EXECUTIVE SUMMARY
TO THE SPOKANE CLIMATE VULNERABILITY AND RESILIENCE ASSESSMENT

Climate Impacts Research Consortium
A NOAA RISA TEAM

RISA
Regional Integrated Sciences and Assessments

About this Report

This executive summary was created as part of the Spokane Climate Project (SCP) and complies the key climate science finding of the project. This summary report is part of a larger climate and weather vulnerability and resilience assessment for Spokane, Washington. The full assessment is scheduled for completion sometime in 2021.

Under the guidance of the Pacific Northwest Climate Impacts Research Consortium (CIRC), Spokane Climate Project participants from Spokane used CIRC's Climate Toolbox, a suite of online climate science tools and related datasets, to investigate how climate and weather-related impacts—including rising temperatures, wildfires, and the loss of snowpack—are projected to affect the community of Spokane, its businesses, working lands, and ecosystems in the decades ahead. The findings presented here also draw upon additional academic resources as well as on interviews with local business owners, emergency responders, and other Spokane residents.

The full version of this report as well as a full list of the citations and methodologies employed for this analysis can be found at the Spokane Climate Project website: https://www.spokaneclimateproject.org/.

Climate Impact Categories

SCP participants chose to explore climate and weather impacts related to the following:

- Temperature
- Precipitation
- Snowfall
- Wildfires
- Streamflow

About the Spokane Community Adaptation Project

The Spokane Climate Project is a collaborative effort between the Pacific Northwest Climate Impacts Research Consortium (CIRC) and the community of Spokane, Washington. The project's goals are to identify climate and weather impacts faced by the Spokane community as well as resiliency actions designed to keep the community, its economy, and natural systems healthy and prosperous. Project participants include representatives from city and county entities, local universities, local nonprofits, and local businesses.

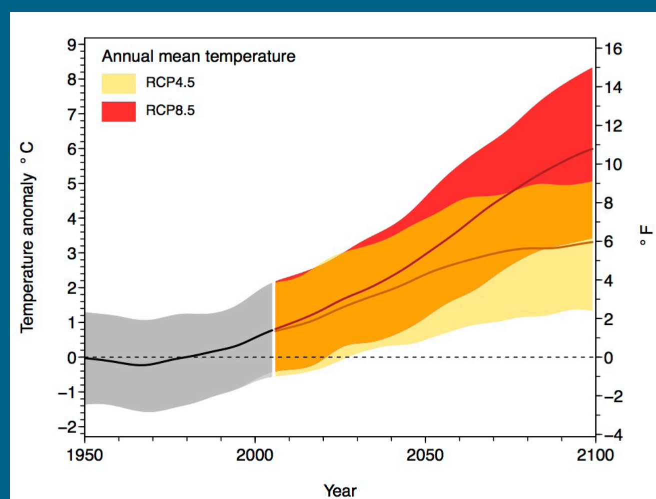
About CIRC

The Pacific Northwest Climate Impacts Research Consortium (CIRC) is a team of climate and social science researchers based in the Pacific Northwest United States. CIRC helps Pacifc Northwest communities become more resilient to extreme climate and weather impacts. CIRC is publicly funded through the National Oceanic and Atmospheric Administration's Regional Integrated Sciences and Assessments (RISA) program. Part of NOAA's Climate Program Office, the RISA program supports research teams that help expand and build our nation's capacity to prepare for and adapt to climate variability and change. CIRC members can be found at Oregon State University, the University of Idaho, the University of Washington, and the University of Oregon.

Key Term: *Emissions Scenario*

The writers of this report primarily used the greenhouse gas emissions scenario (RCP 8.5) when examining future climate impacts. This scenario simulates what is likely to happen if greenhouse gases continue to be released into the atmosphere at their current rate.

RCP 4.5, a lower emissions scenario that assumes dramatic reductions in greenhouse gas emissions, was used by many groups as a useful comparison to RCP 8.5, offering a glimpse into a future in which emissions and climate impacts are reduced.



