrates the water year 2023 total. The colors corresponding to dry conditions are consistent with the U.S. Drought Monitor scale, and those corresponding to wet conditions with the *Climate Toolbox Historical Water Watcher tool*. The sizes of the circles are scaled according to each month's relative average contribution to the total water year precipitation, from dry (*small*) to wet (*large*). August 2023 precipitation in Idaho was 297% of normal, ranking as extremely wet and beyond the y-axis. Provisional NCEI nClimDiv data accessed on January 8, 2024.**

wet in Idaho. The contrast became more pronounced in August, when remnants of Tropical Storm Hilary affected Idaho and eastern Oregon. The storm remnants led to abnormally wet and extremely wet August conditions in Oregon and Idaho, respectively, but Washington precipitation was neutral.

The relative wet and dry periods are also illustrated by the water year average streamflow across the PNW (*Figure 4*). Regional average streamflow was below normal for a majority of fall, winter, and summer. Streamflow was above normal in early November, early January, and mid April, corresponding to short-term wet periods. The above normal streamflow throughout May corresponded to snowmelt rather than precipitation.

Variation in temperature during water year 2023 was beyond typical seasonal changes. The most notable swing occurred from October, which was much warmer than normal (3rd warmest on record), to November and December, which were much colder than normal (11th coldest). Temperatures across the PNW from February through April also were below normal (tied as 14th coldest), but May was much above normal (3rd warmest). Monthly and seasonal conditions are discussed in further detail in the next sections.

## October 2022

### Temperature

October 2022 felt more like the continuation of summer than the first full month of fall across most of the PNW. Temperatures were warmer than normal across the region (*Figure 5*). It was the warmest October on record in Washington, which was the warmest of the three states relative to its normal. The Cascade Mountains in Washington and Oregon were particularly warm, with temperature anomalies that exceeded 4°F. Averaged across the PNW, it was the 3rd warmest October on record.

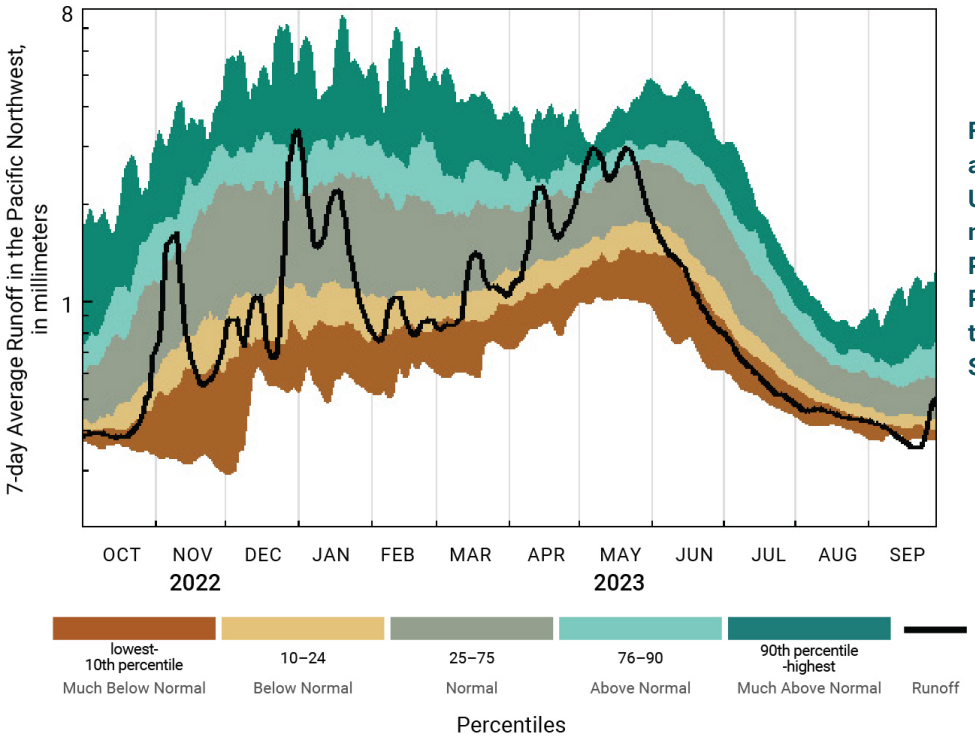
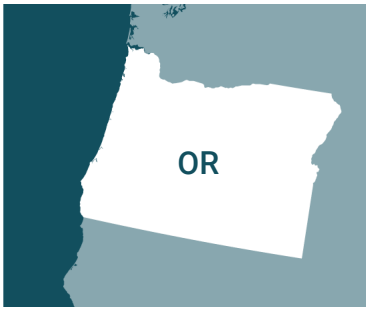



**Figure 4: Seven-day average runoff for all US Geological Survey monitoring stations in the PNW for water year 2023. Percentiles are relative to the historical record. Source: *USGS*.**

## OCTOBER 2022 STATISTICS*




**3rd** warmest; +5.6°F


**RECORD** warmest; +6.4°F


**8th** warmest (tied with 1952); +3.8°F

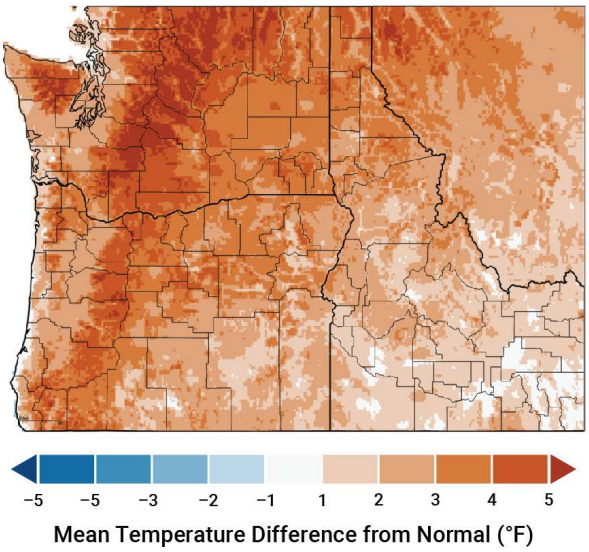
**27th** driest; -1.11", 56% of normal

**40th** driest; -1.38", 67% of normal

**35th** driest (tied with 1945); -0.61", 67% of normal

*Anomalies relative to 1991–2020 normal; records since 1895. Source: NOAA NCEI 2023

**October 2022**



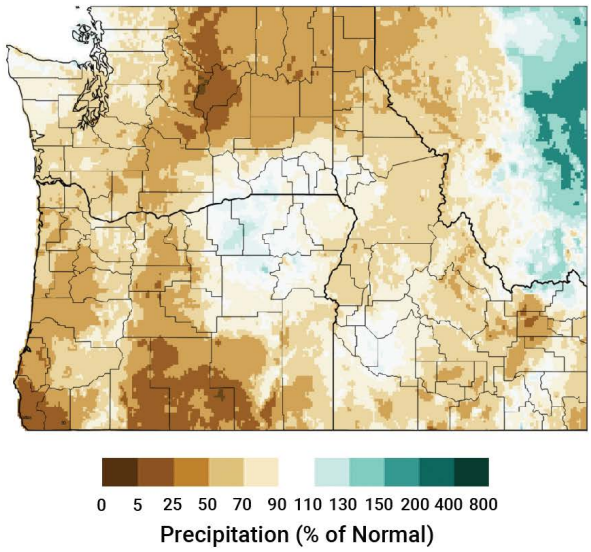
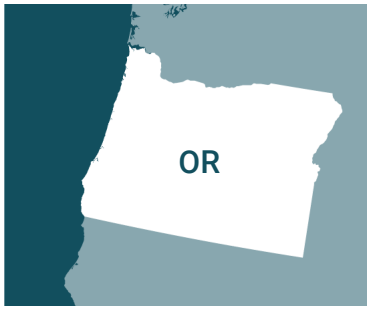




**Figure 5: October 2022 average temperature departures and precipitation percent of normal. The normal period is 1991-2020. Source: PRISM data through the *WestWide Drought Tracker*.**

### Precipitation

October 2022 precipitation was below normal throughout most of the PNW. A few areas in southeastern Washington, northeastern Oregon, and southwestern Idaho had near-normal precipitation. Oregon was the driest of the three states relative to its

## NOVEMBER–DECEMBER 2022 STATISTICS*




**12th** coldest (tied with 1909 and 1990); -3.8°F

**54th** wettest; +0.36", 104% of normal


**5th** coldest (tied with 1922); -5.0°F

**52nd** wettest; +0.31", 102% of normal


**12th** coldest; -4.2°F

**40th** wettest; +0.98", 118% of normal

*Anomalies relative to 1991–2020 normal; records since 1895. Source: NOAA NCEI 2023

normal, and areas across southern Oregon and central Washington received less than 25% of normal precipitation.

### November-December 2022

**Temperature**
In contrast to October, November and December 2022 were much colder than normal across the PNW. Temperature anomalies mirrored October; Idaho's statewide November-December temperature anomaly was -4.2°F compared to October's anomaly of +3.8°F. Similar to October, the November-December temperature anomaly was greatest in Washington. Temperature anomalies were greater east of the Cascade Mountains and in the inland Northwest (between 2 and 5°F below normal) and between 1 and 2°F below normal west of the Cascade Mountains in both Washington and Oregon (*Figure 6*).

**Precipitation**
November through December precipitation was near-normal to above normal across the majority of the PNW (*Figure 6*). Precipitation ranged between 90 and 200% of normal east of the Cascade Mountains and throughout Idaho. Precipitation in Butte County, Idaho, and a few surrounding counties exceeded 200% of normal. In contrast, a few locations in western Washington and western Oregon had slightly below normal (between 70 and 90% of normal) precipitation.

**Snowpack and Soil Moisture**
With the colder than normal temperatures in November and December, the near-normal precipitation fell as snow in the mountains, resulting in near-normal to above normal snowpack[4] by January 1 throughout most of the region (*Figure 7*). The lack of fall rains before temperatures transitioned to much below normal in November resulted in lower

4 The term "snowpack" is primarily used in this assessment and refers to the snow water equivalent or SWE.

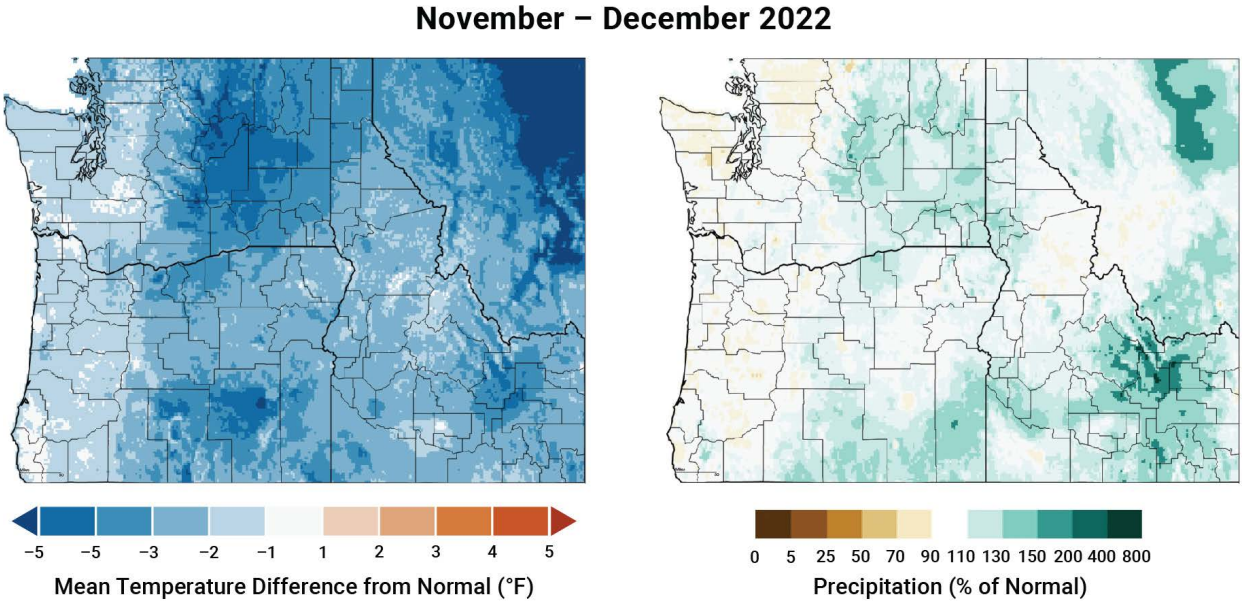



**Figure 6: November-December 2022 average temperature departures and precipitation percent of normal. The normal period is 1991-2020. Source: PRISM data through the *WestWide Drought Tracker*.**

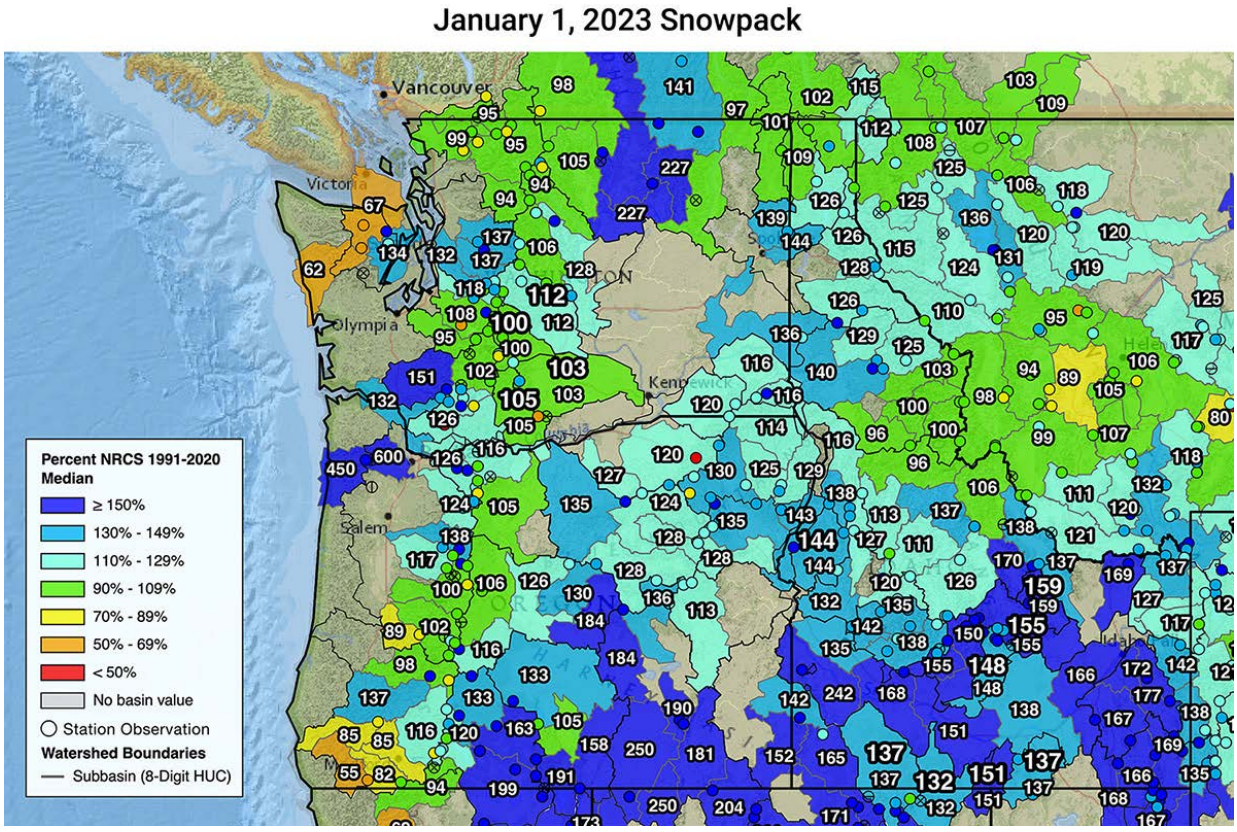



**Figure 7: January 1, 2023 snow water equivalent (SWE) percent of 1991-2020 median. Station values may differ from the sub-basin averages. Source: *NRCS*.**

than usual soil moisture, particularly in the Washington and Oregon Cascade Mountains. The 8" soil moisture at Harts Pass (6,490') in the northern Washington Cascades was only 8% of the median on October 31, 2022, for example. The lack of soil moisture recharge prior to the ground freezing may have had delayed significance; it appears that more of the snowmelt than usual the following spring went into recharging the soils rather than running off into rivers.

