North Clackamas Watersheds 2023 Temperature Study

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Supported by:

Executive Summary

Purpose

In 2019-20 the North Clackamas Watersheds Council (the Council) completed a Watershed Bio-Assessment. The Bio-Assessment determined that the absence of temperature data has made it difficult to prioritize projects that protect cold water refugia, or to track long term watershed conditions over time. Thanks to funding from the PGE Habitat Support Program and Oak Lodge Water Services, the North Clackamas Watersheds Council has begun to fill some of these stream temperature data gaps, with 2023 being the second year of data collection. Robust temperature monitoring information is critical to the management and restoration of our watersheds in four ways:

1. Determining the location of cold-water sources that create refugia for fish
2. Tracking on-going watershed trends
3. Informing decision-making by multiple agencies in project prioritization, land management, policy, and resource allocation
4. Educating landowners and land managers about watershed health

The methodology for this monitoring study was developed in cooperation with the Oregon Department of Environmental Quality (DEQ) Volunteer Monitoring Program. Temperature probes were launched in mid-May and were collected mid-October. The months of July and August were identified as the time period where temperatures were most critical for cold water species. We placed loggers at the confluences of the creeks in our service area to see how they function as potential cold water refugia (CWR) for fish migrating through the Lower Willamette.

Findings

1. *Several Willamette River confluences are potential cold water refugia*
   Boardman Creek was identified as CWR. Both Kellogg Creek and River Forest Creek were warmer than the Lower Willamette River. However, loggers placed above Kellogg and River Forest Lakes showed that those impoundments significantly increased water temperatures. If Kellogg Dam and its associated impoundment could be removed then the mouth of Kellogg Creek would function as CWR habitat. And if River Forest Lake could be hydraulically disconnected from River Forest Creek, that confluence could also function as CWR habitat. Rinearson Creek however does not seem to be functioning as CWR because of the warm water in the beaver pond.

2. *Kellogg Creek, Dean Creek, the North Fork of Boardman Creek, and Minthorn Springs provide cold water*
   We were able to identify several cold-water sources in the North Clackamas watersheds. The water flowing from Dean Creek and Kellogg Creek upstream of its confluence with Mt. Scott Creek was significantly cooler than Mt. Scott Creek. Phillips Creek was also slightly cooler than Mt. Scott Creek. The upper reaches of Mt. Scott also appear to be quite cool; however, our logger at that location stopped working early in the monitoring season which will require another year of monitoring to confirm this finding. The coldest water found was at Minthorn Springs, however, this water warmed significantly to become the warmest water studied as it travelled through Minthorn Springs Wetland. In Boardman Creek, the temperatures in the North Fork of Boardman Creek were significantly cooler and may function as a thermal refuge in the summer.

3. *Water heated up through the Sunnyside corridor of Mt. Scott Creek, and through water impoundments.*

There were several areas where we recorded significant increases in water temperatures. Wide shallow impoundments of water allowed water to heat up, including Kellogg Lake, Minthorn Springs Wetland, River Forest Lake, the pond in Rinearson Creek Natural Area, and the pond downstream of the diversion structure in 3-Creek Natural Area. We also saw increases in water temperatures along major urban arteries such as McLoughlin Boulevard and along Sunnyside Road.

1. *The south fork of Kellogg Creek seems to be significantly cooler due to the presence of springs and beaver wetlands at Parmenter Ponds.*
   Parmenter Ponds seem to have a significant cooling effect on the south fork of Kellogg Creek.

Implications for Restoration, Protection and Management

1. *Fix heat-loading effects at impoundments*
   Water temperatures increased significantly through water impoundments. Potential treatments vary at each site:
   - When Kellogg Dam is removed, the associated impoundment will be dewatered and the channel will be restored to a sinuous flowing creek.
   - River Forest Lake could potentially be disconnected hydraulically from River Forest Creek, while maintaining the lake for its surrounding residents. Further study should be conducted to determine the feasibility of accomplishing this.
   - Minthorn Springs Wetland heats up considerably in the summer and restoration of that wetland should focus on controlling summer temperatures.
   - As Clackamas WES plans the 3 Creeks Floodplain Enhancement Project, consideration should be given to the pool downstream of the water diversion structure to determine how best to mitigate the temperature impacts at that site.
   - The pond in the Rinearson Natural Area was maintained in the mitigation project at the request of adjacent landowners who wanted to be able to see the open water and to maintain habitat for western painted turtles. However, the heat loading that occurs in this pond during the summer is problematic. Consideration should be given to restoring this area to a beaver-managed wetland complex that would allow the creek to access the floodplain.

2. *Target cold water areas for protection and fish access*
   The cold-water areas (Boardman/Willamette Confluence, Dean Creek, Upper Kellogg Creek below Parmenter Ponds, North Fork Boardman Creek) should be prioritized for protection and fish access. These areas will provide thermal refuge for fish in the summer, and the Council will focus on removing any barriers to fish accessing these reaches, especially during summer low flows.

3. *Identify solutions for reducing heat loading through urbanized corridors with large heat island effects*
   Significant temperature increases occur where streams pass through industrialized and urbanized corridor, such as the upper reaches of Mt. Scott Creek at the presumed end of anadromy down to Mt. Talbert Nature Park. Projects should be explored that reduce the heating effect such as reducing impervious surface area, improving stormwater inputs, or preventing point-source inputs of warm water from businesses.

Further Study

As with any research project, this study has generated several more questions that need answering. Future monitoring years should study the following in more depth:

- Repeat temperature monitoring in the upper reaches of Mt. Scott Creek to verify potential cold-water sources and determine why it heats up so much as water flows down to Mt. Talbert.
- Continue long-term trend monitoring to track changes in watershed temperature impacts from climate change, development, and restoration actions.
- Compare the results of this study with the Council's fish passage barrier and eDNA studies to better understand fish utilization.
- Conduct a year-round study of temperatures in areas that have potential spawning habitat in the Kellogg Creek watershed.
- Utilize drone technology mounted with an infrared camera to look at temperature dynamics such as point-sources for heating and cooling, and the management of these impacts in restoration sites.

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Introduction

In 2019-20 the North Clackamas Watersheds Council (the Council) completed a Watershed Bio-Assessment and developed a list of high-priority restoration projects for ecological uplift of the Clackamas fish population (NCWC, 2020). The Bio-Assessment found there is little to no continuous temperature monitoring underway in these watersheds, the exceptions being one project on Lower Rinearson Creek and 3 stations maintained by the Clackamas Water Environment Services (WES) to calibrate flow meters. The absence of this fundamental information has made it difficult to prioritize projects that protect cold water refugia, or to track long term watershed conditions over time as we monitor impacts from restoration, climate change, and urbanization.

Water temperature affects the distribution, health, and survival of native salmonids and other aquatic organisms by influencing their physiology and behavior. Water that is too warm can cause direct mortality of fish. But while lethal high temperatures can be locally problematic, temperatures in the range that cause sublethal effects are much more widespread and may have the greatest effect on the overall wellbeing of our native fish populations. These sub-lethal effects resulting from abnormally high temperatures include impaired feeding, reduced growth, diminished resistance to disease, inability to compete, and poor predator avoidance (EPA, 2001). Evidence suggests that small increases in temperatures (2-3 °C) above biologically optimal ranges can begin to reduce salmonid fitness. Temperature related impacts to lamprey are more difficult to describe as there are few studies in nature to describe such impacts. Researchers investigating lamprey through laboratory experiments, field observations, and telemetry work concluded that water temperature in the Willamette Basin ≥ 20 °C is corelated with developmental abnormalities in larvae, expedition of sexual maturation, pre-spawning mortality, slowed or stopped upstream migration by adults, and gonadal tissue damage (Ben Clemens, ODFW Statewide Lamprey Coordinator, personal communication with Todd Alsbury, November 2020).