Caption: Projected annual temperature simulations for both high emissions scenario (RCP 8.5) and lower emissions scenario (RCP 4.5) for the Northwest United States to the year 2100. (*Figure source: David E. Rupp; data source: Rupp et al. 2016, adapted.*)

Temperature

From Chapter 1—Temperature Impact Study for Spokane, Washington
Full Chapter: https://www.spokaneclimateproject.org/temperature

Lead Authors: Rebecca MacMullan (350 Spokane), Kara Odegard (Measure Meant), Jim Simon (Gonzaga University), and David Camp (Northwest Renewables)

Climate Data Story—Bloomsday

Held every year in May to coincide with the seasonal blooming of lilacs, Spokane's Lilac Bloomsday Run (Bloomsday) is a seven-and-a-half mile run that draws roughly 50,000 participants and raises money for charities (**Bloomsday Run 2019**). From 1979 to 2019, Spokane has seen above average temperatures for May. As a consequence of these rising temperatures, Bloomsday is already experiencing an increase in heat-related health issues.

During the May 2018 Bloomsday race, warmer-than-normal temperatures likely led to an increase in heat-related illnesses and an increase in the dropout rate for the race (**Lutz 2018**). Heat-related illnesses will likely be a factor during future Bloomsdays. A comparison between recorded historical temperatures and projected future temperatures shows how.

The first Bloomsday run was held in 1977 (**Bloomsday Run 2019**). Historically temperatures during Bloomsday races have varied considerably, ranging from an historical low of 42 degrees Fahrenheit (recorded at 2:00 pm during the 1984 race) to a high of 78 °F (recorded at 2:00 pm during the 1977 and 1980 races). The mean maximum daily temperature for the entire month of May for the race's early years, defined here as 1971–2000, was roughly 68 °F (**Bloomsday Run 2019**). However, under the high emissions scenario (RCP 8.5), mean maximum daily temperatures for May are projected to be 74 °F by the middle decades of this century (2051–2080) and 76 °F by the late decades of this century (2081–2099), a projected 8 °F increase. The projected future increase in May temperatures strongly suggests the likelihood of a corresponding increase in heat-related illnesses occurring during future Bloomsdays.

Climate Data Story—Urban Tree Canopy

Protecting and expanding urban tree cover nationwide is increasingly understood as important for minimizing the effects of heat and drought. Supporting coverage of trees that are fire-resistant, drought-resistant, and deciduous hardwood species will be especially important. Deciduous, leafy trees

Key Findings:

1. Strong evidence suggests that human-caused climate change is leading to rising temperatures in Spokane that will likely correspond to a rise in heat-related illnesses.
2. By the middle of this century (2040–2069), mean annual temperatures in Spokane are projected to be 4.4 °F warmer under the lower emissions scenario (RCP 4.5) and 5.9 °F warmer under the high emissions scenario (RCP 8.5) than they were during the historical years 1971–2000. Temperature increases in Spokane become more extreme by late century (2070–2099), rising by 5.5 °F under RCP 4.5 and by 9.5 °F under RCP 8.5.
3. Throughout this century, temperatures in the Spokane region are projected to rise across all months of the year.
4. Under the high emissions scenario (RCP 8.5), Spokane's hottest summer day is projected to reach 106 °F by mid-century (2040–2069) and 111°F by late-century (2070–2099) compared to the mean of 99 °F for the years 1971–2000.
5. Under both the lower emissions scenario (RCP 4.5) and the high emissions scenario (RCP 8.5), Spokane is projected to see an increase in the number of days annually where the heat index reaches or exceeds 90 °F, 100 °F, and 105 °F.
6. Rising temperatures create future challenges in the Spokane region that will require planning and preparation to protect the health and safety of all Spokane residents, as well as groups identified as being vulnerable to heat-related illnesses.

Resiliency Actions:

1. Reduce Emissions—The negative outcomes of the high emissions scenario (RCP 8.5) can be mitigated by swift and significant reductions in greenhouse gas emissions.
2. Plan for High Temperatures—Over the next 30–60 years, high heat dangers should be considered when scheduling outdoor public events.
3. Safety Protocols—Health and safety officials should create and promote safety protocols for extreme heat events with particular concern for outdoor workers, outdoor recreation participants/athletes, and heat-vulnerable populations.
4. Train and Equip First Responders —First responders should be adequately trained and equipped to treat heat- related illnesses.
5. Urban Forest—The City of Spokane should take immediate action to protect and expand the urban tree cover to mitigate the effects of rising temperatures on human health.

cool streets and structures in summer while allowing winter sun to provide heat and light. As summers grow hotter, trees can absorb 90% of incoming solar radiation (**Heisler 1986**) while evapotranspiration from their leaves cools the air, and their shade cuts the solar heating of buildings and parking lots—effects that can reduce air temperatures by as much as 5.8° Fahrenheit (**Akbari and Taha 1992**). As side benefits, trees boost property values (**Nowak et al., 2002**), increase tax revenue (**Dwyer et al.,1992**), and increase general feelings of wellbeing (**Kardan et al., 2015; Donovan et al., 2013**).