## January 2023

**Precipitation and Snowpack**

January 2023 precipitation was below normal across a majority of the PNW (not shown), with each state ranking between the 23rd and 27th driest. A few locations in each state received normal to near-normal precipitation, but importantly, most of the mountainous areas received below normal precipitation. Snowpack percentages of median were lower on February 1 than on January 1, with each state's average snowpack between 90 and 117% of median.

## February-April 2023

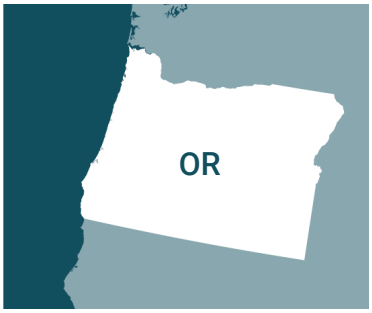
**Temperature**

February through April temperatures were below normal across the PNW, with Idaho being the coldest relative to its normal (-4.7°F). Parts of southeastern Idaho exceeded 5°F below normal (*Figure 8*). Southern and southeastern Oregon had temperatures 3°F or more below normal. Washington's temperatures were below normal but not as anomalous, with a majority of the state between 1 and 2°F below normal.

**Precipitation**

February through April precipitation was near normal averaged across Oregon and Idaho, but below normal in Washington. There was spatial variability within each state,

## JANUARY 2023 STATISTICS*




**74th** coldest; -1.3°F

**25th** driest; -1.76", 61% of normal


**23rd** warmest (tied with 1931 and 2018); +1.4°F

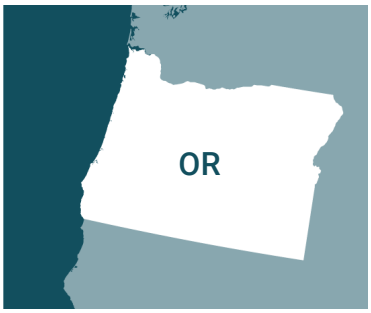
**27th** driest; -1.97", 68% of normal


**67th** coldest (tied with 1908 and 1927); -1.6°F

**23rd** driest (tied with 1994); -0.94", 67% of normal

*Anomalies relative to 1991–2020 normal; records since 1895. Source: NOAA NCEI 2023

## FEBRUARY–APRIL 2023 STATISTICS*




**12th** coldest (tied with 1923); -3.8°F

**45th** wettest; +0.53”, 105% of normal


**31rd** coldest (tied with 1920, 1976, and 1982); -2.3°F

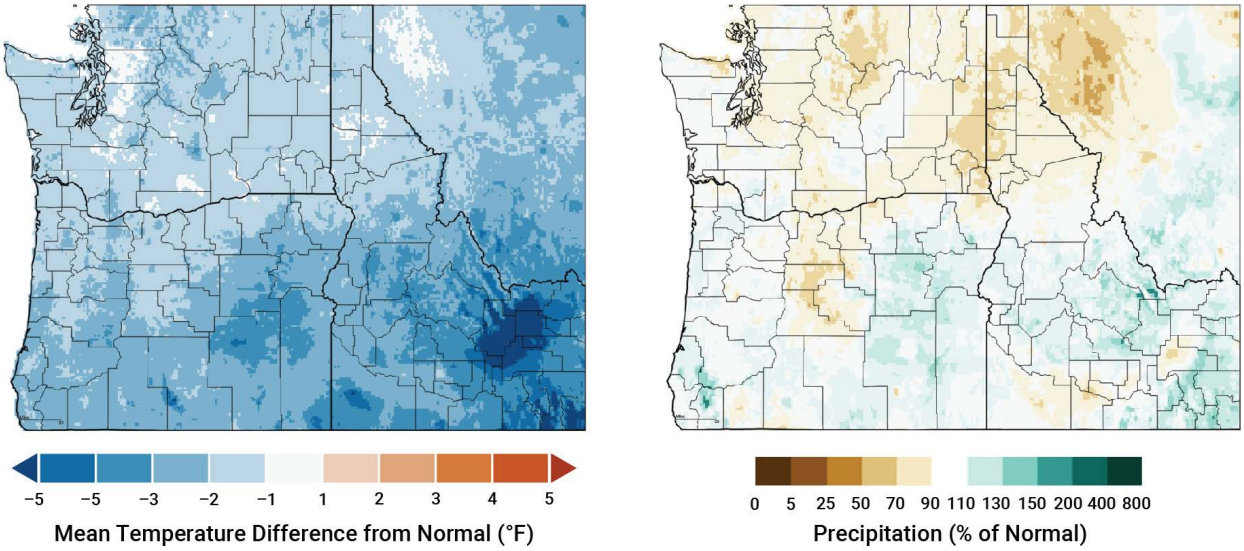
**55th** driest; -1.39”, 89% of normal


**12th** coldest (tied with 1952); -4.7°F

**60th** wettest; -0.12”, 98% of normal

*Anomalies relative to 1991–2020 normal; records since 1895. Source: NOAA NCEI 2023

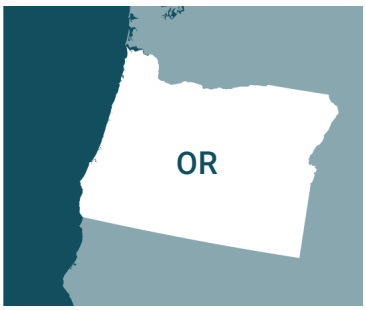
**February – April 2023**




with the Idaho panhandle, north central Washington, southeastern Washington, the northern Cascade Mountains in Oregon, and southwestern Idaho receiving between 50 and 90% of normal precipitation.

**Figure 8: February-April 2023 average temperature departures and precipitation percent of normal. The normal period is 1991-2020. Source: PRISM data through the *WestWide Drought Tracker*.**

## APRIL 1, 2023 SNOW WATER EQUIVALENT*




**151%** of median


**101%** of median


**100%** of median North of the Salmon River

**136%** of median South of the Salmon River

*Statewide, compared to 1991–2020 median. Source: National Resources Conservation Service

**Snowpack**
Despite the drier than usual weather, April 1 snowpack was normal to above normal across most of the PNW (*Figure 9*). On the state level, April 1 snowpack was the 4th and 7th highest since 1991 in Oregon and Idaho, respectively. In Washington, April 1 snowpack ranked closer to median as the 15th highest of the last 33 years. April 1 snowpack was above normal across Oregon and southern Idaho, where precipitation was normal to above normal. The unusually cold temperatures also helped to ensure that precipitation fell as snow in the mountains; even the central and southern Cascade Mountains of Washington and the Blue Mountains in Washington had normal to above normal April 1 snowpack despite below normal precipitation. Snowpack was below normal in parts of the Olympic Mountains and northern Cascade Mountains in Washington, where precipitation was below normal. Snowpack in parts of the Idaho panhandle and the Canadian Rocky Mountains was also below normal and had lower percentages of median compared to totals on January 1 (*Figure 7*).

The date of peak snowpack was normal or slightly later across the PNW due to the colder than normal April weather. Peak snowpack occurred during the last week of April as measured by a majority of the SNOTEL[5] stations in the three states.

### May 2023

**Temperature**
May was warmer than normal across the PNW (*Figure 10*). Temperature anomalies were greatest in eastern Washington and the Idaho panhandle, exceeding 4°F. Washington

5 SNOTEL stations are the weather stations installed in mountain locations by the Natural Resources Conservation Service that measure temperature, precipitation, and snow water equivalent, and sometimes other air and soil variables. The stations are represented by circles in *Figure 7* and *Figure 9*.

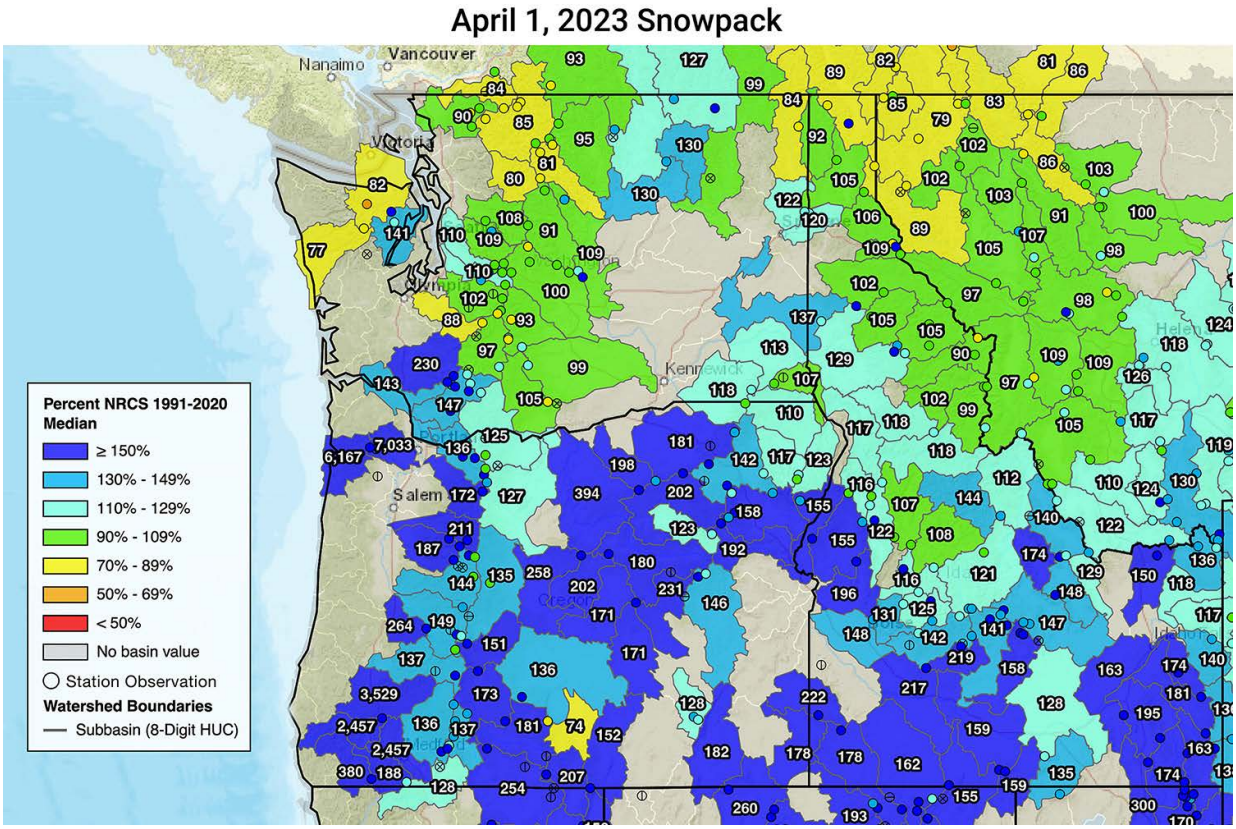



**Figure 9: April 1, 2023 snow water equivalent (SWE) percent of 1991-2020 median. Source: *NRCS*.**

was the warmest relative to its normal, and 2023 tied as the warmest May in the 128-year record. A heat wave impacted the PNW from May 13 through May 22, with much above normal temperatures in western Washington and western Oregon earlier in that period and in Idaho later in that period. Average temperatures were 10 to 18°F above normal during the heat wave, with widespread high temperatures in the 80s and 90s.

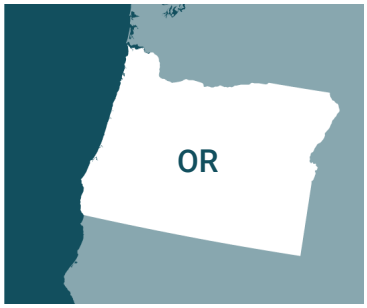
**Precipitation**

There was stark variation in the percent of normal May precipitation across the region. Western Washington and western Oregon received less than 50% of normal monthly precipitation. Some locations in coastal Washington and Oregon and southeastern Washington received only 5 to 25% of normal precipitation. In contrast, most of eastern Oregon and northeastern Washington received near-normal to above normal precipitation. Idaho was drier than usual, but the departure from normal was not as extreme.

**Snowpack**

The warmer than normal May temperatures, including a heat wave in mid May, caused rapid loss of the accumulated snowpack, ultimately reducing the benefits of a normal to above normal snowpack for the following summer. For individual SNOTEL stations, snowpack completely melted across Washington and the Idaho panhandle 10 to 30 days earlier than usual. In contrast, throughout most of Oregon and southern Idaho, complete melting of the above normal snowpack occurred from the median date to 30 days later than usual. Regional streamflows (*Figure 4*) were above normal during this time due to the rapid snowmelt.