Water temperatures are influenced by solar radiation, stream shade, ambient air temperatures, channel morphology, groundwater inflows, and stream velocity, volume, and flow. Surface water temperatures may also be warmed by anthropogenic activities such as discharged heated water, changed stream width or depth, lowered stream complexity that decreases hyporheic exchange, reduced stream shading, and water withdrawals.

The Kellogg-Mt. Scott, Rinearson, River Forest, and Boardman watersheds provide rearing habitat and some spawning habitat to threatened and endangered salmonids and other priority species including winter steelhead, coho salmon, Pacific lamprey, cutthroat trout (resident, fluvial, and anadromous), and fall and spring Chinook salmon (Clackamas Partnership, 2018). Furthermore, they provide both potential off-channel cold-water refugia in a stretch of the Willamette where geological features largely prevent alcoves and significant side channel refugia in the Willamette mainstem (DEQ, 2020). This makes the availability of cold water refugia critical in lower Willamette tributaries and tributary junctions. However, the lack of information on cold-water refugia in these tributary systems of the Willamette floodplain is a key knowledge gap that has hindered strategic restoration.

NCWC has begun to fill some of these stream temperature data gaps, and this year is the second year of monitoring. The first year of data collection was completed in 2022 (NCWC, 2023), and that data informed this year’s study sites and priorities. Funding has been secured through OWEB to continue the research for a total of five years, and the hopes is that this monitoring program will run in perpetuity. This effort is being undertaken in cooperation with multiple jurisdictions and partners including the

Oregon Department of Environmental Quality (DEQ), Oregon Department of Fish and Wildlife (ODFW), Oak Lodge Water Services (OLWS), Clackamas Water Environment Services (WES), City of Gladstone, City of Milwaukie, and City of Happy Valley.

Project Goals

Robust temperature monitoring information will be critical to the management and restoration of these watersheds in four ways:

1. *Determine the location of cold-water sources that create refugia for fish:* This study helps address knowledge gaps regarding cold-water refuges in tributaries of the lower Willamette and North Clackamas watersheds. By closing information gaps on temperature, the Council will ensure that future projects are located to protect and maximize cold water refugia, and remove barriers that potentially prevent access to cold water refugia. The thermograph monitoring effort will also be supplemented by flying some sites with a drone carrying a thermal infrared camera, thanks to a grant from ODFW.

2. *Track ongoing watershed trends:* Ongoing continuous temperature monitoring is fundamental to a long-term understanding of watershed function and how it changes over time with impacts from climate change, urbanization, and ongoing restoration efforts. We will maintain these temperature stations in the same locations, creating a long-term trend analysis that will guide the Council's restoration and advocacy.

3. *Inform decision-making by multiple agencies:* The information gathered in this study will be shared with local and state jurisdictions, allowing them to utilize it to engage in informed planning when projects may impact these watersheds. It will also help to monitor the impact natural areas have on stream temperatures as local jurisdictions advocate to create, protect and manage natural areas, parks and public lands and take other steps to improve water quality and climate resilience in their jurisdictions. Finally, the data will provide baseline information to better understand how man-made impacts such as development and point-source discharges affect stream temperatures.

4. *Use for landowner education:* Projects such as these provide vital opportunities to engage the public in watershed science. Discussions with landowners and residents during the Bio-Assessment revealed a lack of understanding by well-meaning landowners of the role of large wood, side channels, wetlands, in-channel complexity, and temperature as a limiting factor for aquatic health. This field work opened the door to these conversations and informed the Council of a need for public education. This temperature monitoring information will be incorporated into these on-going landowner education efforts.

Methods

The Council developed the temperature monitoring methodology in cooperation with the Oregon Department of Environmental Quality (DEQ) Volunteer Monitoring Program. The Council developed a Sampling and Analysis Plan (SAP) which was approved by DEQ in 2022. We are collecting Level A quality data, as defined by DEQ in the Quality Assurance Project Plan (QAPP): Volunteer Water Quality Monitoring, July 2021. Level A data can be used to assess compliance with water quality standards, permitting requirements, or other regulatory activities; however, the Council is not a regulatory agency and will not be using the data in this way. Level A data requires that the accuracy of every thermograph is checked with a NIST thermometer within an accuracy +/- 0.5°C and a precision of +/- 0.5°C. All temperature data was collected using Onset HOBO MX2203 Tidbit Data Loggers in Celsius. The Tidbits are durable and designed for data collection up to 400-foot depths. They are waterproof with a precision sensor with ±0.2°C accuracy, 0.01C resolution, and ranges between -20°C and 50°C (-4 to 122°F) in water. The accuracy of the thermographs were tested against a NIST certified temperature probe before and after field deployment to ensure that they operated within their designed range of accuracy (+/- 0.5°C), which they all did. These pre- and post-season logger calibrations are then submitted to DEQ with the data every year. The monitoring was intended to capture high summer water temperatures, which predominantly occur from June through September.

Temperature monitoring occurred in Kellogg-Mt. Scott, Rinearson, River Forest, and Boardman watersheds and their confluences with the Willamette River. This year two additional sites were added in the Willamette River; however, both of those loggers were stolen. The Council selected some sites as reference sites to reflect baseline conditions within a specific stream year after year. Other sites were chosen as study sites to answer specific questions about how water temperatures are impacted by water impoundments, nature areas, or instream temperatures, and those research questions change year to year. Temperatures were monitored May to October. The Council secured access permission from private landowners and obtained agreements from agency partners for publicly owned land.

Figure 1 - Locations of temperature monitoring stations in 2022 and 2023.