Urban forestry will become more challenging as temperatures increase, both for maintaining trees planted in cooler times and for establishing species better suited to hotter summers. Urban foresters will need to adapt to new conditions and anticipate still warmer conditions to come. Insect pests, including bark beetles, will likely continue to infest conifers as warmer winters expand insect ranges, especially as drought stress makes more trees susceptible to these insects (**NCA 4, Chapter 6 2018**). At the same time, horticulturists in Spokane, currently in U.S. Department of Agriculture zone 6a or 6b (**USDA Plant Hardiness Zone Map 2018**), will have a broader palette of plant species to work with as Spokane continues to warm. The Climate Toolbox's Future Cold Hardiness Zones Tool reports Spokane as being in zone 7a for the years 1971–2010. The tool projects the city will be in zones 7b, 8a, and 8b by 2010–2039, 2040–2069, and 2070–2099, respectively under RCP8.5 (**Future Cold Hardiness Zones Tool 2018**).

For reference, among Intermountain western United States cities, Portland, Oregon, is currently in zone 8b (**Future Cold Hardiness Zones Tool 2018**) (**USDA 2018**). Because frequent watering is critical when establishing newly planted trees (**University of Minnesota Extension 2019**), increased summer and spring irrigation could be more important when establishing trees under a warmer climate.

While planting more trees is desirable and wise, planting on the south sides of homes and buildings could interfere with rooftop solar power, which will be a fast-growing requirement in a decarbonizing world. Policymakers might make allowances for this by allowing or even assisting in tree removal where needed to accommodate solar, even as they tighten protections for trees overall. Further analysis is required to determine the net impact on carbon emissions if policymakers are going to prioritize tree removal for solar installation.

Precipitation

Chapter 2—Precipitation Impact Study for Spokane, Washington
Full Chapter: https://www.spokaneclimateproject.org/precipitation

Lead Authors: Joel Breems (Avista) and Kevin Booth (Avista)

Climate Data Story—Dryland Wheat Farming

In the Inland Pacific Northwest, dryland farming dominates much of the landscape. In 2018 alone, Washington dryland farmers produced 153 million bushels of wheat, making the state the fourth largest wheat-producing state in the nation, with the second highest average yield per acre, according to the Washington Grain Commission. All told, dryland wheat is Washington's third largest commodity and accounts for nearly $691 million in production value for the state (**Washington Grain Commission 2019**). Dryland wheat farming is also dependent solely on precipitation for all of the moisture required for crop growth, maturation, and productivity.

This relationship to precipitation makes dryland wheat ideal for studying how projected future changes to precipitation could impact dryland farming in the Spokane region. Dryland wheat production requires 8–25 inches of precipitation during the fall, winter, and spring, and benefits from relatively dry summer months (**Schillinger et al., 2012**). Historically, the majority of Spokane's annual precipitation has fallen during the winter and spring months. This trend is expected to continue under both the lower emissions scenario (RCP 4.5) and the high emissions scenario (RCP 8.5). Under both scenarios, precipitation projections for Spokane show a slight increase in annual precipitation; a slight increase in precipitation during the fall, winter, and spring months; and a slight decrease in precipitation over the summer months.

Key Findings:

1. In recent decades, the Spokane region has observed a slight increase in precipitation during the fall, winter, and spring months, and a slight decrease in precipitation during the summer months.
2. The timing and volume of precipitation in the Spokane region is not projected to dramatically change over this century.
3. Precipitation projections for Spokane for this century show a slight increase in annual precipitation, with a slight increase in precipitation during the fall, winter, and spring months, and a slight decrease in precipitation over the summer months. However, these projections do not preclude the existence of periodic future droughts due to low precipitation levels.
4. The Spokane region will continue to meet the precipitation timing and volume requirements for dryland wheat production.
5. During the 2015 drought, drought loss claims filed for wheat in Spokane, Adams, Whitman, and Lincoln Counties totaled a combined $22 million.