## MAY 2023 STATISTICS*




**6th** warmest; +3.4°F


**RECORD** warmest (tied with 1958); +5.3°F


**5th** warmest (tied with 1928); +4.3°F

**45th** driest (tied with 1910); -0.77", 68% of normal

**15th** driest; -1.21", 51% of normal

**62nd** driest (tied with 1913 and 2009); -0.28", 88% of normal

*Anomalies relative to 1991–2020 normal; records since 1895. Source: NOAA NCEI 2023

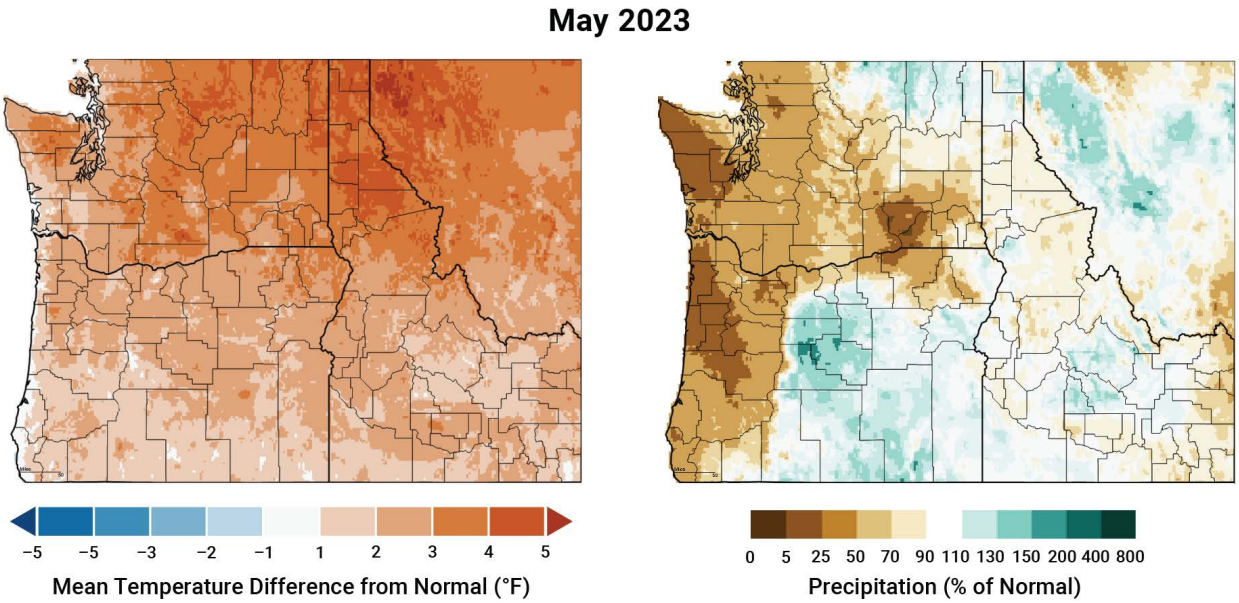



**Figure 10: May 2023 average temperature departures and precipitation percent of normal. The normal period is 1991-2020. Source: PRISM data through the *WestWide Drought Tracker*.**

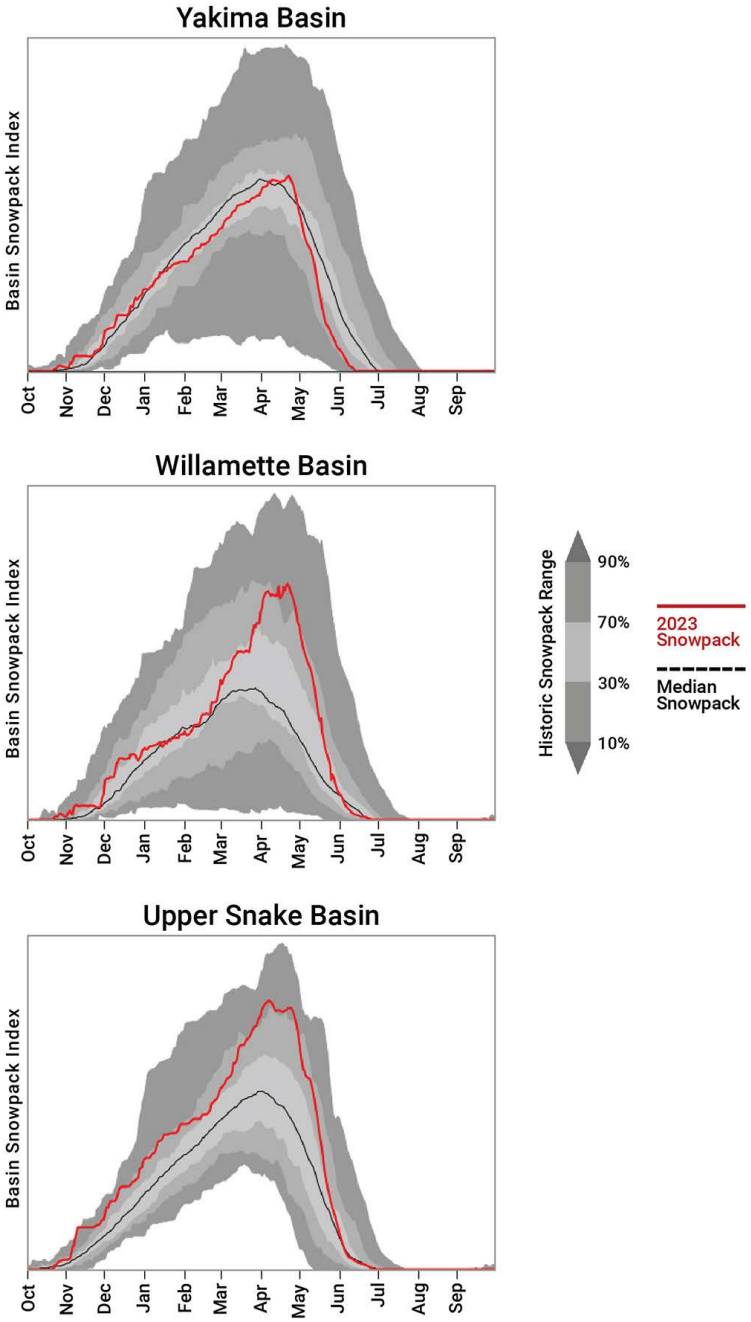



**Figure 11: Water year 2023 snow water equivalent (red line) compared with historical percentiles (shading) and the 30-year median (black line) for the Yakima (*top*; average of 17 SNOTEL stations), Willamette (*middle*; average of 20 SNOTEL stations), and Upper Snake (*bottom*; average of 39 SNOTEL stations) Basins. Source: Matt Warbritton, *USDA-NRCS*.**

In the Yakima Basin in Washington, Willamette Basin in Oregon, and Upper Snake Basin in Idaho, peak snowpack occurred later than usual (*Figure 11*). The Yakima Basin peaked on April 23, close to the 30-year median, but the snowpack melted completely two weeks earlier than usual. Peak snowpack in the Willamette and Upper Snake basins was well above median, leading to expectations that the snowpack would last well into summer. However, complete melting of the snowpack occurred close to the 30-year median date.

# SECTOR-SPECIFIC IMPACTS OF MAY HEAT WAVE

**Diablo Dam, part of the Skagit River Hydroelectric Project in Washington. Credit: Dan Huntington, Creative Commons**

The abnormally high temperatures and heat wave in mid May had immediate effects on the drinking water, agriculture, and hydropower sectors, and contributed to the low water supply later in summer. The Annual Pacific Northwest Water Year Impacts Survey (*see page 26*) asked whether people experienced impacts associated with the heat in May, and several respondents responded affirmatively.

## Drinking water

Residential water use, particularly for irrigation, was higher than average during May. One water association noted that water consumption in May was typical of June. Some water providers indicated that more water supply was needed, seasonal wells were used sooner, and that they needed to pump higher volumes than usual.

## Agriculture

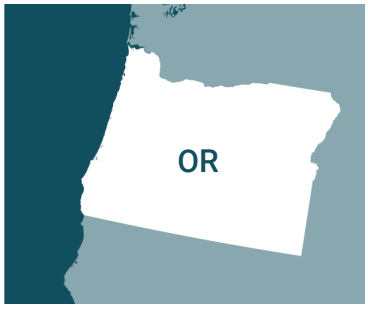
Producers commented that recently planted crops died and irrigation of fruit and berries began earlier than normal. In eastern Washington, a producer reported that the hot, dry weather killed cover crops despite enhanced irrigation.

## Hydropower

Hydropower generation across the region was affected by the rapid snowmelt associated with the May heat wave. Some utilities generated less hydropower in May than in April. Others generated high levels of hydropower in May due to rapid snowmelt, but water supply and generation were lower in the following months. Several supply reservoirs in western Washington did not refill, hydropower generation was lower than average in June, and summer drawdown of reservoirs began earlier than normal.

The May heat wave and dry conditions set up portions of the northwestern PNW for intensification of drought. Low water levels in several reservoirs in western Washington in late spring, summer, and early fall were attributed to the rapid snowmelt in May. By August and September, river levels were abnormally low, causing water shortages that affected irrigation, fisheries, and hydropower generation until the fall rains began.

## JUNE–AUGUST 2023 STATISTICS*




**7th** warmest; +1.8°F

**42nd** driest; -0.44", 82% of normal


**5th** warmest (tied with 2022); +2.3°F

**16th** driest (tied with 2021); -1.47", 59% of normal


**16th** warmest (tied with 1933); +0.9°F

**25th** wettest; +1.27", 140% of normal

*Anomalies relative to 1991–2020 normal; records since 1895. Source: NOAA NCEI 2023

**June – August 2023**

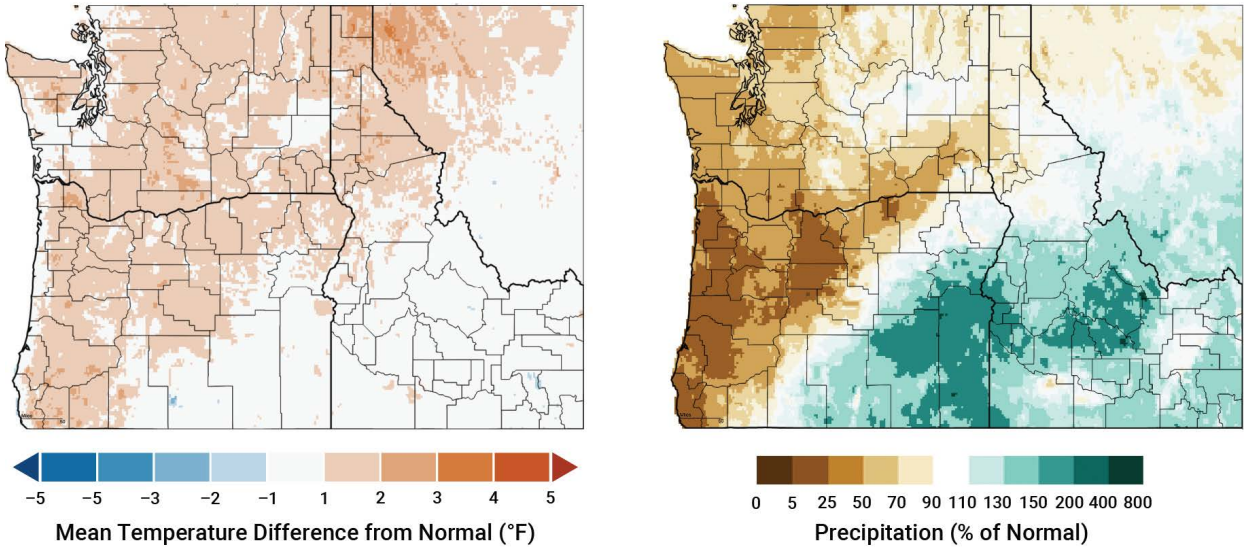



**Figure 12: June-August 2023 average temperature departures and precipitation percent of normal. The normal period is 1991-2020. Source: PRISM data through the *WestWide Drought Tracker*.**

### June-August 2023

**Temperature**

June-August temperatures were above normal across Washington and most of Oregon (*Figure 12*). Temperatures were above normal in the Idaho panhandle but near normal elsewhere in Idaho and in southeastern Oregon. While average summer temperatures were warmer than normal in

some places, they were not as anomalously high as they were during May. Regardless, evaporative demand was elevated over summer across the locations with the above normal temperatures due to both the elevated temperatures and lower than usual cloud cover. For the period of May through July, northwestern Oregon and southwestern Washington had the record fewest clouds since 1979 (*Figure 13*).

**Precipitation**

There was a distinct spatial pattern in precipitation from June through August. The northwestern PNW was drier than normal and the southeastern PNW was wetter than normal. Washington was the driest relative to its normal and had the most consistent spatial anomalies. Coastal Oregon and the northern Cascade Mountains in Oregon received less than 25% of normal precipitation, but precipitation was above normal in southeastern Oregon. Idaho received above normal precipitation as a whole, and areas of southern Idaho received more than 200% of normal precipitation (see *Remnants of Tropical Storm Hilary*).

## September 2023

**Temperature**

September average temperatures were near-normal across the majority of the PNW (not shown). The exception was parts of southern Oregon and the Oregon Cascade Mountains, which had below normal temperatures, and resulted in a below normal monthly temperature anomaly for the state.

**Precipitation and Streamflow**

September precipitation was above normal across most of the PNW (*Figure 14*), with statewide totals from 125 to 155% of normal for each of the three states. There were

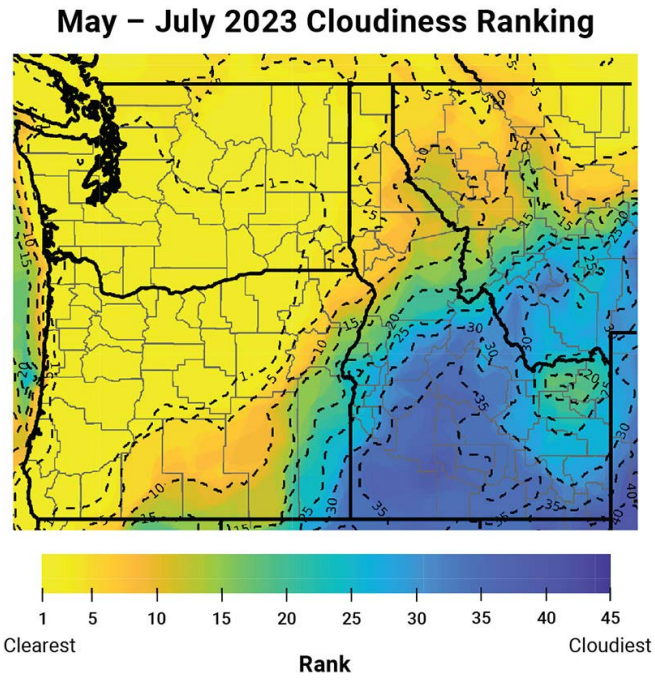



**Figure 13: May-July 2023 ranking of cloudiness based on the ERA5 reanalysis since 1979. Low numbers (yellow shading) represent clearer skies and high numbers (blue shading) represent cloudy skies.**

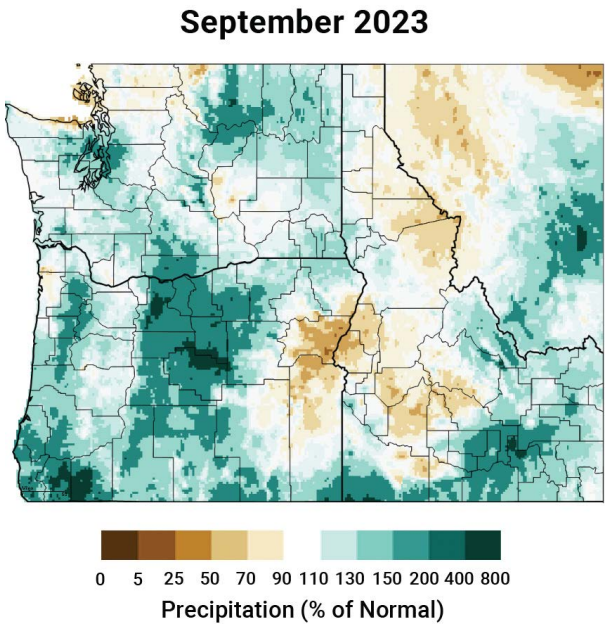



**Figure 14: September 2023 precipitation percent of normal. The normal period is 1991-2020. Source: PRISM data through the *WestWide Drought Tracker*.**

some exceptions: in parts of the Puget Sound region in Washington, the border between Oregon and Idaho, and parts of the Idaho panhandle and southern Idaho totals were below normal. The timing of the precipitation was such that it did not begin until the end of the month. Before fall rains returned between September 21 through September 24, regional average streamflow was record low (*Figure 4*). The record lows were primarily driven by extremely low streamflow in western Washington and western Oregon, but flows in Idaho rivers were also below normal (*Figure 15*).