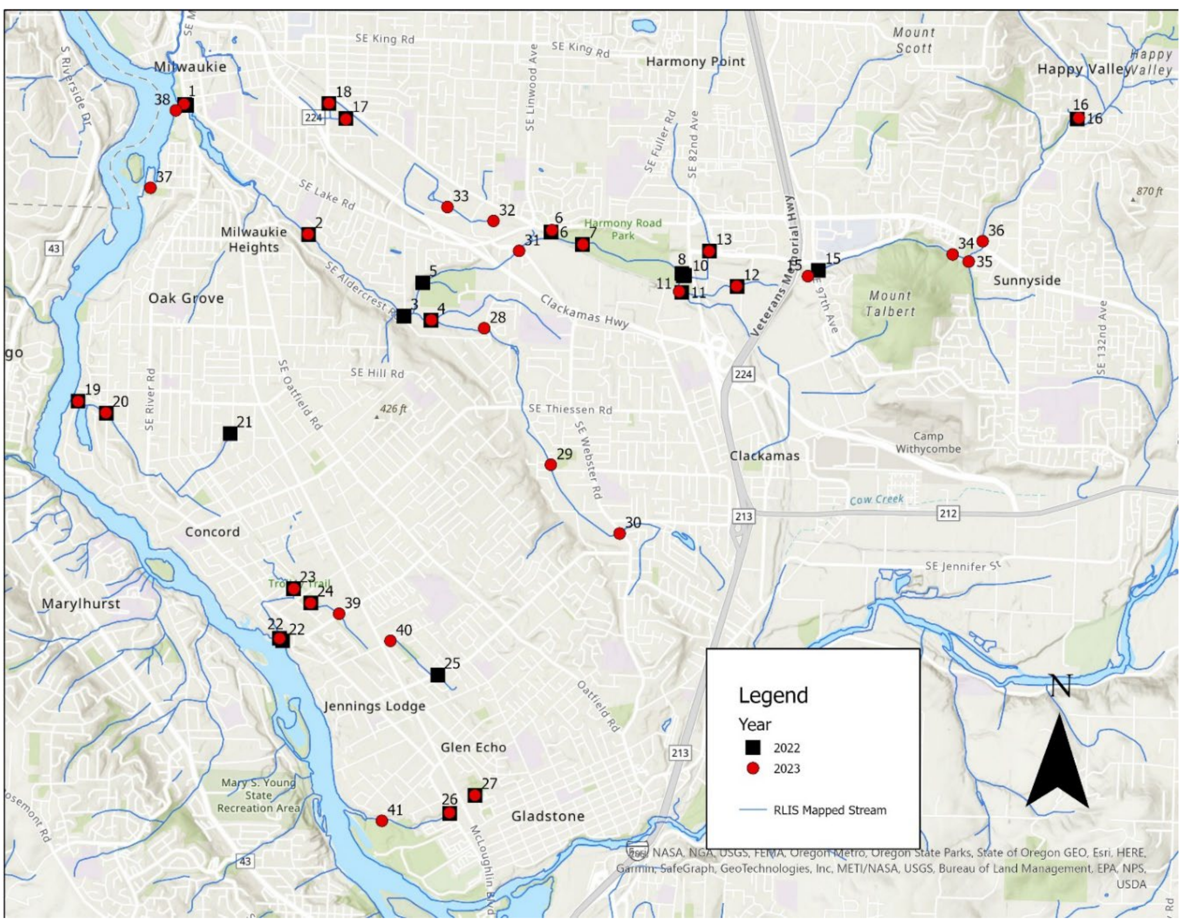


Table 1 - Station descriptions and research questions being asked at each location. Table arranged by geographic proximity.

Site ID#	Station Description	Research Question
1	Kellogg Dam fish ladder	What are the temps at the downstream end of the Kellogg Dam impoundment?
2	Kellogg Creek upstream of impoundment (on private land)	What are the stream temps flowing into the Kellogg Dam impoundment?
4	Kellogg Creek at Amiguitos Preschool (private property)	What is the temperature profile of Kellogg Creek?
28	Kellogg Creek at Rusk Road culvert	What is the temperature profile of Kellogg Creek?
29	Kellogg Creek at SE Clackamas Road culvert	What is the temperature profile of Kellogg Creek?
30	Kellogg Creek at SE Webster Road culvert	What is the temperature profile of Kellogg Creek?
18	Spring entering Minthorn Wetlands	What temperature is the spring feeding Minthorn Wetlands?
17	Leaving Minthorn Wetlands	What are the temps flowing out of Minthorn Wetlands compared to the springs?
32	Minthorn Creek behind Breakside Brewing	What is the temperature of Minthorn Creek before it dumps into Mt. Scott Creek?
33	Minthorn Creek at SE Mallard Way culvert	What is the temperature of Minthorn Creek in the Industrial Way area?
31	Mt. Scott Creek at SE Lake Road	What is the temperature of Mt. Scott Creek below the confluence with Minthorn Creek?
6	Mt. Scott Creek at downstream end of 3-Creeks Natural Area	What effect does the 3-Creeks pond have on temps as water passes through the natural area? What is Mt. Scott Creeks temperature before
7	Mt. Scott Creek upstream of water control structure	What are the temps going into the pond downstream of the water control structure at 3 Creeks?
11	Mouth of Dean Creek behind PCC	What are the temps in Dean Creek before entering Mt. Scott?
12	Mt. Scott at SE 84th	What are the temps of Mt. Scott before being influenced by Dean & Phillips Creeks?
13	Phillips on WES 84th property north of Sunnybrook	What are the stream temps in Phillips Creek?
15	Mt. Scott downstream of Mt. Talbert east of 97th	What are the stream temps flowing out of Mt. Talbert Nature Park?

Site ID#	Station Description	Research Question
34	Mt. Scott in Mt. Talbert downstream of unnamed tributary confluence	What are the temps of Mt. Scott Creek after the confluence with the unnamed tributary?
35	Unnamed tributary in Mt. Talbert	What are the temps of this unnamed tributary before entering Mt. Scott Creek?
36	Mt. Scott at SE Sunnyside Road	What is the temp of Mt. Scott Creek before being influenced by the unnamed tributary in Mt. Talbert?
16	Mt. Scott end of anadromy	What are the temps at the uppermost limit of anadromy (as defined by ODFW)?
38	Willamette River behind wastewater treatment plant	What is the temps of the Willamette before influence by Kellogg Creek?
37	Willamette River at Elk Rock Island back channel	What is the temps of the Willamette in the back channel as compared to Site 38?
19	River Forest downstream of lake below culvert	How does the lake impact River Forest temps before it drains into the Willamette?
20	River Forest upstream of lake at SE Fairoaks	What are the temps of River Forest before it enters River Forest Lake?
22	Boardman at OLWS lift station	What are Boardman's temperatures before draining into the Willamette?
23	NF Boardman (on private property)	What are the temps of the north fork before it joins with the south fork?
24	Boardman at Stringfield Park	What are the temps of the south fork before it joins with the north fork?
39	Boardman at SE Roethe Road	What are the temps of just after the HW99 corridor?
40	Boardman at SE Boardman Ave	What are the temps just before passing through the HW99 corridor?
41	Rinearson in Meldrum Bar Park	What are the stream temps in the mitigation site, before the confluence with the Willamette?
26	Rinearson downstream of River Road	What are the stream temps going into the restoration site after creek flows through Hwy99?
27	Rinearson at Olson wetlands (end of Risley Ave)	How does the influence of Olson Wetlands affect stream temps?

At all sites except Site 1, a three-foot piece of rebar was driven into the streambed and was used to secure each thermograph. This rebar was driven to a depth below the surface of the water level, keeping the installation relatively hidden (see Figure 2). At locations that were accessible to the public, the rebar was topped with a plastic cap to prevent people from injuring themselves on it. The probes were housed in a 2” ABS pipe that had 15-20 ¼ inch holes drilled out to allow water to through on a constant basis while preventing potential sediment accumulation around the probe. Stainless steel cable and clamps then attached the ABS pipe to the rebar to ensure probes were not lost during the sampling period. Once the rebar and pipe were installed, the probe was not noticeable from above the water to prevent tampering. For this reason, photos were taken at every installation location and the sample sites were geo-located utilizing the ArcGIS Field Maps phone app to ensure that the rebar could be found when collecting the probes at the end of the sample season. The installation at Site 1 was slightly different. This logger was installed at the mouth of Kellogg Creek in the fish ladder located at the dam by putting the thermograph in the ABS pipe, affixing that to a 10-pound weight, and then sinking into the fish ladder.