Resiliency Actions:

1. Planting Techniques—There are several steps farmers can take to minimize the compounding effects of climate change to our agricultural community. Current efforts to minimize erosion in our region, including no-till and direct seeding planting techniques as well as re-establishing stream and field buffers, will become even more important in the future.

According to future climate projections tracked in the Climate Toolbox, the Spokane region will continue to meet the precipitation timing and volume requirements for dryland wheat production. Independent research has also concluded that dryland winter wheat production in the Pacific Northwest could see increased yields under both the rising temperatures and the rising atmospheric carbon dioxide levels expected under both RCP 4.5 and RCP 8.5 (**Stöckle et al., 2014; *Fourth National Climate Assessment*, Chapter 24 2018**).

Historically, however, dryland wheat farming has not been immune to the effects of drought. To better understand how drought might impact dryland wheat farming in the Spokane area, CIRC examined drought-associated insurance loss claims for wheat filed from 2001 to 2015 across the 24-county region of the Inland Pacific Northwest, a region that includes Spokane County and nearby Adams, Whitman, and Lincoln Counties (**Seamon et al., 2019a**).

In 2015, wheat insurance loss claims filed across the Inland Pacific Northwest totaled $240 million for all damage causes, of which losses attributed to drought accounted for 56%. In Spokane, Adams, Whitman, and Lincoln Counties in 2015, drought loss claims filed for wheat totaled a combined $22 million (**Seamon et al., 2019b**).

The drought conditions during 2015 provide a potential analog for future droughts in terms of both precipitation and temperature. The year 2015 is an ideal analog because the year saw near-normal precipitation levels but with temperatures similar to those projected for the middle decades of this century (**Marlier et al., 2017**). While the 2015 drought and its effect on wheat and insurance loss claims is not a clear guide to how dryland wheat might be affected in the future, it does raise the possibility that dryland wheat farming might be more susceptible to certain climate conditions than previously estimated.

Discussion—Why Precipitation Should Not Be Considered Alone

When precipitation is considered with other climate variables, such as temperature, several other potential impacts to agriculture become apparent. While there is evidence to suggest that dryland wheat farming in Washington State may see higher yields due both to rising temperatures and rising CO_2 levels at least through the middle of this century (**Stöckle et al., 2014**) (***Fourth National Climate Assessment*, "Chapter 24: Northwest" 2018**), other crops might not benefit from rising temperatures. For instance, warmer winter temperatures are expected to lead to precipitation falling more as rain and less as snow, particularly at the lower elevations. This is important for some crops because winter snow cover can provide an insulating effect, protecting dormant crops from freezing temperatures (**Aase and Siddoway 1979**).

Additionally, as the *Snowfall* and *Streamflow* chapters of this report describe, the shift in precipitation from snow to rain during the fall, winter, and spring months is expected to alter the timing of streamflow in the region and is likely to impact the amount of stored water available for irrigated agriculture. Without large increases in storage or conservation, the decline in spring snowpack will tax summer irrigation and water resources. However, this is likely to be a larger problem in other parts of the Pacific Northwest rather than Spokane (***Fourth National Climate Assessment*, "Chapter 24: Northwest" 2018**). In the farmlands surrounding Spokane, direct irrigation from the Spokane River is limited. Most agriculture in the region is dryland farming and is not irrigated.

Snowfall

Chapter 3—Snowfall Impact Study for Spokane, Washington
Full Chapter: https://www.spokaneclimateproject.org/snow

Lead Authors: Brian Henning (Gonzaga University), Levi Keesecker (E2 Environmental), David Camp (Northwest Renewables), and Erik Budsberg (Eastern Washington University)

Climate Data Story—Projected Future Snow at Mt. Spokane Ski & Snowboard Park

Over the course of this century, projected temperature increases and the increasing likelihood that precipitation will fall as rain rather than snow during the cold months of the year will likely shrink the length of the ski season and lead to adverse economic impacts for all five Spokane-area ski resorts: Mt. Spokane Ski & Snowboard Park, 49 Degrees North Mountain Resort, Silver Mountain Resort, Schweitzer Mountain Resort, and Lookout Pass Ski Area.

For the purposes of this summary climate data story, the authors of this chapter focused on future climate impacts at one of these five resorts: Mt. Spokane Ski & Snowboard Park (Mt. Spokane).

By the middle of this century (2040–2069) during the prime ski season (December–February), the average mean temperature at Mt. Spokane is expected to rise from a historical (1971–2000) mean of 25.9 degrees Fahrenheit to 30.6 °F under the lower emissions scenario (RCP 4.5) or 31.8 °F under high emissions scenario (RCP 8.5).