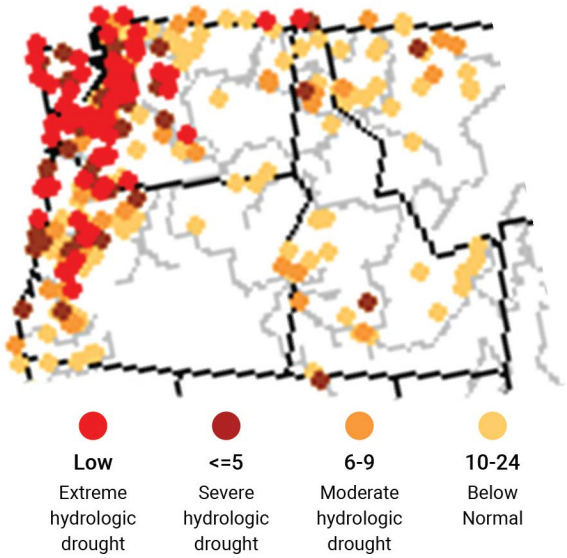



**Figure 15: Average 14-day streamflow on September 21, 2023, the day on which fall rains returned to the PNW, in the rivers in which streamflow was below normal (*USGS*).**

## Multi-year drought

There has been persistent drought in the PNW since fall 2019, but overall, drought conditions improved during water year 2023. The 36-month Standardized Precipitation Evapotranspiration Index (SPEI) was highlighted in the *2022 PNW Water Year Impacts Assessment* to illustrate the long-term dryness experienced through most of the region. The SPEI has both precipitation and temperature components; indices less than -1.0 typically signify the beginning of drought, and lower values indicate increasingly severe drought. Long-term drought persists in western and central Oregon, southeast Washington, and the Idaho panhandle, as shown by the 48-month SPEI (October 2019-September 2023; *Figure 16*), but SPEI is now neutral to positive in southeastern Oregon and most of southern Idaho as a result of near-normal 2023 water year temperatures and above normal precipitation. 2023 was the second consecutive water year during which there were improvements overall in the long-term PNW drought.

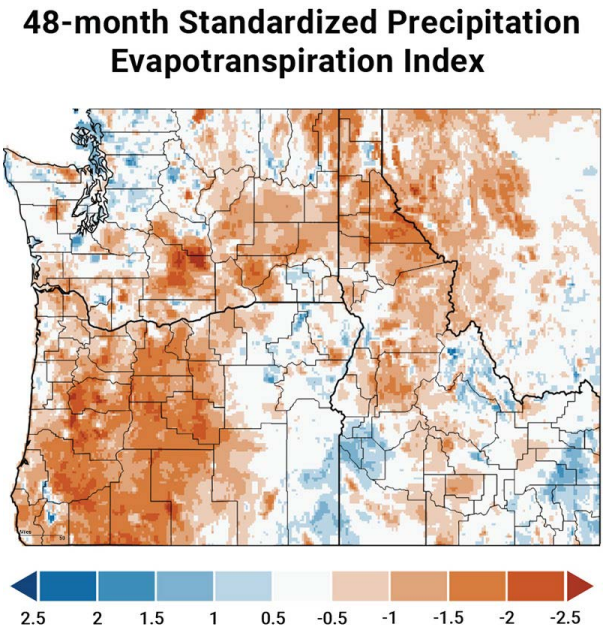



**Figure 16: 48-month Standardized Precipitation Evapotranspiration Index (SPEI) for the period ending September 30, 2023. Source: PRISM data through the *WestWide Drought Tracker*.**

# REMNANTS OF TROPICAL STORM HILARY

In August, Mexico and the United States experienced a highly unusual event when Hurricane Hilary struck the Baja Peninsula and then moved into California as a tropical storm, causing California to issue its first tropical storm warning. Remnants of this tropical storm sent waves of precipitation through Nevada and into the PNW from August 19 through August 23. Precipitation exceeded 2" from the Wallowa Mountains of eastern Oregon to the Madison and Bitterroot Mountains of western Montana. The heaviest precipitation fell within the Lemhi Mountains, Lost River Range, Pioneer Mountains, Sawtooth Mountains, and Smokey Mountains of central Idaho (*Figure 17*).

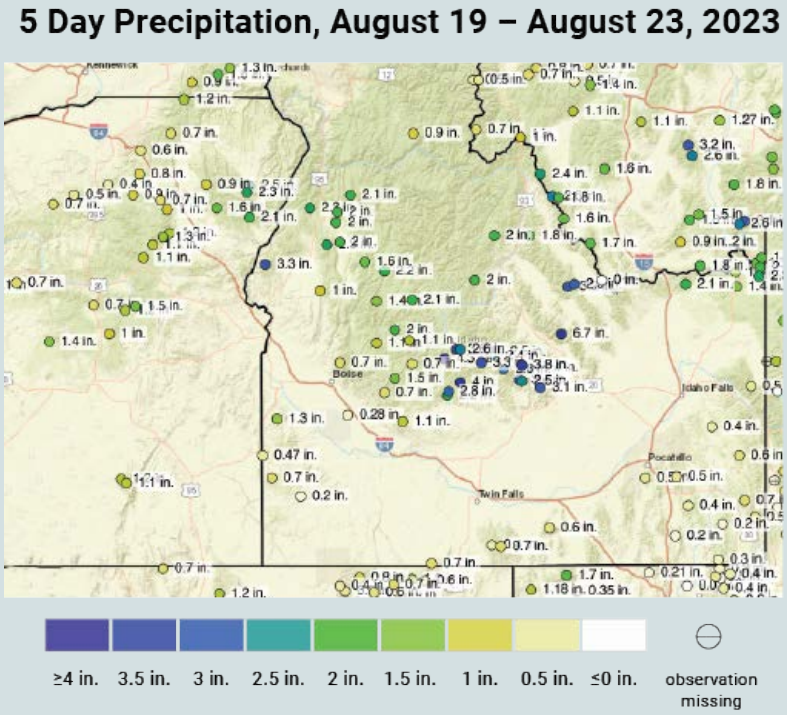



**Figure 17: Total five-day precipitation (August 19-23) from the remnants of Tropical Storm Hilary recorded by SNOTEL stations in eastern Oregon, southern Idaho, and western Montana. (*USDA*)**

The highest recorded five-day precipitation, 6.7", occurred at the Hilt's Creek SNOTEL station (elevation 8,000 ft) in the Lost River Range. On average, this station receives 1.3" in August and 21.8" during the water year. The heavy precipitation caused runoff that greatly increased streamflow in nearby rivers and ultimately reduced the rate at which reservoirs were drawn down in the region. For example, streamflow in Lower Cedar Creek in the Lost River Range rose rapidly, from 25 cubic feet per second (cfs) on August 20 to above 80 cfs on August 21, 22, and 23rd. By the end of August, streamflow gradually receded to 40 cfs, 1.5 times greater than before the event.

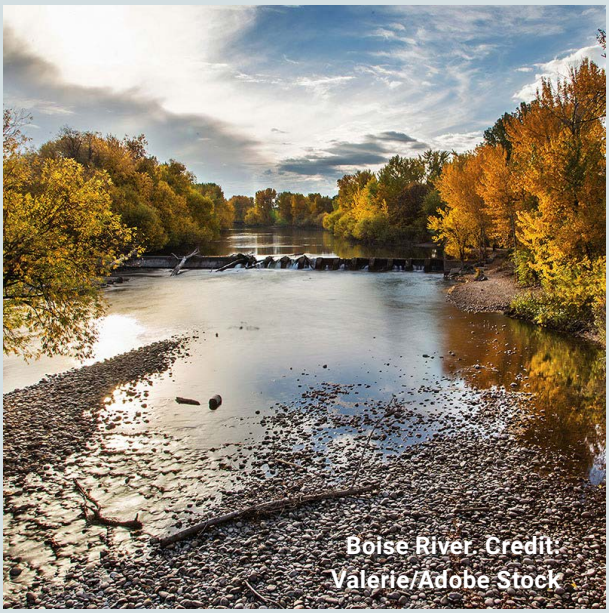
Discharge of the Big Lost River from the Pioneer Mountains rose from 200 cfs to 1,300 cfs on August 21, with a second peak of 1,130 cfs on August 22 as measured by the gauge at Big Lost River at Howell Ranch near Chilly (USGS 13120500). Overall, an additional 6,921 ac-ft entered Mackay Reservoir downstream of the gauge. Prior to this event, water users expected the reservoir to be empty by the end of August because water volume was declining by about 600 ac-ft per day. On August 21, the decline of the reservoir suddenly stopped at a volume just below

9,000 ac-ft and then rose and held steady for a few days as runoff from the mountains surged. The reservoir did not fall below 9,000 ac-ft again until August 27, after which the rate of decline was much slower due to high base flows. The reservoir did not empty until the second week of September, extending the irrigation season by a month for those with junior water rights.

The precipitation event increased runoff in four basins:

- Little Lost River: 1,010 ac-ft (no reservoir)
- Little Wood River: 1,290 ac-ft
- Big Wood River: 7,179 ac-ft
- Boise River: 6,111 ac-ft

Most of the runoff from the remnants of Tropical Storm Hilary were diverted for irrigation in Idaho before reaching the Snake River, except in the Salmon River basin, which is primarily composed of wilderness area. The daily discharge of the Salmon River fell to a streamflow of 4,180 cfs on August 20 and then peaked at 7,490 cfs on August 24. By the end of August, the discharge of the river was 4,990 cfs. The runoff volume that was released from the Salmon River to the Snake River in August as measured at the streamgage near Whitebird Idaho was 35,190 ac-ft.



Boise River. Credit: Valerie/Adobe Stock

A comparison of July to September streamflow percentiles shows the impact of the remnants of Tropical Storm Hilary on Idaho drought. The average change in streamflow percentiles in Idaho's central mountains was 22%. One particularly striking change in streamflow percentiles occurred at the Salmon River near Whitebird, where the streamflow percentiles increased from 33rd in July to 64th in September. In the Big Lost, Little Wood, and Big Wood Rivers, streamflows increased to flood levels. The highest September percentiles on each river were 87th (Big Lost at Howell), 88th (Little Wood at Carey), and 92nd (Big Wood below Magic Reservoir).

Another impact of the remnants of this tropical storm in Idaho was reduction of evapotranspiration from crops across the Snake River Plain. As measured at the AgriMet weather station in Kimberly, the grass-based reference evapotranspiration averaged 0.25" per day for the five days preceding the event. From August 17 through August 21, the reference evapotranspiration dropped to an average of 0.15" per day. If this drop in evapotranspiration (0.10") is multiplied over the roughly 3,000,000 irrigated acres within the Snake River Plain, the impact is a decrease in evapotranspiration of 125,000 ac-ft over a five-day period. Over these five days, the precipitation at Kimberly was 0.46".

# 4 WATER YEAR IMPACTS

Information on the impacts of drought and other seasonal climate conditions is critical to connect conditions to their effects on natural resources, people, and economies. Here we summarize impacts on multiple sectors in Oregon, Idaho, and Washington on the basis of three sources. None of these sources nor the impacts presented in this assessment are exhaustive.

**Information on the impacts of drought and other seasonal climate conditions is critical to connect conditions to their effects on natural resources, people, and economies.**

1. Local observer reports including the national *Condition Monitoring Observer Reports on Drought (CMOR)* and *Community, Collaborative Rain, Hail, and Snow Network (CoCoRaHS)* reports, which allow members of the public to submit location-specific impact reports throughout the year.

2. The Annual Pacific Northwest Water Year Impacts Survey, which is distributed at the end of the water year to natural resource managers, agency staff, and all registrants for the water year meetings.

3. The 2023 water year meetings presentations which highlight particularly compelling stories of climate impacts and responses within the region.

# 2023 CONDITION MONITORING OBSERVER REPORTS

The Condition Monitoring Observer Reports on Drought (CMOR), provided by the National Drought Mitigation Center (NDMC), collect local observations of drought impacts to aid in drought monitoring and research. Observations inform the U.S. Drought Monitor and agencies that make drought-related decisions. During the 2023 water year, observers submitted 14 reports from Oregon, 25 from Washington, and none from Idaho.


Photo taken in early July 2023 in Grant County, Oregon (*CMOR*).

**Spatially Variable and Local Drought Impacts in Oregon:** Observations from Oregon highlight the variability in drought impacts in space and time across the state. For example, observations from Crook County early in the water year reflected the dry conditions that persisted from the 2022 water year into the 2023 water year. Reports describe lake and reservoir levels so low that vegetation, including invasive species, became established in dry lake beds. Low reservoir levels for several years have affected recreation by rendering boat docks unusable and fishing sites inaccessible. Above normal water temperatures led to harmful algal blooms. Other areas were much wetter. For example, above normal snowpack in Baker County, Oregon helped to refill reservoirs by April. Reports indicated that drought-related impacts in Baker County were restricted to isolated agricultural lands, whereas many areas had normal production.

Reports from late summer and early fall depicted intensifying drought impacts in central Oregon and along the central coast. Severely dry conditions in inland Morrow County greatly reduced the availability of irrigation water and production of dryland hay. Farmers described their need to buy hay to compensate for low production. Similarly, reports described severely dry conditions in coastal Lincoln County. The commercial forestry industry was affected only by high fire danger, but widespread impacts to agricultural producers prompted a county-level drought declaration. Limited water for irrigation led to plant stress, reduced pasture forage and hay yields, and the need to purchase supplemental feed or hay and sell livestock.

**Early Onset Drought Impacts in Western Washington; Later Impacts in Eastern Washington:** Observation reports from western Washington (Clark, King, Pierce, and Thurston counties) quickly shifted from describing wet conditions in winter to describing moderate or severely dry conditions in May and early June. Reports depicted reduced crop yields and pasture forage and increased irrigation as early as mid May. Reports described voluntary and mandatory water conservation in early June and unusually early wildfire risk. Reports of moderately to severely dry conditions in western Washington extended into early October. Observations of severely dry conditions in eastern Washington, especially Okanogan County, began in early September and illustrated the late-emerging drought impacts in northeastern Washington. Reports from Okanogan County reflected agricultural impacts such as dry wells, loss of flow from natural springs, insufficient water for irrigation, and exceptionally low hay and forage production, including on federal lands.

## CoCoRaHS Condition Monitoring Reports

The volunteer members of the Community, Collaborative Rain, Hail, and Snow (CoCoRaHS) Network take daily measurements of precipitation in their backyards or schools and enter the measurement in a national database. CoCoRaHS observers are also encouraged to submit Condition Monitoring Reports in which they rate their local conditions on a scale of mildly, moderately, or severely dry, near normal, or mildly, moderately, or severely wet. A condition monitoring guide provides examples of conditions associated with each of these categories to assist the observer's determination. CoCoRaHS encourages their observers to submit Condition Monitoring Reports on a regular basis to develop a baseline.

During the 2023 water year, observers in Washington, Oregon, and Idaho submitted a total of 980 Condition Monitoring Reports. These local reports closely align with the water year evolution (Section 3) and impacts presented in this assessment (Section 4). The reports from Washington and Oregon are similar in their patterns and show a dry start to the water year, near-normal to wet conditions from December 2022 through April 2023, and dry conditions for the remainder of the water year (*Figure 18*). The majority of reports from Idaho also indicated dry conditions early in the water year, but the overwhelming majority of reports later in the water year are not as dry. This reflects the overall drought improvement in Idaho largely associated with the remnants of Hurricane Hilary.