Figure 2 – All temperature loggers are protected in 2” ABS pipes that had 15-20 ¼ inch holes drilled out to allow water to through on a constant basis while preventing potential sediment accumulation around the probe.

At the end of the sampling season, the thermographs were recovered and downloaded. The data was summarized based on a 7-day average maximum (7dAM), which is calculated by averaging the daily maximum instream water temperatures for 7 consecutive days. Because the criteria apply to every 7-day period, it is often referred to as the rolling 7dAM. For example, one 7-day period is July 1-7, and the next is July 2-8. The 7dAM value for each 7-day period is reported on 7^{th} day of the period. All raw and analyzed data has been backed up in NCWC’s Google Drive cloud storage.

Unfortunately, at several sites loggers with either lost/stolen or the logger became corrupted and the data was not recoverable. This occurred at the following locations:

- Site 34 – Mt. Scott Creek in Mount Talbert Nature Park (stolen)
- Site 36 – Mt. Scott Creek above Mount Talbert Nature Park (not recoverable)
- Site 37 – Willamette River in Spring Park back channel (stolen)
- Site 38 – Willamette River behind wastewater treatment plant (stolen)
- Site 24 – Boardman Creek in Stringfield Park (unable to retrieve due to beaver flooding)

Temperature Standards

The Council is not a regulatory entity, and will not be using temperature data in a regulatory capacity. Temperature standards are simply a way that we can reflect on a waterbody's capacity to provide habitat for cold-water fish species. This data will predominately be used for the purpose of strategic watershed planning, with of goal of prioritizing cold-water areas for restoration and protection. The data will be provided to DEQ annually as per our Sampling and Analysis Plan (SAP) through DEQ's Volunteer Water Quality Monitoring Program.

Beneficial Uses

The objective of a water quality standard, as required by the Clean Water Act, is to protect the beneficial uses of the waters of the State. In the case of temperature, the most sensitive beneficial use is Oregon's native cold-water aquatic species such as salmon and trout. The DEQ established temperature standards for specific life history stages of salmon and steelhead (as seen below in Table 2). The standards are used in establishment for Total maximum Daily Load (TMDL) criteria for water quality limited streams in Oregon (DEQ, 2008), and are based on 7dAM.

Table 2 - List of designated beneficial uses and associated temperatures.

Beneficial use	7dAM
1. Salmon & steelhead spawning (during spawning use)	55.4 °F / 13 °C
2. Core coldwater habitat (year round)	60.8 °F / 16 °C
3. Salmon & trout rearing & migration (year round)	64.4 °F / 18 °C
4. Migration corridor for salmon & steelhead (year round)	68.0 °F / 20 °C

1. *Salmon & steelhead spawning* – Waters that are or could be used for salmon and steelhead spawning, egg incubation, and fry emergence
2. *Core coldwater habitat* – Waters that are expected to maintain temperatures within the range generally considered optimal for salmon and steelhead rearing
3. *Salmon & trout rearing & migration* – Waters that are thermally suitable rearing habitat for salmon, steelhead, rainbow trout, and cutthroat trout.
4. *Migration corridor for salmon & steelhead* – Waters that are predominantly used for salmon and steelhead migration during the summer and have little or no anadromous salmonid rearing in the months of July and August.

The creeks being studied here are primarily limited to rearing habitat since very few spawners are able to access Kellogg Creek due to the existing dam, so the ideal 7dAM threshold would be 18°C. Once Kellogg Dam is removed, there is potential for the Kellogg-Mt. Scott watershed to be utilized by salmonids and Pacific lamprey for spawning in the future. For this reason, a future temperature study may want to target areas with spawning gravels in Kellogg-Mt. Scott Creek for year-round monitoring to consider temperatures during potential spawning seasons (fall through spring), as well as the summer months when thermal loading is a problem.

Cold-Water Refugia

DEQ also establishes standards for identifying cold-water refuge (CWR) along the Lower Willamette. The CWR provision supplements the migration criterion in the Lower Willamette of 20°C to protect migrating populations of salmon and steelhead. The criterion states that these water bodies must have sufficiently distributed CWR that allow salmon and steelhead migration without significant adverse effects from 7dAM temperatures up to 20°C (DEQ, 2020). Candidates as cold-water refuge from tributaries was defined as having at least a 2°C colder temperature than the daily maximum temperature of the adjacent well-mixed flow of the water body. Therefore, at creek confluences with the Willamette we will be assessing the differences between average daily maximum temperatures during the months of July and August, which is slightly different than the 7-day rolling average temperatures (7dAM) that we will be assessing outside of the Lower Willamette confluence CWR analysis.

Wetlands

Oregon has no unique temperature criteria for wetlands at this time. However, wetlands with direct connections to creeks and rivers have the potential to impact water temperatures. For example, in this study the Minthorn Springs wetland acts as the headwaters of Minthorn Creek and directly impacts water temperatures flowing into that system.

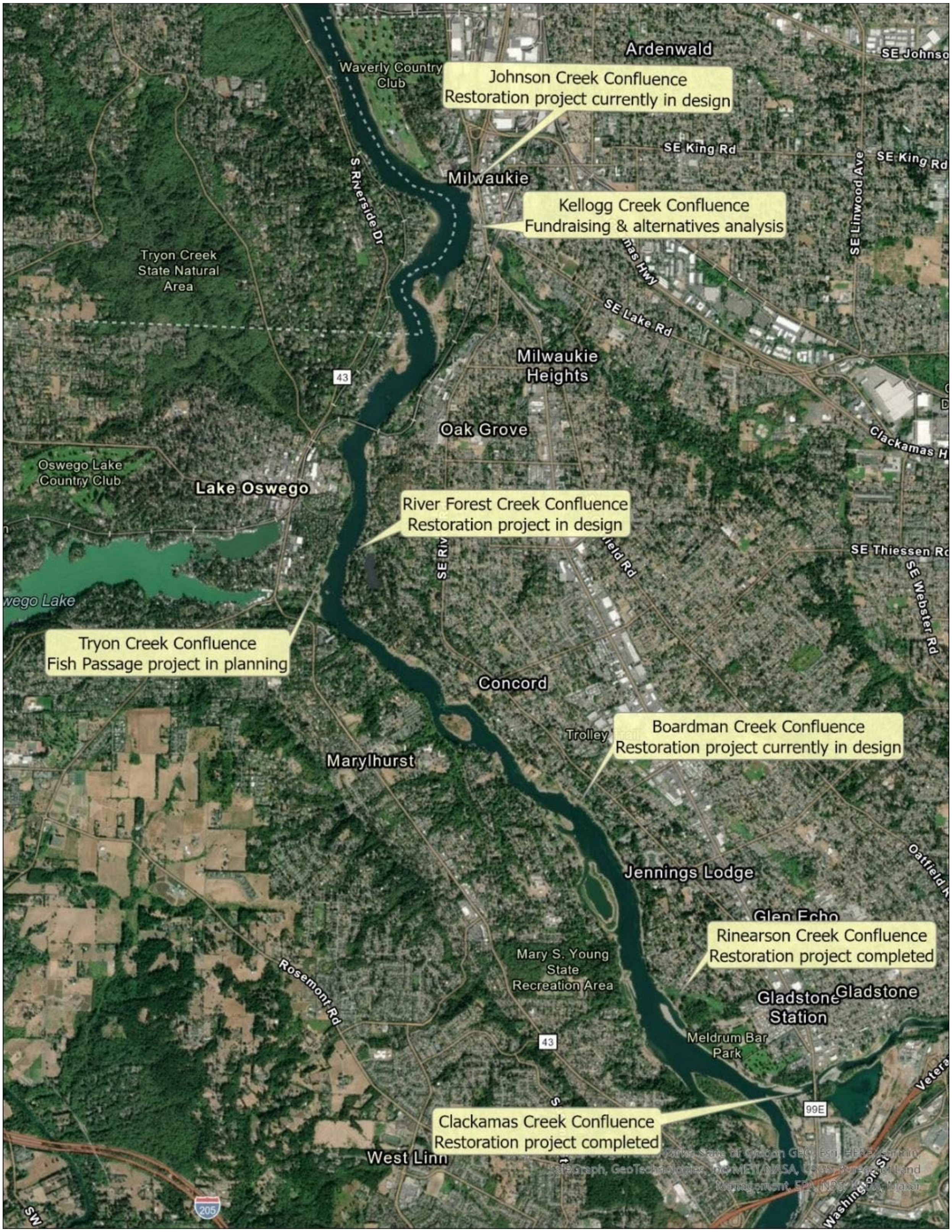
Results: Lower Willamette Confluences as CWR