The rise in mean temperatures at Mt. Spokane is expected to correspond to a decline in snow at the ski park. Simply put, as temperatures rise, it becomes far more likely that precipitation will fall as rain rather than as snow. To determine how much snow Mt. Spokane might have by mid-century, our team used the variable *snow water equivalent* (SWE), which is a measure of how much liquid water is available in a given amount of snow on the ground. By mid-century, our analysis found, SWE accumulated on Mt. Spokane by the date January 1st—a key date for the local ski industry—is expected to decline from a historical mean of 10.7" to 8.8" under RCP 4.5 and to 7.5" under RCP 8.5.

Key Findings:

1. All five Spokane-area ski resorts (Mt. Spokane Ski & Snowboard Park, 49 Degrees North Mountain Resort, Silver Mountain Resort, Schweitzer Mountain Resort, and Lookout Pass Ski Area) are likely to be impacted by rising temperatures.
2. Projected climate changes at Spokane's five ski resorts by the middle of this century include:
   a. An increase in mean temperatures
   b. An overall decline in snow on the ground (as measured as snow water equivalent)
   c. A decrease in the total number of winter days below 32 °F, potentially hindering opportunities to make snow
3. Taken together, these projected climate changes pose a continuing threat to the vitality of winter sports recreation in the Spokane region.
4. Reducing greenhouse gas emissions—moving from our current path on the high emissions scenario (RCP 8.5) to the lower emissions scenario (RCP 4.5)—could mean the difference between a degraded but viable ski industry (RCP 4.5) and a nonviable ski industry (RCP 8.5) for five Spokane-area ski resorts, according to our analysis.

Resiliency Actions:

1. Reduce Emissions—The primary action for lessening the impacts to Spokane's winter sports industry associated with projected higher temperatures is to reduce greenhouse gas emissions, specifically to move away from the high emissions scenario (RCP 8.5) to the lower emissions scenario (RCP 4.5).
2. Prepare for Shorter Seasons—As temperatures in the Spokane region continue to rise, Spokane's regional snow-dependent recreation industries—including skiing, snowboarding, snowshoeing, and snowmobiling—need to prepare for snow seasons that start later, are shorter, have less snow, and potentially provide fewer days cold enough to make snow.
3. Diversify—Winter recreation industries in the Spokane region should consider diversifying their business models, including emphasizing warmer weather recreation activities.

Moreover, if we examine precipitation projections, we can make the reasonable inference that this loss of snow is due to rising temperatures and not declines in precipitation. By mid-century, winter (December to February) precipitation at Mt. Spokane is projected to move from a historical mean of 14.6" to 15.8" under RCP 4.5 and to 16.0" under RCP 8.5.

During this same mid-century period, the annual number of days below freezing (32 °F) at Mt. Spokane is projected to drop from a historical average of 169 days to 127 days under RCP 4.5 and to 111 days under RCP 8.5 (Table 6). In other words, there is expected to be 42–58 fewer freezing days per year at Mt. Spokane by mid-century compared to what was observed during the last three decades of the 20th century.

If we consider this trend of fewer freezing days, we can make the reasonable interference that by mid-century Mt. Spokane will see fewer days cold enough for snow to form in the atmosphere and remain frozen on the ground. Fewer days below freezing also means fewer days cold enough to make snow with equipment, which generally requires temperatures below freezing (specifically 30 °F or lower).

Streamflow

Chapter 4—Streamflow Impact Study for Spokane, Washington
Full Chapter: https://www.spokaneclimateproject.org/streamflow

Lead Authors: John Porcello (GSI Water Solutions, Inc.), Kara Odegard (Measure Meant), Karl Rains (Washington Department of Ecology), Jule Schultz (Spokane Riverkeeper), and Brad Morin (Spokane Riverkeeper)

Climate Data Story—Recreation on the Spokane River

The Spokane River is arguably Spokane's top natural attraction, especially during the spring and summer months when outdoor enthusiasts and visitors spend more time along or on the river. As the Spokane area's primary source of visitor information, the organization Visit Spokane encourages visitors to float down the river, paddleboard, fish, or simply take in the scenery from along the shoreline (**Visit Spokane 2019**). It is no surprise that summertime recreation activities associated with the river have a significant economic impact for our region. According to a 2015 report from Washington's Recreation & Conservation Office, the total annual economic contribution of all types of outdoor recreation in Spokane County amounted to nearly $1.2 billion and 12,500 jobs annually (**Washington State Recreation & Conservation Office 2015**). Although not broken down at a county level, annual state expenditures on non-motorized boating and rafting activities have been estimated to exceed $640 million (**Briceno and Schundler 2015**).