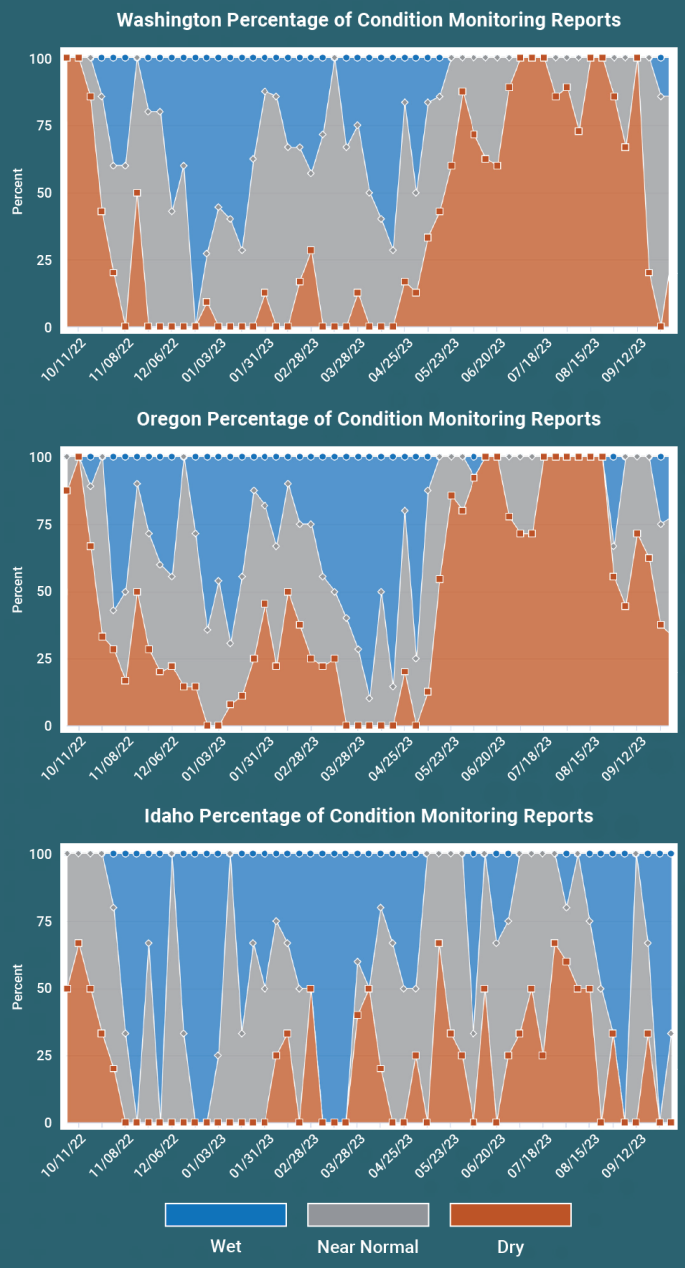



**Figure 18. The percentage of weekly CoCoRaHS Condition Monitoring Reports that classified local conditions as wet, near-normal, or dry over the 2023 water year. Because the number of reports varies weekly, the reports are more appropriate for tracking general changes in conditions over several weeks to a season, rather than changes from week-to-week (*CoCoRaHS*).**

Deschutes National Forest, OR
Credit: m01229/Creative Commons

## Annual Pacific Northwest Water Year Impacts Survey

The PNW Water Year Impacts Survey collects information on impacts of abnormally dry or wet conditions on the drinking water, agriculture, forestry, fisheries, hydropower, recreation, and stormwater sectors. Unlike CMOR, we distribute the survey once the water year has ended. Survey respondents indicate whether they experienced abnormally dry and/or abnormally wet conditions during the water year and may either select impacts from a list or report other impacts that they experienced from these conditions.

We distributed the 2023 water year survey in October 2023 via listservs of NIDIS, Office of the Washington State Climatologist (OWSC), Climate Impacts Group, PNW Tribal Climate Change Network, and Agriculture Climate Network. Furthermore, we sent the survey to all registrants of the Oregon/Washington Water Year Meeting and the Idaho Water Year Meeting, and featured it in the OWSC monthly newsletter and the USDA Northwest Climate Hub newsletter. In an effort to increase the number of responses, we also collaborated with the Washington Department of Health's Office of Drinking Water, Washington Department of Agriculture, and Washington Conservation Commission to refine survey questions and distribute the survey via their listservs.

One hundred and forty five (145) people responded to the survey, 66 of whom reported impacts to at least one sector. About 25% of respondents were employed

by local governments and another 25% by power and water utilities or associations (*Figure 19*). We include responses from agencies, resource managers, and producers, and multiple responses may describe the same impacts.

We received many more reports from people affiliated with the drinking water and agriculture sectors in 2023 than in previous years given the emphasis of our survey distribution. However, several respondents affiliated with these sectors did not report impacts. We reference a given impact to the drinking water or agriculture sector below if it was reported by at least three people. We reference all reported impacts on the forestry, recreation, and fisheries sectors to highlight the diversity of impacts despite lower response rates from these sectors. We exclude the reported impacts on the hydropower and stormwater management sectors because of very low response rates.

Advantages of the PNW Water Year Impacts Assessments are that they are available shortly after the end of the water year and that they describe preliminary reports of impacts across multiple sectors. Later in 2024, other government agencies release detailed sector-specific reports of conditions and impacts from the 2023 calendar year. We link to several of these annual reports as another source of information on sector-specific impacts that can provide more in-depth discussion of some of the impacts highlighted in this report.

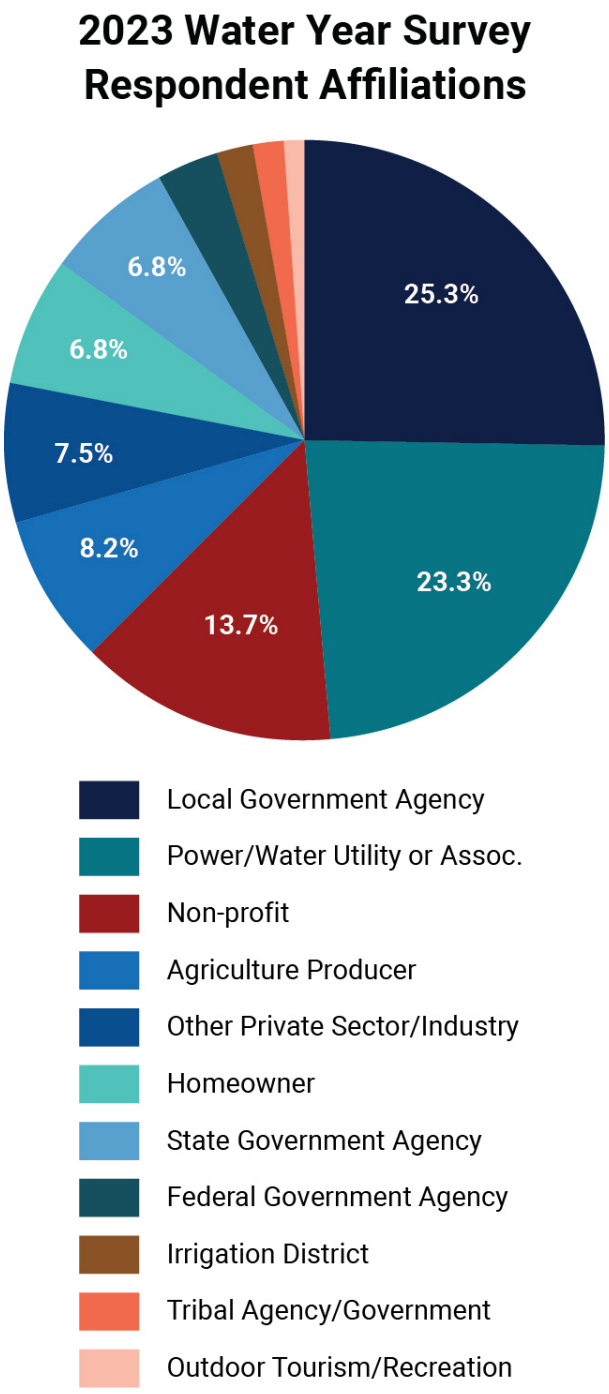



**Figure 19: Self-identified affiliation of the 145 respondents to the 2023 Water Year Impacts Survey.**

# SECTOR-SPECIFIC WATER YEAR IMPACTS

### Drinking water

Most reported impacts on the drinking water sector were local. Of the 36 respondents who reported impacts to this sector, 34 (94%) reported impacts due to abnormally dry conditions and 9 (25%) reported impacts due to abnormally wet conditions.

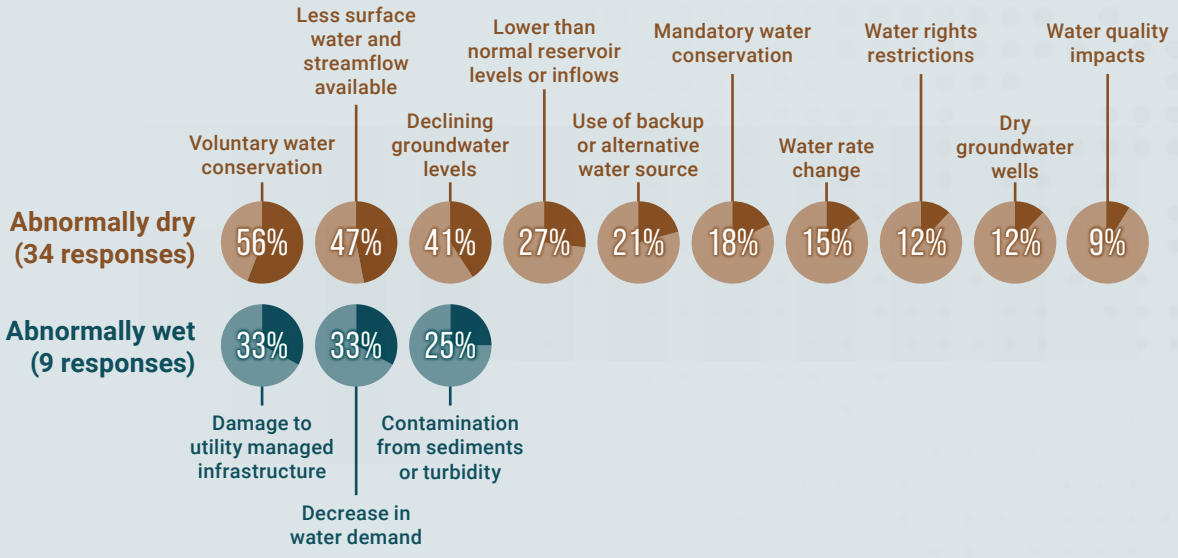
The most common impacts reported were reduced availability of surface water and streamflow and voluntary conservation measures. Other reported impacts demonstrated the diverse ways in which drought directly affected the ability to supply drinking water, including mandatory conservation measures, changes in water rates, use of alternative or back-up water sources, and higher pumping costs. Both surface water and groundwater sources were affected by the dry conditions. Some respondents noted the resilience of groundwater.

> "Wells cavitated more often and private wells further down the aquifer had less water when we pumped more (they sometimes dried up)."

> "Public water systems around Tillamook County [Oregon] were experiencing low surface water and springs supplies, which impacted the amount of water they could treat and send to customers, or other water systems with interties or who purchase water."

> "Wells of three water associations west of Ferndale went dry, additional domestic and agricultural wells went dry in other locations around the County [Whatcom, Washington]."

## DRINKING WATER IMPACTS SURVEY



# SECTOR-SPECIFIC WATER YEAR IMPACTS

Cattle in Central Washington State. Credit: Washington State Department of Agriculture/ Creative Commons

## Agriculture

Of the 19 respondents who reported impacts to agriculture, 18 (95%) reported impacts of abnormally dry conditions and four (21%) reported impacts of abnormally wet conditions. Similar to the drinking water sector, most reported impacts were described as site-specific or affecting a local jurisdiction.

Most respondents who reported impacts of abnormally dry conditions reported increased plant stress and increased water demand due to lower than normal soil moisture.

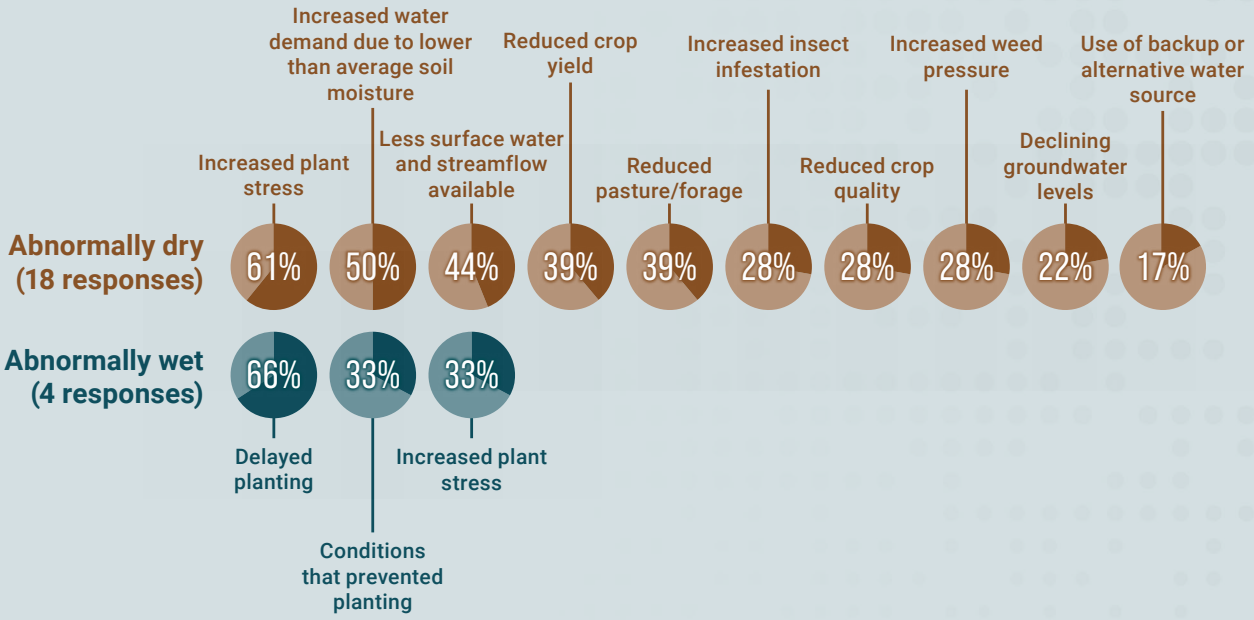
The 2023 survey included additional questions for agricultural producers about the supply of water for irrigation and crops that were affected by abnormally dry conditions. Eight of the 19 respondents indicated that they changed the timing of irrigation or stopped irrigating earlier than usual. Many crops were negatively affected by abnormally dry conditions; most commonly reported were pasture, hay, apples, and vegetables. Most respondents did not indicate any crops that were positively affected by dry conditions, but a few reported positive effects on apples, cherries, grapes, hay, and pears. Annual state-level statistics are released each year by the *U.S States Department of Agriculture's National Agricultural Statistics Service*.

Four respondents reported impacts on agriculture from abnormally wet conditions, primarily delayed planting or conditions that prevented planting. One respondent noted challenges associated with irrigating when cool, wet weather was quickly followed by hot, dry weather. The abrupt transition caused irrigation systems to apply more water and create conditions that were too wet in some soil types.

> "Hay yield was down 60% [Washington]."

> "Sun scald, plant stress with some demise, seed demise [Stevens County, Washington]."

## AGRICULTURE IMPACTS SURVEY



## Idaho Fall Water Supply Meeting

During water year 2023, a three-year drought in the Big Wood and Big Lost basins and a two-year drought in eastern Idaho ended. A slow start to the irrigation season in April, and depressed irrigation demand and increased streamflows from August rains (an impact of Tropical Storm Hilary remnants reaching southern Idaho), resulted in substantial reservoir carryover at the end of the irrigation season. The extra 2.2 million ac-ft of carryover provides a considerable buffer should southern Idaho face drought in 2024 (*Table 1*).