Evaluating creek confluences that flow into migration corridors as potential CWR is important, particularly in the Lower Willamette where side channels and backwater habitats are limited by the area's geology. Migration corridors are often channels that are too large to be cooled by shading vegetation and groundwater inflow. Because of the importance of CWR in the Lower Willamette, NCWC has developed a confluence strategy to prioritize protecting and enhancing potential cold-water inputs into the Willamette River (see Figure 3). As part of that strategy, the need for confluence temperature monitoring was identified, and loggers were placed at the mouths of all confluences within NCWC's service area.

Any identified CWR habitat may be enhanced and protected by:

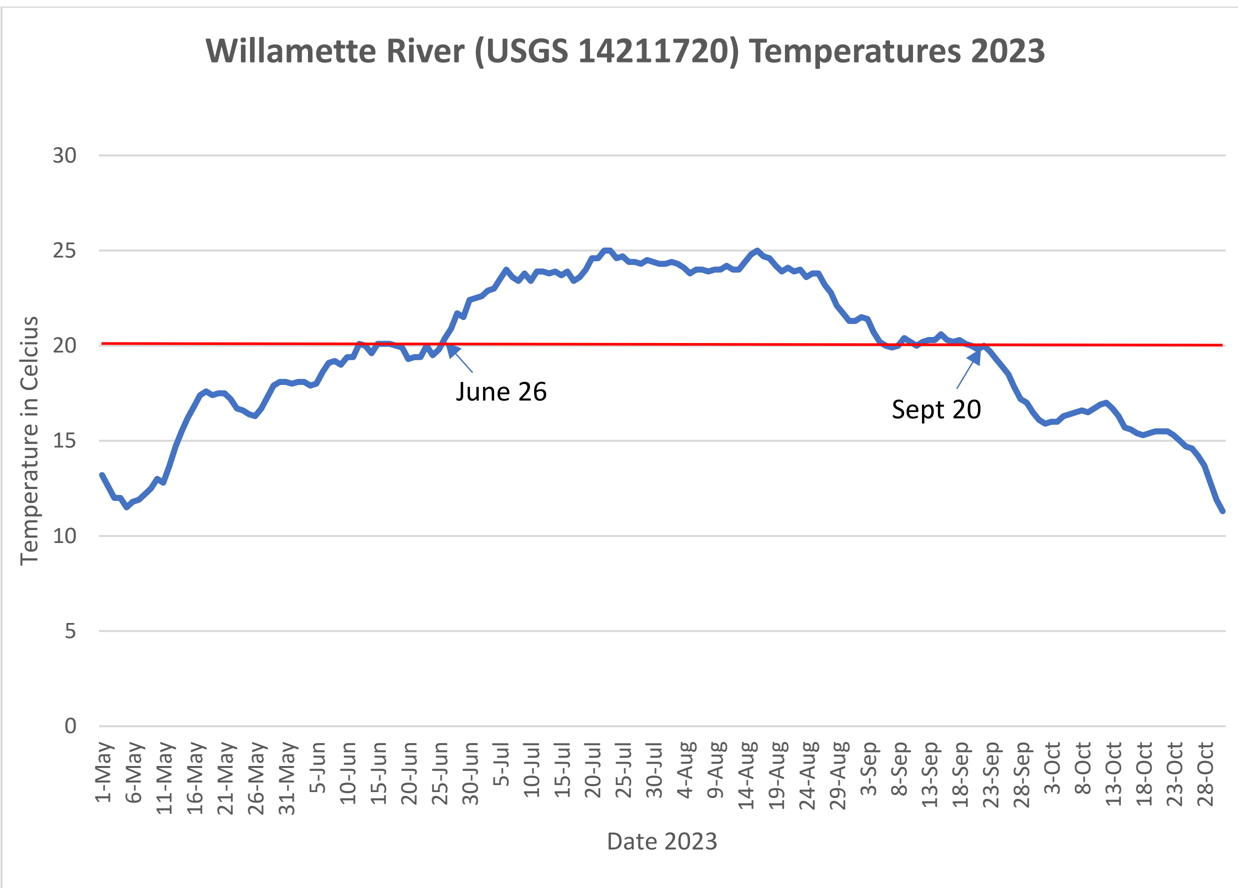
1. maintaining or enhancing vegetation for shade,
2. protecting cold tributaries from development in riparian areas,
3. reducing heat impacts from stormwater,
4. protecting and creating channel features that create cold water flows through hyporheic exchange,
5. protecting sources of groundwater inflows,
6. reducing heat impacts from stormwater inputs through detention and treatment, and
7. removing physical and thermal barriers to fish accessing areas of cold water.

Figure 3 - Potential CWR along the lower Willamette River located in creek confluences.



The USGS gaging station for the Willamette River at Portland (USGS 14211720) was used as the reference temperature for the main stem Lower Willamette because the loggers the Council installed in the Willamette River were stolen. This same gage station was also used last year during the temperature study, and during the DEQ 2020 study. In 2023, the lower Willamette River exceeded the DEQ 20°C temperature standard for migration corridors from June 26, 2023 to September 20, 2023, as seen below in Figure 5. The 2012 EPA study identified July and August as the season of concern for quantifying CWR in the lower Willamette River. Our 2022 temperature study (NCWC 2023) concurred with that assessment. However, this year the season of concern extended much further into September. This longer season of high water temperatures should be tracked over time to see how it impacts fish in context of climate change. For consistency we will continue to focus on July and August as the limiting season, however, after five years of data collection we will do an analysis for to look at trends over time. One of the variables that should be looked at closer is the persistence/longevity of the high summer temperatures.

Figure 4 - Summer daily maximum water temperatures in the lower Willamette River at USGS gage station 14211720.