Several individuals representing local paddling organizations and commercial rafting enterprises were interviewed in an effort to determine potential ramifications to recreational users and businesses from an earlier high streamflow and extended summer low-flow on the Spokane River. Although qualitative information from the individuals was mixed, a few common themes came out of the discussions. The first is that the lower portion of the river between Spokane Falls and Nine Mile Reservoir—which includes the Spokane River Gorge, the Bowl & Pitcher rock formation, and the Devil's Toenail whitewater rapids—relies on a minimum flow of approximately 2,500 cubic feet per second (cfs) for commercial rafting companies and most kayakers to safely navigate the section.

Once flow drops below 2,000 cfs, all but the most extreme kayakers are limited to milder "float" trips that include longer sections of calmer water. Historical trends in streamflow typically allowed rafting companies to market whitewater trips through this section of the Spokane River during the month of June, when school is out and many Americans begin their summer vacations. With earlier spring high flows and an earlier and extended summer low-flow period, future whitewater conditions may cease as early as June, according to our analysis. This means that optimum whitewater conditions could shift from June to May, resulting in a reduced consumer base. (**Rains 2019**). This would limit local rafting companies from capitalizing on summer tourism.

Key Findings:

1. In the coming decades, the shift of precipitation from snow to rain coupled with earlier snow melts is expected to alter the timing of streamflow on the Spokane River, even while the total annual volume of streamflow in the river is expected to remain similar to historical levels.
2. Impacts from low summer flows are likely to intensify over time, particularly if greenhouse gas emissions are allowed to continue increasing at their current rate.
3. By the end of the century, flows conducive to optimum whitewater rafting and kayaking on the Spokane River may cease as early as June.
4. The expected changes to the unregulated flow of the Spokane River is expected to have several detrimental impacts, including for native Redband trout, summer recreational opportunities, and the general aesthetic value that the Spokane River provides to the community.

Resiliency Actions:

1. Reduce Emissions—Take all possible actions to reduce greenhouse gas emissions and avoid the high emissions scenario (RCP 8.5).
2. Prioritize Trout Habitat—Reconsider regulations at Post Falls to help prioritize Redband trout habitat.
3. Future Research—Conduct more research to fully understand the long-term impacts of climate change on the Spokane Valley-Rathdrum Prairie Aquifer.
4. Future Research—Investigate well depth and pump technology.

Although representatives of the commercial rafting companies contacted for this report recognized existing and potential financial impacts from an earlier whitewater season on the Spokane River, they also reported that they already mitigate for seasonal variations through a variety of methods, including operating on multiple regional rivers, highlighting scenic float trips on the Spokane River versus whitewater trips, and/or by offering other types of river activities, such as tubing. Representatives also indicated that while the instream flow rule (See full report for more details) is not as favorable to recreational use as they would prefer, the rule does mitigate against potential extreme low flow conditions occurring in mid to late summer. Rafting company representatives also noted that during the last several years, smoke from seasonal wildfires has had an even greater detrimental effect on river use than streamflow.

Climate Data Story—Redband Trout

"Interior Redband trout are considered a species of special concern by the American Fisheries Society and the U.S. Fish and Wildlife Service (FWS) in most states where the subspecies historically existed and are classified as a sensitive species by the U.S. Forest Service and Bureau of Land Management."

— *Western Native Trout Status Report*

The Redband trout is a subspecies of Rainbow trout and is the primary native Salmonid species of the Spokane River. The Washington Department of Fish and Wildlife considers Redband trout a sentinel species, meaning the health and abundance of the species are indicating factors of the overall health of a river ecosystem (**Gerber 2017**). Over the past century, many factors have contributed to a decline in the population of Redband trout. Projected changes in-stream flow rates would exacerbate the problem, according to our analysis. It is estimated that Redband trout once occupied 37,465 miles of streams and 152 natural (un-impounded) lakes throughout Washington, Oregon, Idaho, Nevada, Montana, and northern California. Currently Redband trout occupy approximately 42% of their historical stream habitat (**Western Native Trout 2018; Muhlfeld et al., 2014**).