Salmon Falls Creek Reservoir. Credit: Ron/Adobe Stock

Conditions in northern Idaho, however, degraded into drought. Flow was especially low in the Kootenai River, which flows from Canada into Montana and then across the northwest corner of Idaho. Drought severity across northern Idaho by the end of water year 2023 ranged from moderate to severe.

**Table 1: Southern Idaho reservoir storage (million acre-ft) at the start of the 2023 irrigation year (November 1, 2022) compared to the start of 2024 irrigation year (November 1, 2023). Source: data compiled from the U.S. Bureau of Reclamation and U.S. Geological Survey.**

| | 11/1/2022 | 11/1/2023 | CHANGE |
|---|---|---|---|
| Payette Reservoir System | 439,617 | 477,768 | 38,151 |
| Boise Reservoir System | 420,435 | 485,417 | 64,982 |
| Magic Reservoir | 13,330 | 111,400 | 98,070 |
| Little Wood Reservoir | 6,136 | 14,430 | 8,294 |
| Mackay Reservoir | 14,990 | 922 | -14,068 |
| Upper Snake Reservoir System | 609,818 | 1,878,810 | 1,268,992 |
| Bear Lake | 477,573 | 913,837 | 436,264 |
| Oakley Reservoir | 6,196 | 19,424 | 13,228 |
| Salmon Falls Creek Reservoir | 8,600 | 34,090 | 25,490 |
| Owyhee Reservoir | 60,381 | 357,078 | 296,697 |
| | | TOTAL | 2,236,100 |

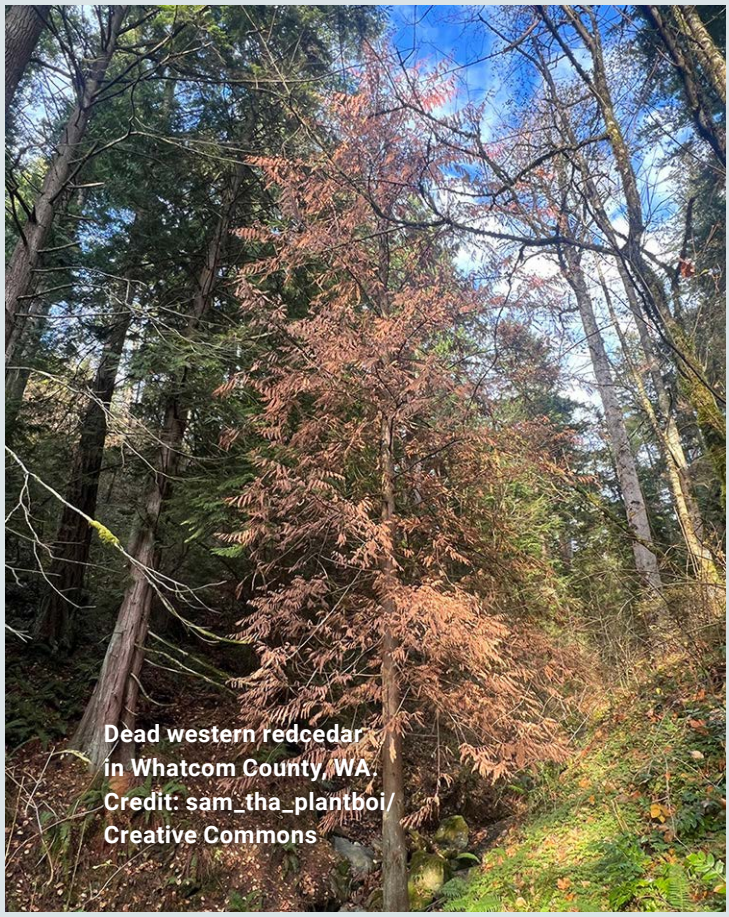
# SECTOR-SPECIFIC WATER YEAR IMPACTS

> "Pretty significant indication all around Whatcom County [Washington] that all western redcedars are being very stressed with 60% of the branches brown (dead) and significant leaf (branchlets & cones) fall on the ground. Many other ornamental conifers (pines, etc.) also showing significant signs of stress."

## Forestry

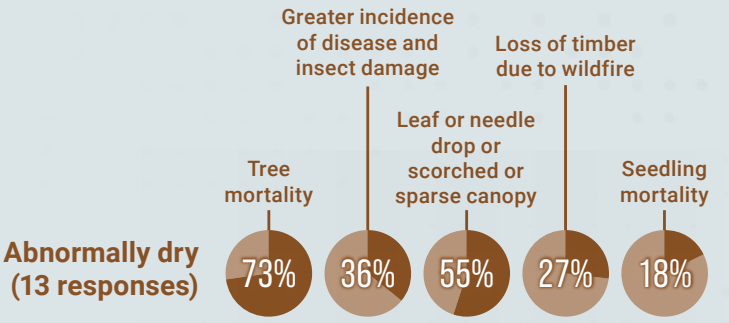
Thirteen survey respondents reported impacts on forestry, all of which (100%) were due to abnormally dry conditions. Impacts were reported almost exclusively in western Washington. The most commonly reported impacts of dry conditions were tree mortality and leaf and needle drop or sparse canopy.

More impacts on forest conditions and wildfire in 2023 can be found in agency reports that will be available in the coming months, such as the Washington Department of Natural Resources *Annual Forest Health Highlights Report*, *Oregon Department of Forestry Forest Health Highlights*, *Idaho Department of Lands Forest Health Highlights*, and the *Northwest Interagency Coordination Center Northwest Annual Fire Report*.



Dead western redcedar in Whatcom County, WA. Credit: sam_tha_plantboi/ Creative Commons

## FORESTRY IMPACTS SURVEY



## Reductions in Hydropower Generation

Seattle City Light's hydropower generation was adversely impacted by multiple weather conditions during the 2023 water year. Seattle City Light serves nearly one million customers in the wider Seattle metropolitan area, and 80-90% of the supplied electricity is from hydropower. Their two largest hydroelectric projects are the Skagit project in Whatcom County, Washington, and the Boundary project in Pend Oreille County, Washington, both of which had below average power generation during all months except October 2022 and May 2023 (*Figure 20*).

Water year inflows to the Boundary project and the Skagit project were the second and third lowest, respectively, in the 26-year record. Several weather conditions during the water year affected these projects, particularly the Skagit. First, winter inflows to the reservoirs were lower than average due to below normal precipitation and colder than normal temperatures, which caused the precipitation to fall more as snow and less as rain. Ross Reservoir elevation and inflows were lower than average throughout winter, which coincided with the period of peak heating demand. Heating demand also was higher than usual given the colder than normal temperatures in the service area. Second, rapid snowmelt in May filled the reservoirs but was not enough to reach the reservoir elevation typically achieved for recreation. Below normal summer precipitation continued to constrain reservoir inflows. Nevertheless, the National Park Service was able to adjust to the lower-than-normal reservoir levels, which allowed for recreation at Ross Reservoir and minimized adverse recreational impacts.

**Release of water through lower outlet valve of Ross Dam on August 6, 2023. Credit: Jeff Anderson, Seattle City Light**

By contrast, hydropower generation was below average during every month except May 2023 (*Figure 20*). Across the water year, Seattle City Light produced 1000 GWh less than usual, 17% below the five-year average. Normally a net supplier of hydropower, Seattle City Light was a net purchaser for the water year, and needed to dip into savings to purchase power. Furthermore, because May runoff was high across the PNW due to warmer than normal temperatures, the excess power that Seattle City Light was able to sell during May was priced lower than usual.

**Sourdough wildfire north of Diablo Dam on August 2, 2023. Credit: William Anderson, Seattle City Light**

Aside from major hydropower impacts and averted recreation impacts, a wildfire in late July above Diablo Dam, the Sourdough Fire, caused staff evacuations and both Ross and Diablo dams were shut down for 13 days. The shutdown resulted in about 23,000 MWh of lost power production, and the need to purchase power on the market during that time. Seattle City Light also needed to release water to maintain flows for fish despite not being able to generate hydropower from the released water.

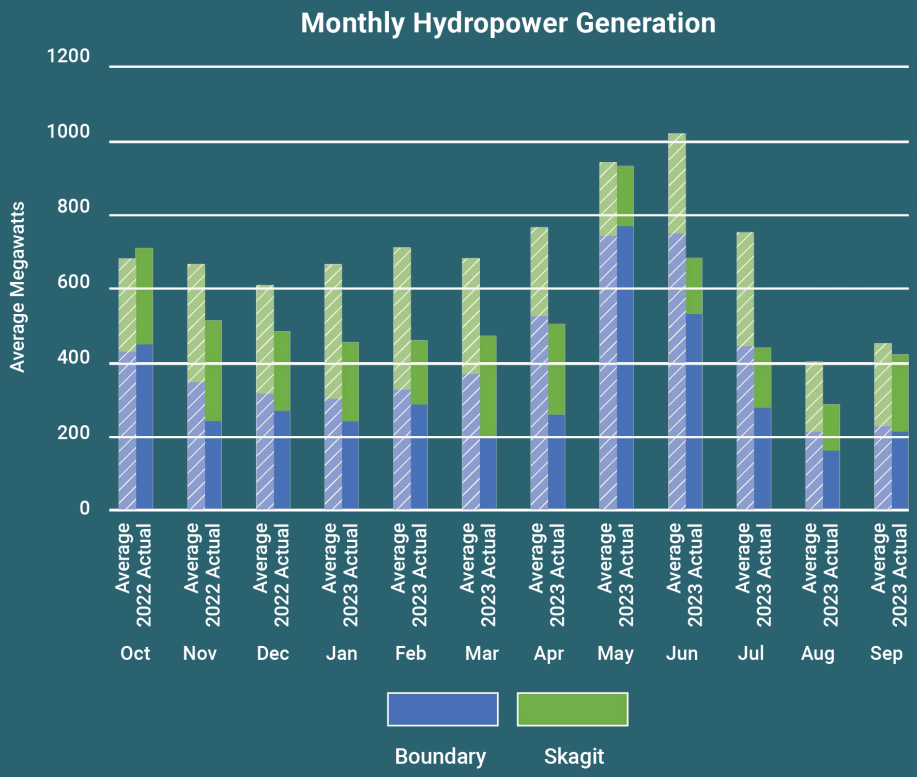



**Figure 20: Monthly hydropower generation for the Seattle City Light Boundary (blue) and Skagit (green) projects. The hashed bars represent the 20-year average hydropower generation and the solid bars represent the actual generation for the 2023 water year. Source: Ronda Strauch, Seattle City Light.**

# SECTOR-SPECIFIC WATER YEAR IMPACTS

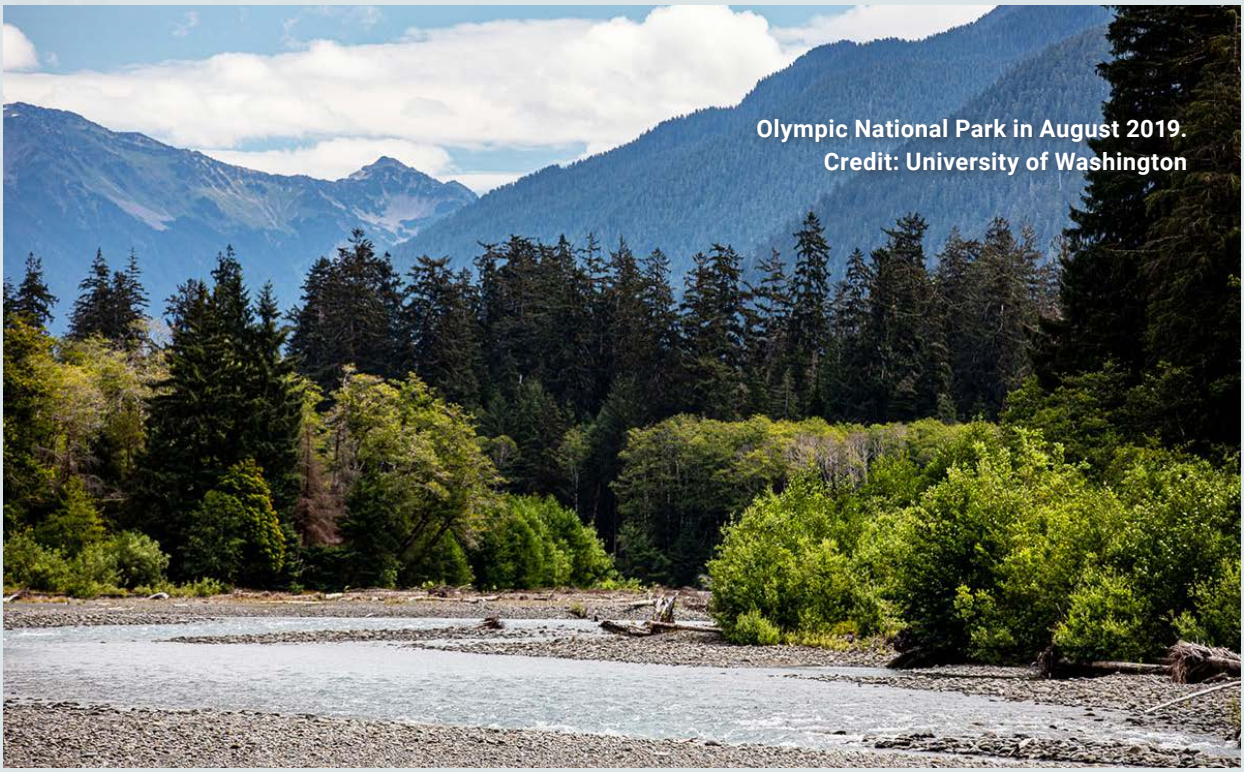
## Fisheries

Thirteen (93%) survey respondents reported impacts on fisheries due to abnormally dry conditions, and five (36%) reported impacts due to abnormally wet conditions.

The most commonly reported impacts of abnormally dry conditions were reduced streamflows, warmer stream temperatures, and blocked fish passage. Some fisheries had low production or closures, especially watersheds on the Olympic Peninsula. Several respondents indicated that abnormally wet conditions caused high sediment loads.

> "The National Park Service, Washington Department of Fish and Wildlife, and the Quileute Tribe closed fisheries throughout the Quillayute River Basin. Additionally, the Salmon Cascades on the Sol Duc River in Olympic National Park appeared to be a complete barrier to passage of summer coho until the first significant rainfall in September. Summer coho historically can ascend the cascades throughout the summer."

> "Side channels lost connectivity and dried out faster than average years. Mainstem reaches dried out that typically do not."