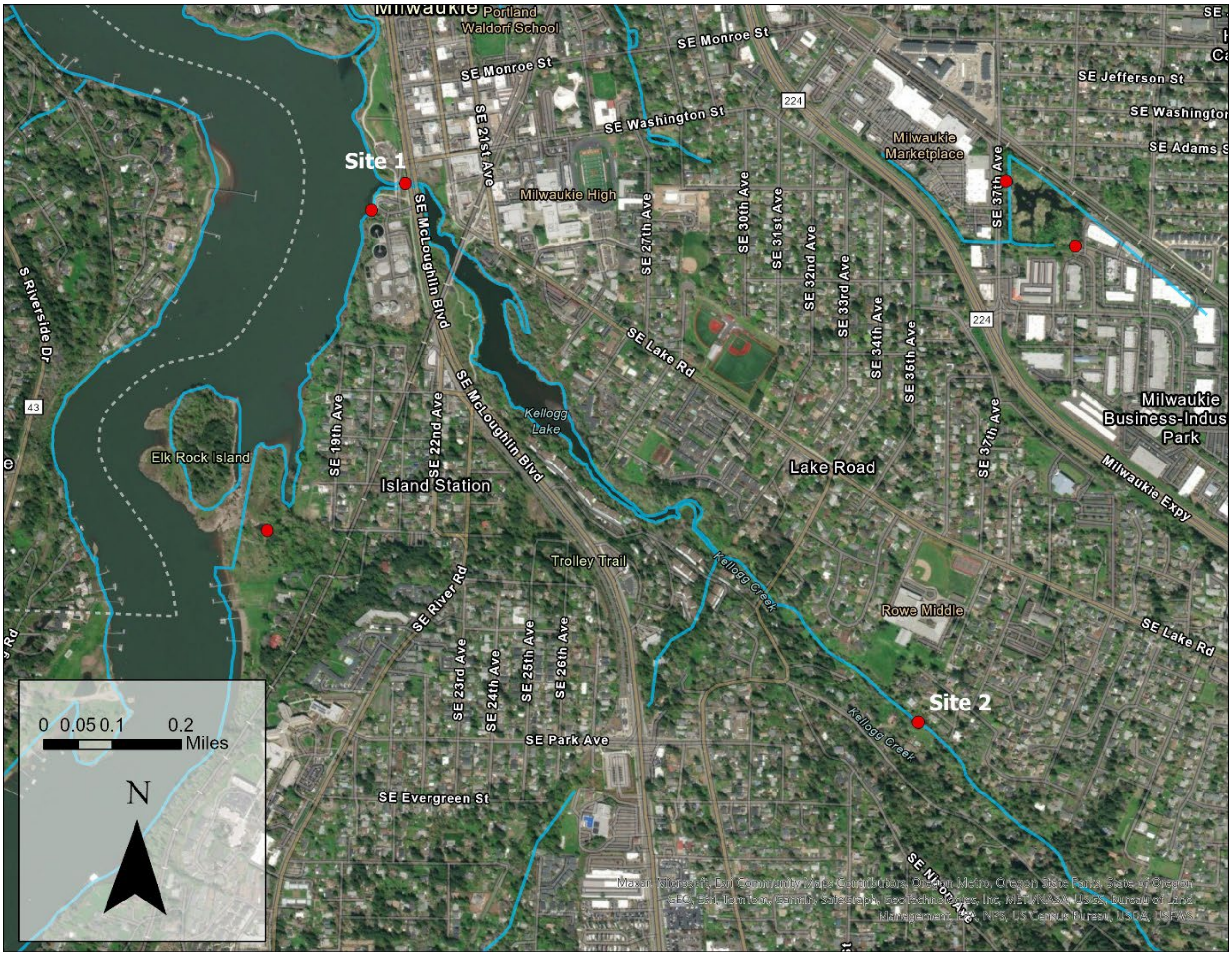


It is important to note that by definition CWR is identified as having at least a 2°C colder temperature than the daily maximum temperature of the adjacent well-mixed flow of the water body. Therefore, for this analysis, we will be looking at the averages of daily maximum temperatures NOT the 7dAM.

Kellogg Creek Confluence

One temperature logger was installed at the mouth of Kellogg Creek in the fish ladder (Site 1). A second logger was installed on private property upstream of the impoundment behind Kellogg dam (Site 2) to determine how water temperatures were specifically affected by the widened, shallow impoundment formed behind the dam. Unfortunately, the Site 2 logger died and stopped recording data on September 6th. For this reason, we could only summarize the data for July and August of 2023.

Figure 5 - Location of Kellogg Creek confluence temperature loggers at the Kellogg fish ladder (Site 1) and upstream of the dam impoundment (Site 2).



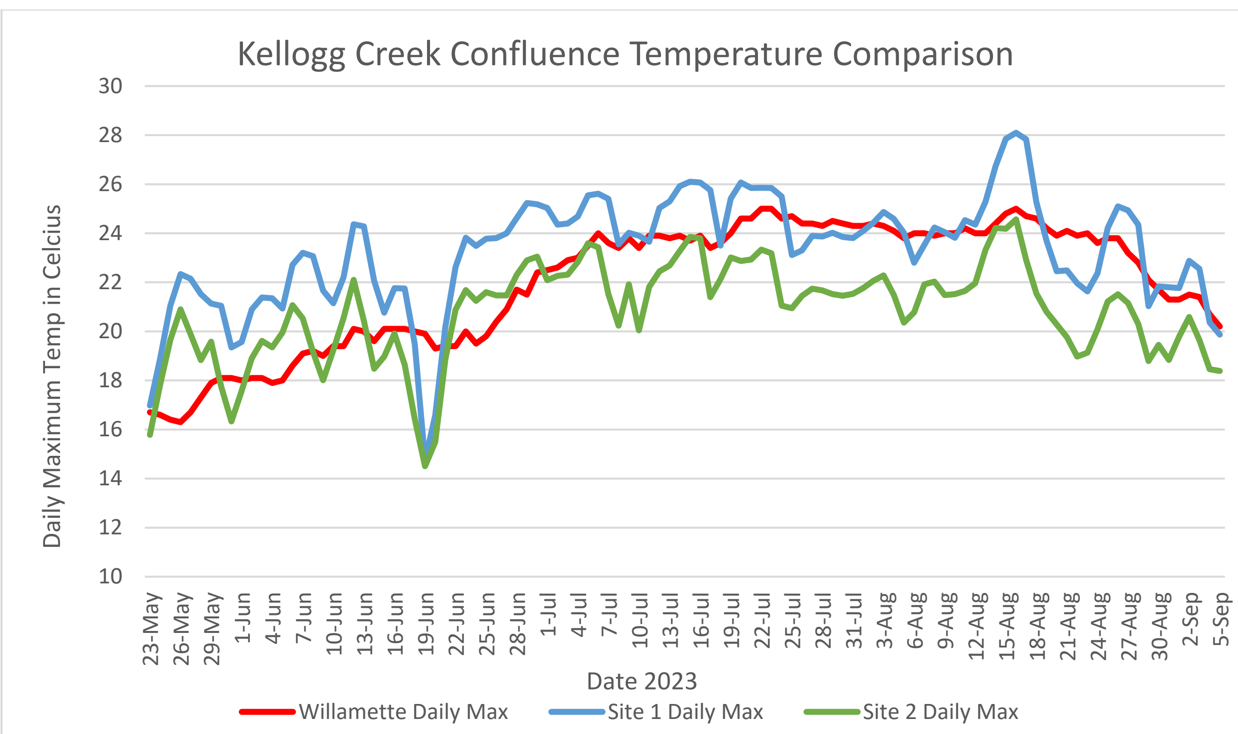
During DEQ's CWR study (DEQ, 2020) Kellogg Creek was identified as a coldwater refuge during the summer months. However, the temperature data collected at Kellogg's mouth and upstream of the dam's impoundment show that the potential of Kellogg's confluence to provide CWR is not only impacted by the dam which prevents fish access into the creek, but the impoundment behind the dam is significantly increasing water temperatures to levels similar to the Willamette mainstem.