Locally, substantial impacts to the species will likely occur in the upper Spokane River, where populations are already depressed (**Lee 2019**). Projected reduced flows below Post Falls Dam could result in warmer water temperatures that benefit smallmouth bass (a non-native species) and approach the upper lethal temperature range for Redband trout. Redband trout generally prefer stream temperatures less than 70 °F (**Wydoski and Whitney 2003**) and experience stress at 71.6 degrees Fahrenheit and above (**Behnke 1992**).

The effects of climate change on rising temperatures and their impacts on salmonids has already been observed (**Isaak et al., 2012**). Earlier peak flow and reduced summer flows projected under climate change could decrease viable rearing habitat for Redband trout, leading to reductions in populations.

During a survey conducted by Michael Taylor McCroskey in the summer of 2015, very few Redband trout were present in the upper reaches near the spawning areas.

The study was conducted during an extreme drought year (in historical context), during which river flows were lower than usual and water temperatures were warmer than normal. This likely influenced species distribution, and may have also impacted spawning success and survival. Additionally, a large population of smallmouth bass was documented, which likely impacted the survival of juvenile Redband trout from predation; to what extent is unknown (**McCroskey 2015**).

The Spokane River (below Sullivan Road) is heavily influenced by groundwater recharge, which moderates summer stream temperatures with an influx of cooler water. However, projections of reduced surface flows would result in reduced carrying capacity for Redband trout and an anticipated increase in predation from species that thrive in warmer water temperatures. Of particular concern to the viability of Redband trout is the projected earlier low-flow period beginning as early as May, rather than later in the summer. According to the Parametrix 2003 spawning report, spawning generally commences at the beginning of April when water temperature reaches 45 °F (**Parametrix 2003**). Emergence occurs near the end of May and into the beginning of June. Future projections indicate that a decrease in streamflow will occur during the Redband trout incubation period that could result in water levels falling below the level of fish nests, a process called *redd dewatering*.

Climate Data Story—Spokane Valley-Rathdrum Prairie Aquifer

The Spokane Valley-Rathdrum Prairie (SVRP) Aquifer is the sole-source drinking water for over 500,000 people (**MacInnis et al., 2009**). According to our analysis, the aquifer appears to be less sensitive to climate change impacts than aquifers in other regions. Aquifer levels are primarily affected by recharge from the Spokane River and from several lakes in the region that bound and recharge the aquifer (**Hsieh et al., 2007; Kahle et al., 2007**).

Seasonal changes in streamflow under future climate conditions are anticipated, according to our analysis. Specifically, peak streamflows may occur earlier in the winter and/or spring months, while the summer-season low streamflows could begin earlier in the summer. However, future climate projections indicate that only small percentage changes in annual total precipitation and streamflows are likely to occur, which suggests—assuming no net change in annual water extraction due to human factors—that there might be just a limited overall change in annual volumes of aquifer recharge on a long-term multi-decadal basis. However, within these long multi-decadal time periods, aquifer recharge periodically could be below historically observed conditions if multi-year droughts were to occur more frequently than in the past or be more intense than in the past.

The primary mid-term vulnerability of the Spokane region's sole source of potable water may have less to do with climate change and more to do with the fact that historically some of the region's water supply wells have been drilled only into the very uppermost portion of the aquifer. The oldest wells in the region were excavated and/or hand-dug within the Spokane city limits during the early 1900s. Accordingly, these wells were constructed no further than necessary into the water table, which means they obtain water by essentially "skimming" off of the top of this thick aquifer (**CH2M HILL 1998; GSI 2012**). The operational efficiencies of some of these shallow wells may be sensitive to small climate-driven changes in summer-season water levels in the aquifer (**GSI et al., 2019**). Newer wells in the region were constructed using more conventional drilling methods, achieving greater penetration depths into the water table. However, even these wells were not typically drilled any deeper than necessary in order to minimize drilling and pumping costs.

Due to the particularly low water levels observed in the aquifer during the past few summers, the City of Spokane is now actively working to understand the resiliency of several of its water supply wells and to evaluate what types of modifications (if any) to certain wells and/or pumping systems might be warranted for future implementation (**GSI et al., 2019**). City officials are conducting this work as part of their planning for capital improvement projects. Although other municipal water providers own conventional drilled wells that penetrate deeper into this aquifer, it is possible that some of those providers could eventually identify that one or more of their wells would warrant resilience evaluations in the future and potential adjustments to their construction and/or their pumping systems to optimize or improve well operations.