Olympic National Park in August 2019.
Credit: University of Washington


Bonneville Dam, Oregon. Credit: Zack Frank/Adobe Stock

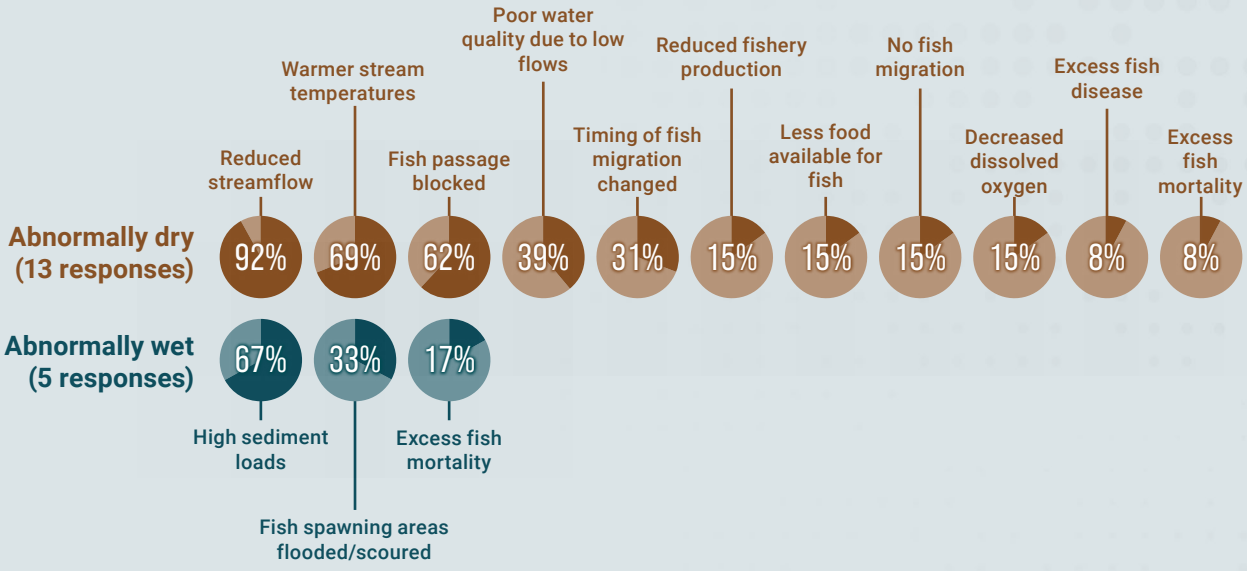
> "Early loss of snowpack and dry warm spring led to unusually low flows and dewatering of some steelhead redds in some Elwha [Washington] tributaries."

> "The high flows resulting from heat in May likely benefited smolt outmigration from the Yakima River [Washington]. High and turbid water would reduce predation and canal entrainment losses as fish out migrate to the Columbia River."

> "High flows associated with a wetter than normal April, followed by rapid loss of snowpack in the Elwha [Washington] at the peak of the steelhead spawning season may have impacted spawning activity."

For more information on water year impacts on the fisheries sector, see the annual *Ecosystem Status Report* released each March by the California Current Ecosystem Integrated Ecosystem Assessment. The report focuses on the marine ecosystem with the goal of informing fisheries management. The annual *Puget Sound Marine Waters Report* summarizes the oceanic, atmospheric, and terrestrial influences on the Puget Sound during the calendar year.

## FISHERIES IMPACTS SURVEY



# SECTOR-SPECIFIC WATER YEAR IMPACTS

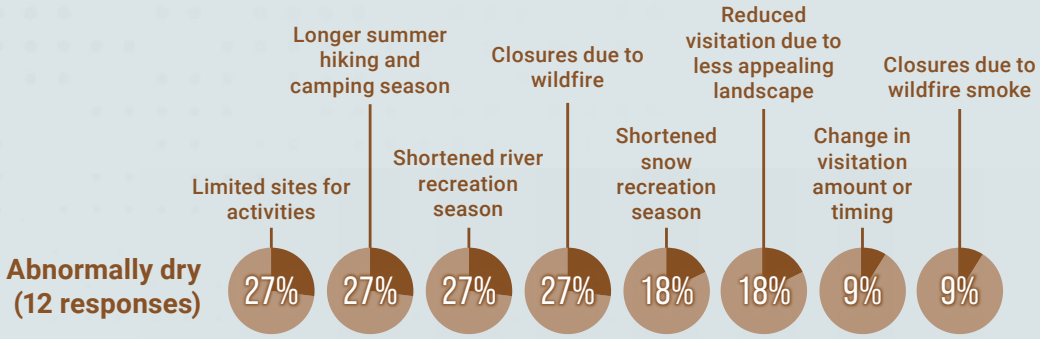
Mt. Hood Meadows Ski area in Oregon. Credit: Alex/Adobe Stock

## Recreation

Twelve respondents reported impacts on recreation. All twelve reported impacts associated with abnormally dry conditions and four (33%) also reported impacts from abnormally wet conditions. Impacts on recreation were reported primarily in Washington and included a strong snowpack for the ski season. However, most reported impacts were negative and related to hot, dry conditions in summer or erosion due to seasonal high flows.

> "Glacier and alpine climbing was limited in summer months due to early and extreme snowmelt on upper glaciers. Many upper reaches of mountains normally covered in snow, had exposed ice and crevasses creating dangerous climbing conditions."

## RECREATION IMPACTS SURVEY



# 5 STATE LEVEL & SECTOR-SPECIFIC RESPONSES

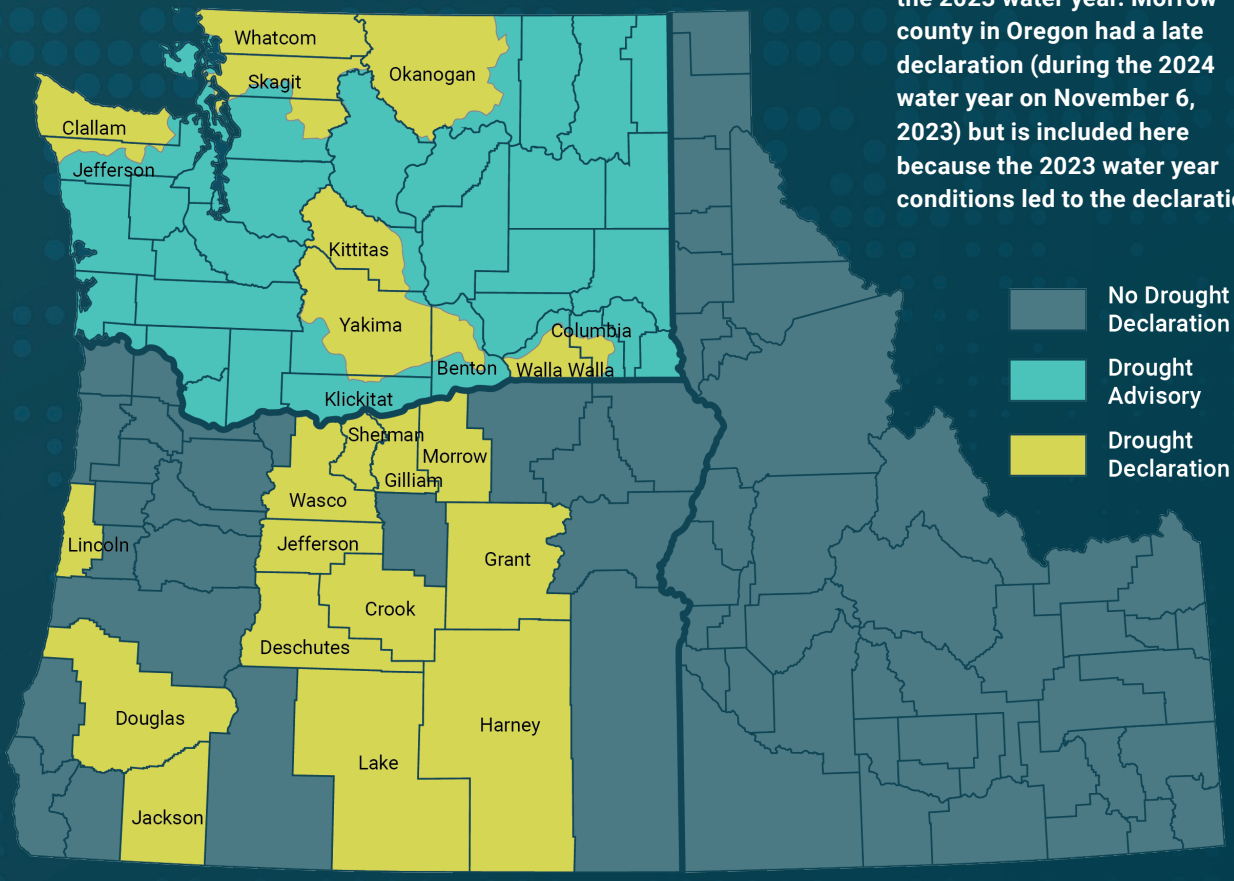



**Figure 21: Counties or watersheds in the PNW for which drought declarations or advisories were issued during the 2023 water year. Morrow county in Oregon had a late declaration (during the 2024 water year on November 6, 2023) but is included here because the 2023 water year conditions led to the declaration.**

## State Responses

State drought declarations are typically used to facilitate the temporary transfer of water rights and offer short-term solutions to water supply challenges. Drought declarations (*Figure 21*) were issued throughout the water year in Oregon and Washington. Idaho did not issue any drought declarations. Oregon issued drought emergencies in 13 counties, beginning with Crook and Jefferson counties on February 15, 2023, and ending with Morrow County on November 6, 2023. About half of the emergencies were declared from March 23 through May 25, but others occurred later: June 26 for Jackson County, August 31 for Gilliam and Douglas counties, September 1 for Lincoln County, and November 6 for Morrow County. All of the Oregon declarations expired on December 31, 2023.

In Washington, a statewide drought advisory was issued on July 5, 2023. A drought emergency for parts of 12 counties followed on July 24. The declaration covered parts of the northern Puget Sound, northern Olympic Peninsula, and Lower Columbia Basin. Since it was already apparent at the time of these declarations that an El Niño would likely be in place during winter 2023-24, the drought declarations and drought advisory were set to expire June 30, 2024.

In addition to drought declarations, emergency proclamations were made in response to the weather and climate conditions in both Oregon and Washington (*Table 2*).

## Sector-Specific Changes in Operations

The Annual Pacific Northwest Water Year Impacts Survey asked respondents if they modified operations in response to abnormally dry or wet conditions during the water year. Of respondents who reported impacts due to abnormally dry conditions, over half indicated that they changed operations in response to those conditions (*Figure 22*). Changes due to abnormally wet conditions were less common, but reported impacts of these conditions were also less common.

**Agriculture:** The agriculture sector reported especially high operational flexibility in response to abnormally dry conditions, with 82% of respondents indicating that they changed operations in response to abnormally dry conditions. Reported changes included starting irrigation sooner and increasing the duration of irrigation cycles. One survey respondent noted that not only did they increase the frequency of irrigation, but they also used telemetry soil moisture sensors and improved irrigation operations. Other changes included harvesting less frequently and replanting failed crops.

**Limited regrowth of grass on the right side of the fence after being cut for hay, with reduced yields, in late June. Photo taken in Wahkiakum County, Washington on August 29, 2023 (*CMOR*).**

**Table 2: A list of emergency proclamations made in Washington and Oregon during the 2023 water year. The dates, type of proclamation, the state and counties it relates to, and a brief reason for each proclamation are listed.**

| DATES | PROCLAMATION | ST | COUNTIES | REASON FOR EMERGENCY |
|---|---|---|---|---|
| Nov 3-8, 2022 | State of Emergency | WA | Clallam, Cowlitz, Grays Harbor, Island, Jefferson, Lewis, Okanogan, Pierce, Skamania, Snohomish, Wahkiakum | Winds, rain, flooding, landslides |
| Dec 18-22, 2022 | State of Emergency | WA | Chelan, Clallam, Grays Harbor, Island, Jefferson, King, Kitsap, Okanogan, Pacific, Pierce, Snohomish, Stevens, Whatcom | Atmospheric rivers |
| Dec 22, 2022-Jan 6, 2023 | State of Emergency | OR | Clackamas, Coos, Curry, Douglas, Hood River, Jackson, Josephine, Lane, Lincoln, Malheur, Multnomah, Washington, and Umatilla | Severe winter storms with winds, rain, flooding, and ice |
| Feb 25-Mar 4, 2023 | State of Emergency | OR | Multnomah | Snow and ice |
| May 14, 2023 | State of Emergency | WA | Skamania | Record high temperatures that caused rapid snowmelt and a landslide |
| Jun 11-19, 2023 | State of Emergency | OR | Harney and Malheur | Flooding and landslides |
| Jun 13, 2023 | Emergency Conflagration | OR | Umatilla | Hat Rock and Mt. Hebron Wildfires |
| Jul 10, 2023 | State of Emergency | WA | Douglas and Grant | Severe thunderstorms, flooding and wildfire |
| Jul 22, 2023 | Emergency Conflagration | OR | Klamath | Golden Wildfire |
| Jul 28, 2023 | State of Emergency | OR | Statewide | Imminent threat of wildfire |
| Aug 13, 2023 | Emergency Conflagration | OR | Lane | Lookout Wildfire |
| Aug 19, 2023 | State of Emergency | WA | Statewide | High wildfire potential |
| Aug 25, 2023 | Emergency Conflagration | OR | Douglas | Portions of the Tyee Ridge Wildfire Complex |
| Sep 3, 2023 | Emergency Conflagration | OR | Umatilla | Bensel Wildfire |
| Sep 5, 2023 | Emergency Conflagration | OR | Josephine | Portions of the Smith River Wildfire Complex |

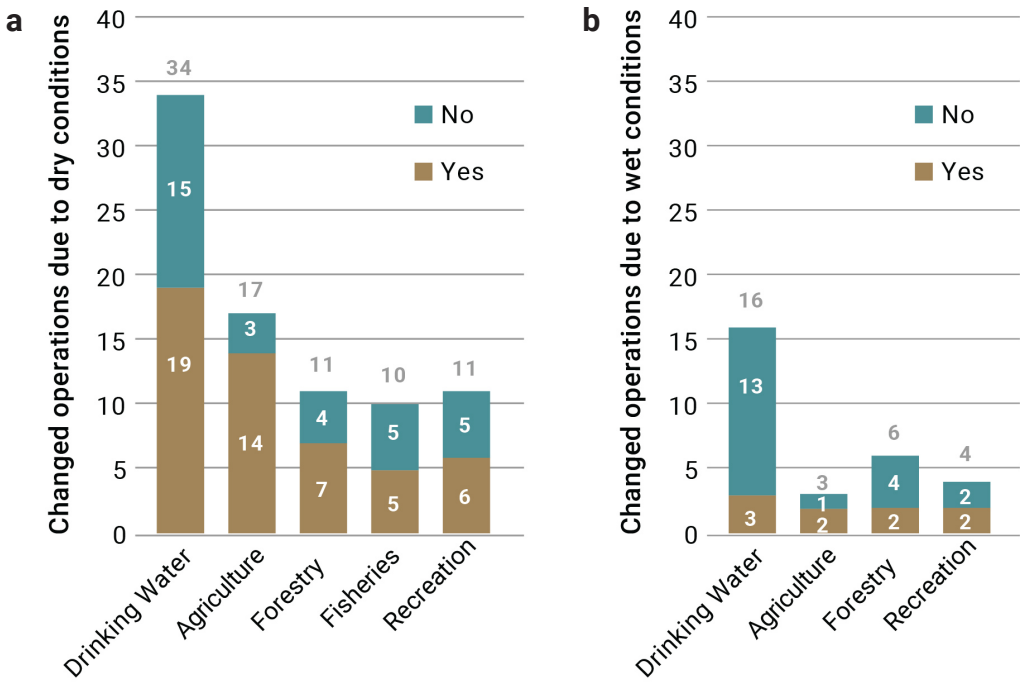



**Figure 22: Annual PNW Water Year Impacts Survey responses to whether operations in multiple sectors were changed in response to abnormally (a) dry or (b) wet conditions.**

**Drinking water:** The drinking water sector also demonstrated operational flexibility in response to dry conditions, with 56% of respondents indicating that they changed operations in response to abnormally dry conditions. Response actions included increasing public education to conserve water, increasing the frequency of monitoring reservoir levels, switching to alternative water sources, reducing irrigation, and requiring or encouraging water conservation.