When comparing daily maximum temperatures in Kellogg Creek versus the Lower Willamette, we found that on average the daily maximums were actually higher in the Kellogg fish ladder in than in the Willamette mainstem for the months of July and August by 0.6 °C (see Table 3). However, we know that the dam's impoundment is wide and shallow and probably affects the water temperature through that reach. In fact, the temperature logger upstream of the impoundment shows water temperatures 2.1 °C cooler than the Willamette, indicating that the water is heating up 2.7 °C (4.9 °F) as it flows through the impoundment and into the fish ladder. This is consistent with the temperature increases we saw in the impoundment last year (NCWC, 2023) of 2.8 °C (5.0 °F). In Kellogg Creek, the continual infill of the dam impoundment by sediment may be causing the channel to become shallower and wider over the years, increasing the water's exposure to the warming effects of convection and radiation.

Table 3 - Average daily maximum temperatures of Kellogg Creek both upstream and downstream of the dam impoundment as compared with lower Willamette River temperatures.

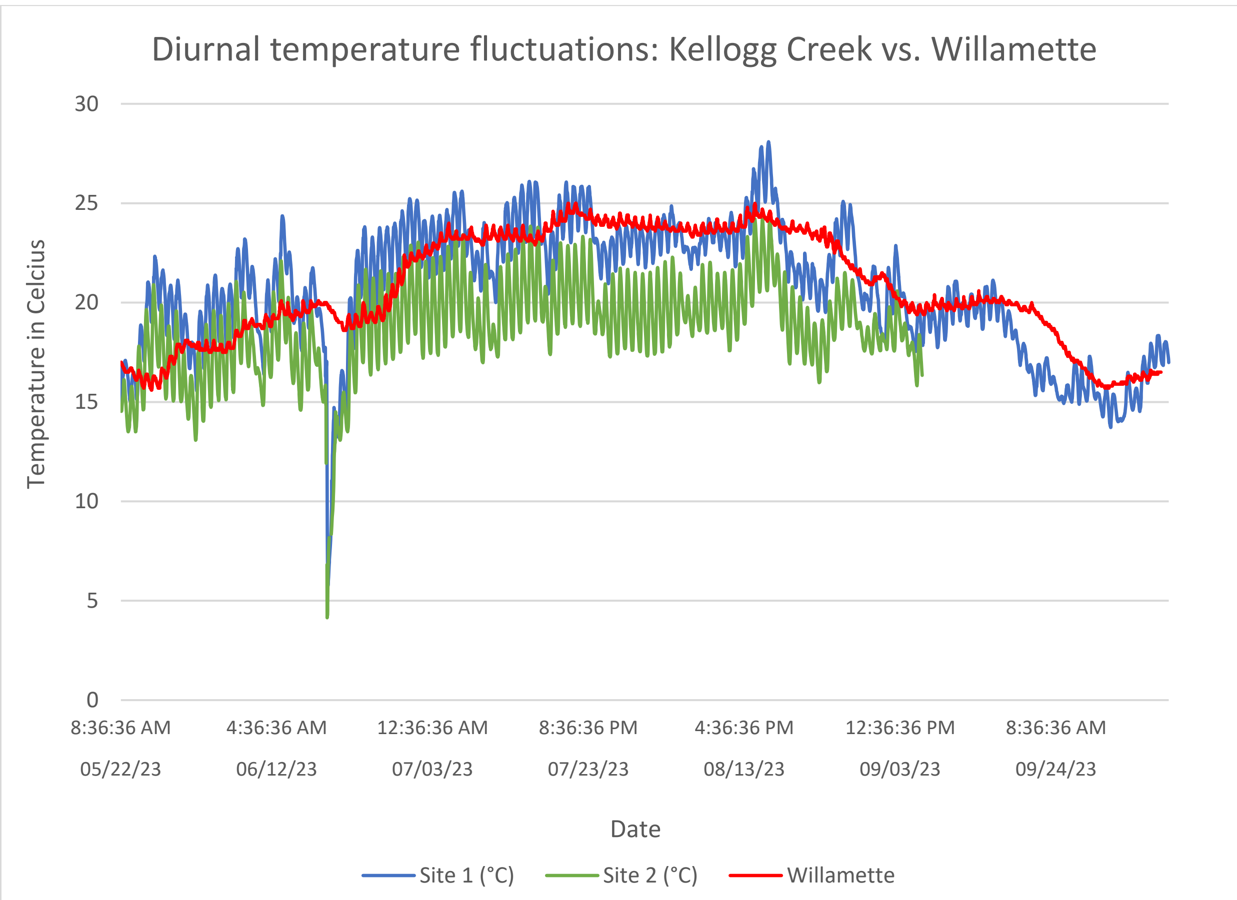
	July 2023 (°C)		**August 2023 (°C)**		**July & August 2023 (°C)**	
Location	July Mean Daily Max Temp	Change from Willamette	August Mean Daily Max Temp	Change from Willamette	Summer Mean Daily Max Temp	Change from Willamette
Willamette (USGS 14211720)	23.9	-	23.8	-	23.9	-
Mouth of Kellogg Creek (Site 1)	24.8	+0.9	24.1	+0.3	24.5	+0.6
Upstream of Kellogg Impoundment (Site 2)	22.2	-1.7	21.3	-2.5	21.8	-2.1

Figure 6 - Average daily maximum temperatures of Kellogg Creek both upstream and downstream of the dam impoundment as compared with lower Willamette River temperatures.



One of the challenges of utilizing daily maximums when looking at CWR habitat, is that maximums do not take into account daily temperature variations. The Lower Willamette is a large well-mixed water body. Larger, deeper water bodies are less influenced by daily fluctuations due to ambient air temperatures and solar radiation. Smaller, shallower creeks like Kellogg Creek are much more susceptible to these factors. If we plot these daily temperature fluctuations at the three sites mentioned above, we see that diurnal flux is much larger in Kellogg Creek than the Willamette. These daily temperature fluctuations are a more accurate representation of the temperature variations facing a fish migrating through the Lower Willamette and potentially utilizing the mouth of Kellogg Creek as CWR.

Figure 7 - Diurnal temperature fluctuations at the Kellogg Creek confluence as compared with the Lower Willamette in 2023.



This temperature analysis supports the efforts by the Council, American Rivers, ODOT, and the City of Milwaukie to create volitional fish passage at Kellogg Dam and remove the warming effect that is created by the upstream impoundment behind the dam. Once the dam and impoundment are removed then Kellogg Creek will be able to function as CWR habitat for migrating fish. Additional design considerations for the new creek channel through this reach should include design elements that will help protect and potentially improve water temperatures at the confluence. These include:

- Creation of a new single- or multi-thread channel that is narrower and deeper than the existing impoundment,

- Planting and maintaining riparian buffers with species that will shade the creek and survive periodic inundation from flood events and Willamette backwatering, and be resilient to climate change, and
- Designing habitat features that will encourage hyporheic exchange to further cool temperatures by encouraging the creek water to interact with groundwater.
- Designing habitat features that lead to formation of deep pools to be used by migrating adult salmon as they move through the lower Willamette in summer months.