More research is needed before we can fully understand the longer-term impacts of climate change on the Spokane Valley-Rathdrum Prairie Aquifer. In addition to further climate analysis, it is also necessary for local policymakers to understand the non-climate related impacts, such as increased demand on the aquifer due to (1) population growth and (2) increased evapotranspiration as temperatures rise in our region. Individual choices, business practices, and government policy are all necessary components of an effective strategy to prevent adverse climate-induced impacts on water availability.

Wildfires

Chapter 5—Wildfire and Smoke Impact Study for Spokane, Washington
Full Chapter: https://www.spokaneclimateproject.org/wildfires

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Climate Data Story—Wildfires in the Forests Surrounding Spokane

Spokane, Washington, is surrounded by forests. While wildfires have long been a natural feature of our landscape—for instance, playing a role in forest succession—wildfires can be incredibly destructive to human life and property as well as wildlife and ecosystem services.

The primary means through which climate change is expected to impact wildfire potential in the Spokane region and the United States Pacific Northwest generally is through fuel dryness. Fire and land management agencies use several diagnostics throughout the fire season to track fire potential. Among these diagnostics are a suite of fire danger indices from the US National Fire Danger Rating System. Our analysis employs the *100-hour Fuel Moisture Index*, the standard metric used by foresters and wildland firefighters to determine the risk of fire ignition and how fast a fire is likely to spread.

For our analysis, we examined the Climate Toolbox metric *Extreme Fire Danger Days*. Extreme Fire Danger Days is defined in the Toolbox as calendar days that fall into the lowest 3rd percentile of fuel dryness as defined by the 100-hour Fuel Moisture Index. These are days when fuels are very dry. Future projections indicate that the number of Extreme Fire Danger Days in the Spokane region is projected to increase throughout this century, starting from a late 20th century baseline of 11 days, then rising to 13.9 days through the early decades of this century (2010–2039), and to 20.4 days by the middle decades (2040–2069) of this century.

Extreme Fire Danger Days and 100-hour Fuel Moisture Index do not predict that fires will occur only that they are more likely to occur given the right ignition source (be it human or natural). The rise in the number of days with extremely dry fuels is very likely to produce more days with wildfires each year.

Key Findings:

1. Throughout this century, climate projections indicate that the Spokane region will see drier, warmer summers, conditions that are ideal for larger, more destructive wildfires.
2. Throughout this century, Spokane is projected to see an increase in the number of days during which fires could ignite.
3. During the fire seasons of 2017 and 2018, Spokane saw an increase in the number of days during which local air quality was listed as unhealthy and very unhealthy by the Environmental Protection Agency's Air Quality Index.
4. Spokane is likely to experience both a longer fire season and a longer smoke season in the decades ahead.

Resiliency Actions:

1. Prepare for Increased Fire, Smoke, and Ash—Spokane emergency planners need to adopt policies and adaptation strategies that help Spokane and the surrounding region prepare for the increased risk of fire, smoke, and ash dangers. This could include strategies for monitoring air quality related to outdoor activities (including school recesses) and, when necessary, issuing particulate masks at large outdoor events.
2. Air Quality Shelters—The creation of "air quality shelters" should be considered for sensitive groups, as defined by the Environmental Protection Agency (EPA), as well as the population generally. This could include providing large public spaces (school gyms, community centers, etc.) with high quality air filtration systems.
3. Forest Management—Forests in and around Spokane should be managed to reduce the amount of fuel available. This could be done through various management techniques, including forest thinning and prescribed burning.
4. Outreach—Educational outreach campaigns should be created that:
    a. Ensure the public understands why fire management strategies, such as prescribed burns are being used;
    b. Encourage voluntary compliance with fire-safe housing recommendations (clear space around homes and structures);
    c. Clearly communicates the health risks associated with smoke and ash.
5. Regulations—New regulations should be designed to increase defensible areas around structures for businesses and homeowners in the wildland/urban interface.

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Resources:

- **Spokane Climate Project Website:**
- **CIRC website:** http://pnwcirc.org/circ
- **The Climate Toolbox:**
- ***The Climate Resilience Workbook Series*:**
- **CIRC's newsletter, *The Climate CIRCulator*:**

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