**Forestry:** Reports from people affiliated with the forestry sector described responding to dry conditions by mulching trees and watering, including of native trees. Others described advising people to plant different tree species or to reduce the density of planting.

## Changes in Operations Based on Forecasts and Outlooks

The NOAA Climate Prediction Center seasonal outlooks and drought outlook are the most commonly used forecast tools (*Figure 23*). These outlooks were used at least rarely during the water year by 60% of survey respondents and often or frequently by about 15% of respondents. The next most commonly used forecast tools are the Wildland Fire Potential Outlook and the Northwest River Forecast Center streamflow forecasts. Some respondents indicated that they use summaries of information from these tools that are released by state agencies or other intermediaries. Other respondents indicated that they used more localized monitoring information. Overall, a higher proportion of respondents in 2023 than in previous years indicated that they did

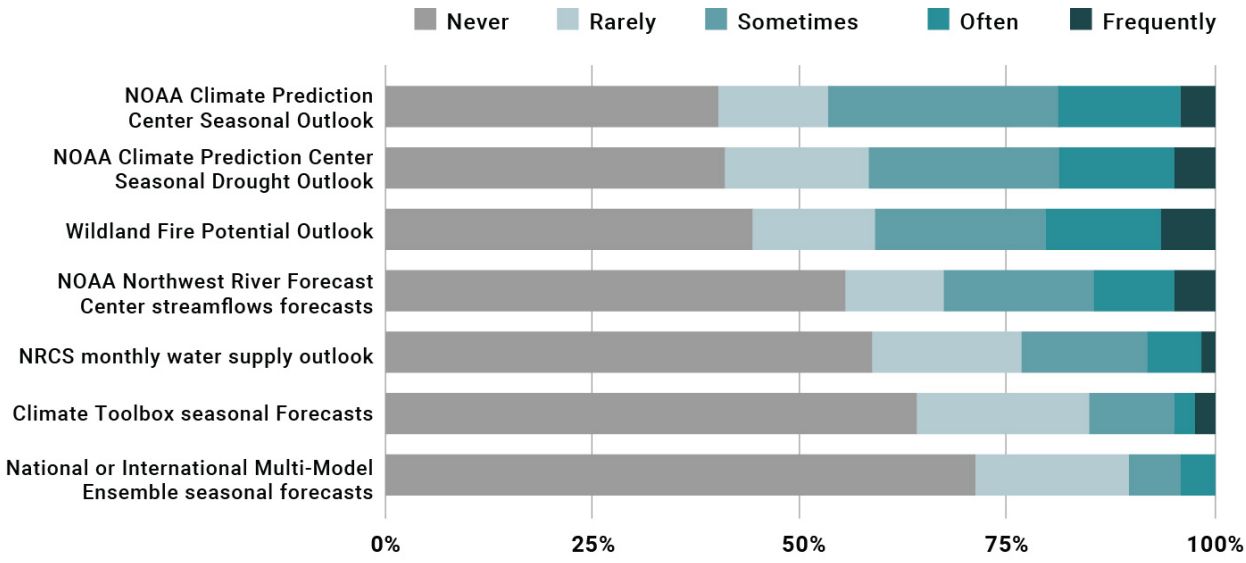



**Figure 23. The Annual PNW Water Year Impacts Survey responses to the question, "During the water year, how often do you use these seasonal forecasts and outlooks?"**

not use any forecast tools during the water year. These results reflect the larger sample size and a greater number of respondents who did not report sector-specific impacts.

Survey respondents described some ways in which they responded to information in the seasonal forecasts and outlooks such as short-term adjustment of operations, greater interagency coordination, and communications.

### Operational changes

- Changed the timing of field operations or monitoring
- Changed timing of planting
- Reduced activities on managed forest lands and inoculated some trees to prevent insect-caused tree mortality
- Watered more frequently
- Imposed water restrictions

### Communication changes

- Increased the frequency of communications regarding water conservation programs, requests for voluntary conservation, and heat mitigation options for people
- Increased outreach, guidance, and assistance for planning in drought or when dry conditions are forecast

# 6 FORECAST VERIFICATION

La Niña during winter 2021-2022 persisted through spring and summer, and was present in the tropical equatorial Pacific Ocean during winter 2022-2023, marking the third consecutive winter with La Niña conditions. The continuation of La Niña for a third consecutive winter was well-predicted. Typically, La Niña events are associated with colder and wetter than normal winters in the PNW, with above normal snowpack by April 1, although there is some variability in the strength of that relationship throughout the PNW. NOAA's Climate Prediction Center (CPC) and other centers for long-term forecasts produce the seasonal weather predictions on the basis of empirical relationships during past La Niña events, other observed properties of the global climate system that provide predictability, and projections from global atmosphere-ocean climate models.

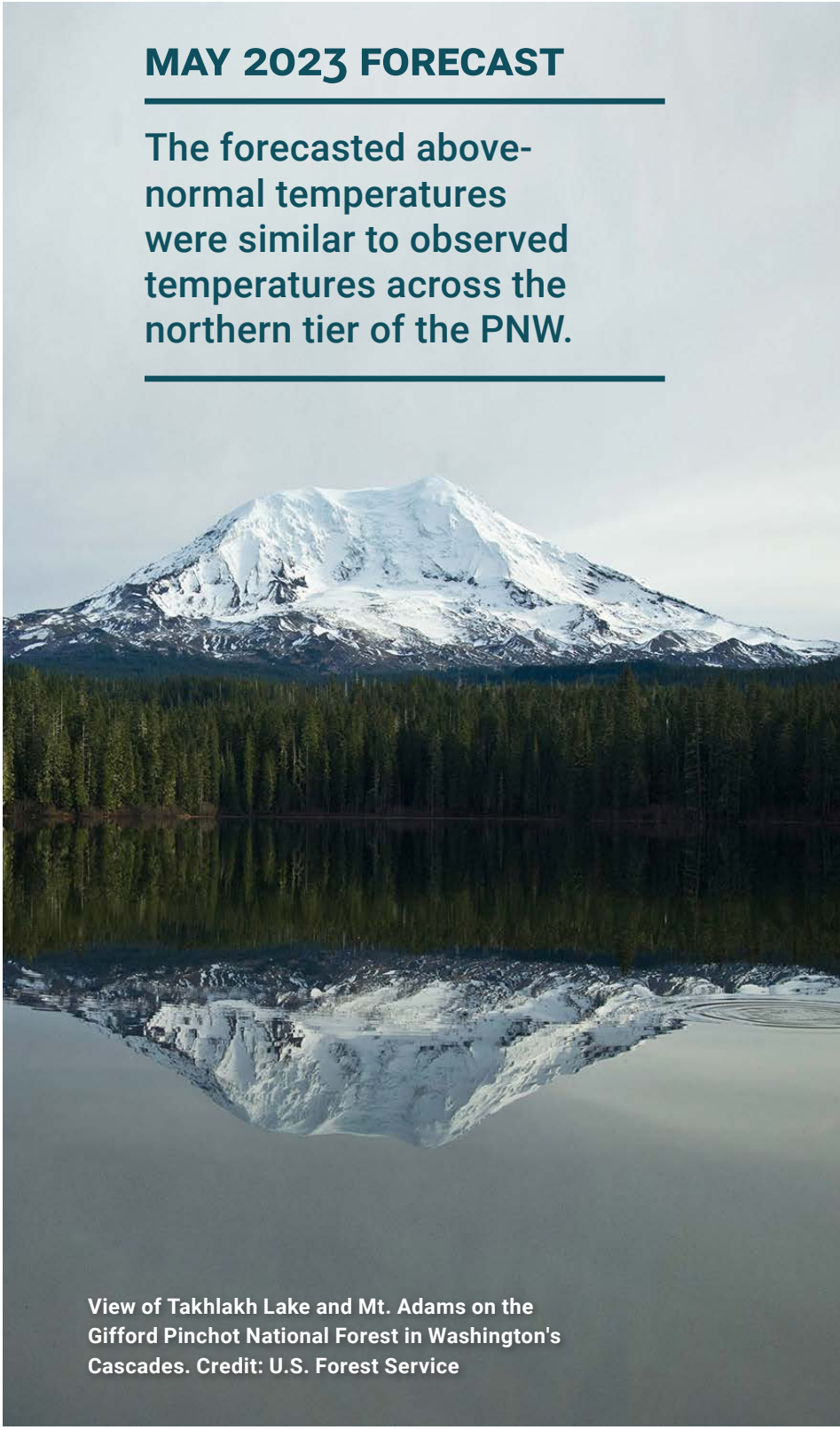
The monthly and seasonal forecasts made during the 2022-2023 winter through the March-April-May three-month period included below normal temperatures and above normal precipitation for a majority of the region, consistent with typical outcomes during previous La Niña events. Because the CPC seasonal outlooks were among the forecast tools most commonly used by our survey respondents, we qualitatively examined the accuracy of one monthly forecast during the 2023 water year. We chose May as our example because it was a critical period in the water year given the rapid snowmelt and above normal temperatures.

**May was chosen as our example because it was a critical period in the water year given the rapid snowmelt and above normal temperatures.**

## May 2023 Forecast and Verification

The CPC temperature forecast for May, issued in mid-April 2023 (*Figure 24*), favored above-normal temperatures across all of Washington, northern Oregon, and parts of the Idaho panhandle. The rest of the PNW had equal (33% each) probability of below, near-normal, or above normal May temperatures.

Observed temperatures throughout the PNW were indeed above normal, resulting in an accurate forecast for the northern tier of the region. While the equal probability forecast across most of Oregon and southern Idaho did not provide much advance warning of the observed above normal May temperatures, the updated May 2023 forecast issued on April 30 (not shown) did include the rest of the PNW in the above normal temperature forecast category.




View of Takhlakh Lake and Mt. Adams on the Gifford Pinchot National Forest in Washington's Cascades. Credit: U.S. Forest Service

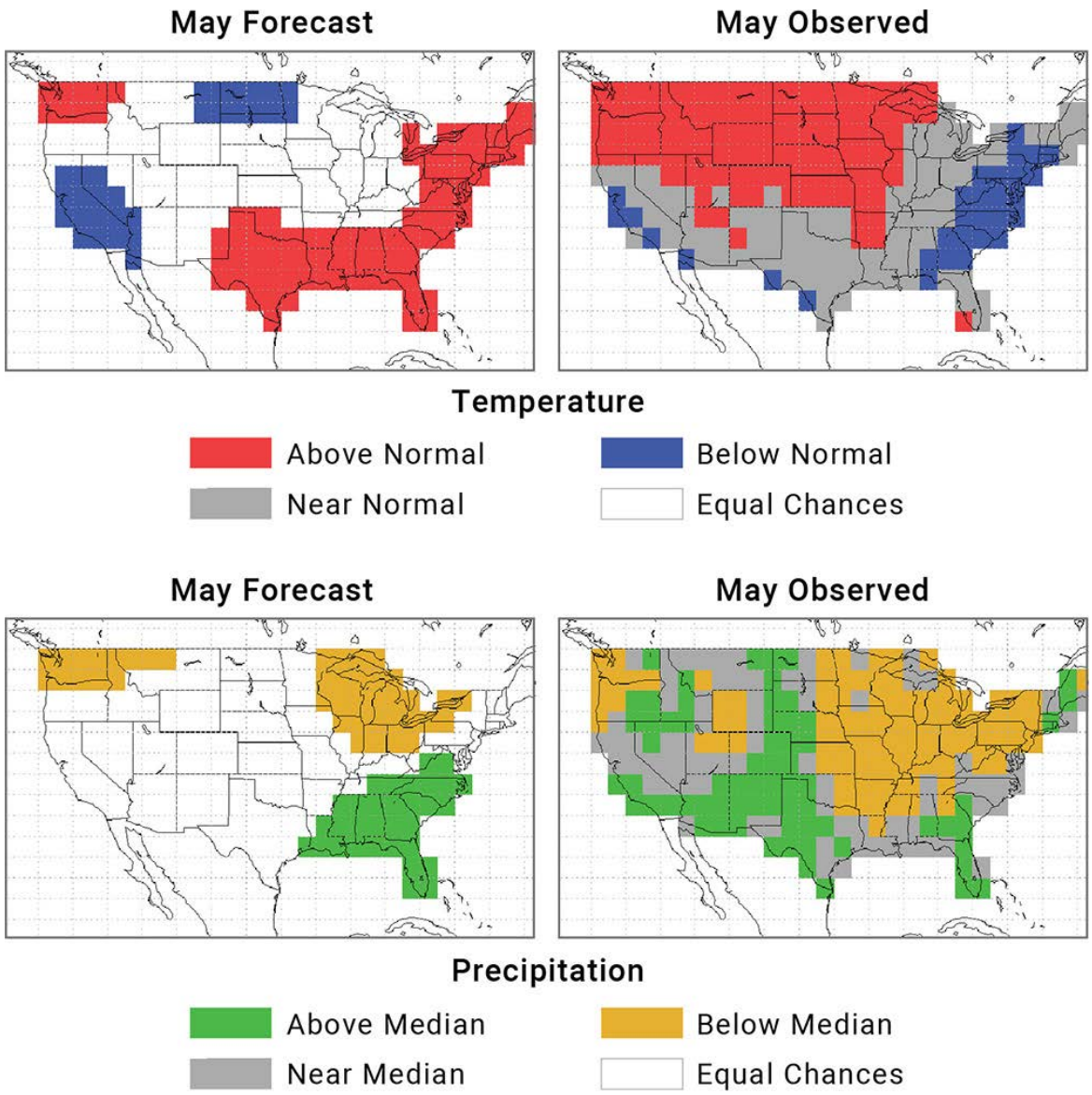



**Figure 24: Categorical temperature and precipitation forecasts for May 2023, issued in April 2023, compared to observations for those months. Source: *Climate Prediction Center.***

The CPC precipitation forecast for May issued in mid-April 2023 indicated below-median precipitation across all of Washington, northern Oregon, and parts of the Idaho panhandle (*Figure 24*). Similar to the temperature forecast, the rest of the PNW had equal probability (33% each) of below, equal to, or above median precipitation.

The below median precipitation forecast for western Washington, northern Oregon, and southern Washington matched the observed conditions, but the below median precipitation in western Oregon was not indicated in the forecast. There was also above median precipitation in southeastern Oregon, southern Idaho, and northeastern Washington, in

## MAY 2023 FORECAST

**The drier than normal conditions were well forecasted in western Washington, northern Oregon, and southern Washington, but there were other areas of the PNW that were either wetter or drier than the forecast indicated.**

contrast to the May precipitation forecast that was either for below median precipitation or equal chances of either outcome. Similar to the case for temperatures, the updated May forecast released on April 30 (not shown) did accurately predict the above median precipitation for southeastern Oregon and parts of southern Idaho.

Overall, the monthly forecast at the end of April captured May conditions better than the earlier April forecast, but the mid-April forecast captured the above normal temperatures for the northern tier of the region and some of the May precipitation variability. It is important to note that below normal temperatures were forecast for monthly and seasonal three-month periods earlier in the water year. Therefore, not only did the CPC forecast the above normal temperatures accurately, but the forecasters successfully predicted the shift in the direction of the temperature anomalies that occurred from April to May.

# 2023

# PACIFIC NORTHWEST WATER YEAR

## IMPACTS ASSESSMENT

Supported by the
NOAA National Drought
Information System