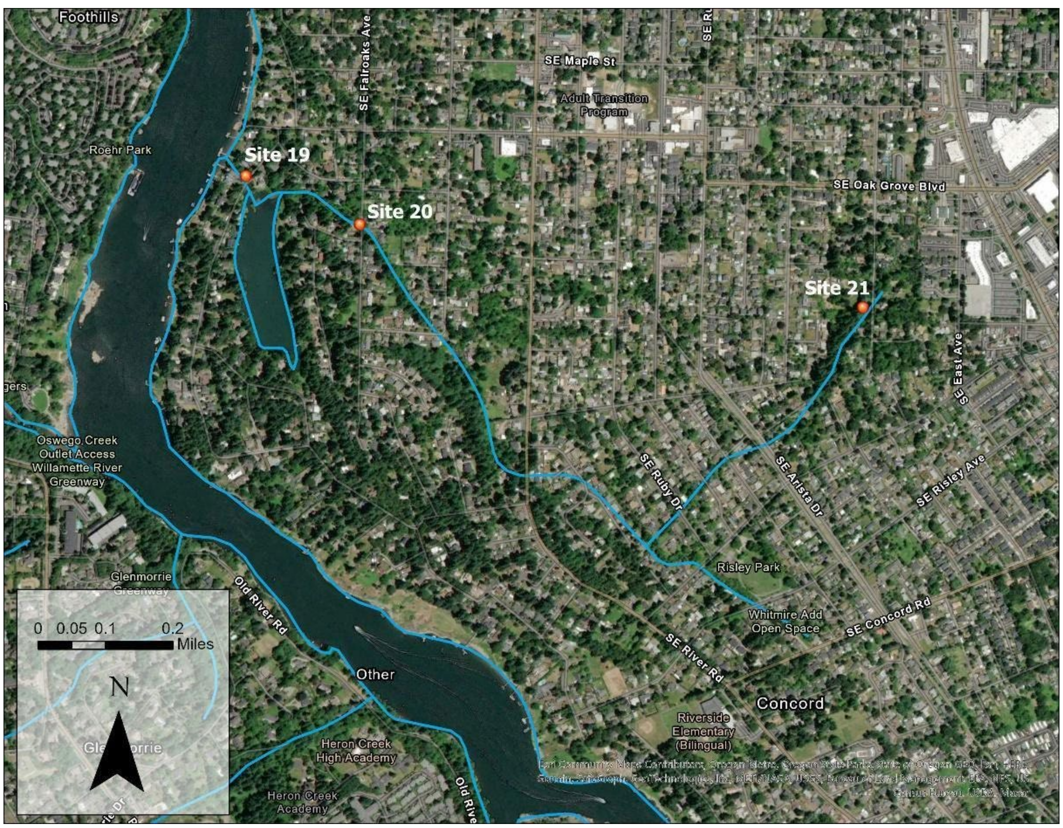
River Forest Creek Confluence

Two temperature loggers were installed in River Forest Creek this year:

- Site 19 – at the confluence downstream of River Forest Lake
- Site 20 – upstream of River Forest Lake

Theses study sites were chosen to determine if the water from River Forest Lake was significantly impacting water temperatures and the ability of the River Forest Creek confluence to act as CWR for the Lower Willamette.

Figure 8 - Location of River Forest Creek confluence temperature loggers.



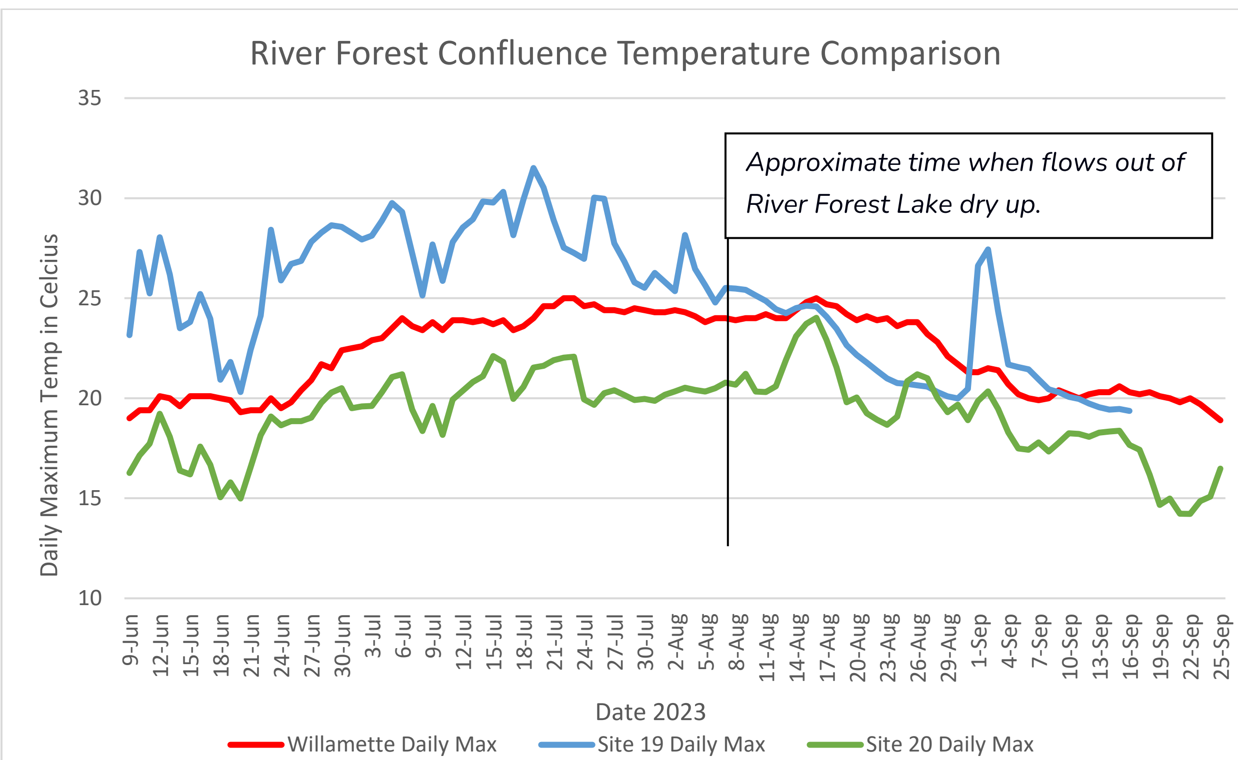
Summer water temperatures found at the mouth of River Forest Creek were higher than the Lower Willamette River as a result of the high temperature water flowing out of River Forest Lake. In July when water is flowing out of the lake, there is a 7.9 C temperature difference between the two sites (see Table 4). Thankfully, flows out of the lake are very low in the summer months and the creek dried up at the confluence downstream of the culvert in August as a result of silt settling at the inlet of the culvert at River Forest Road. We see that change in flow pattern reflected in the temperatures seen in August.

Table 4 - Average daily maximum temperatures of River Forest Creek as compared with lower Willamette River temperatures.

	July 2023 (°C)		August 2023 (°C)		July & August 2023 (°C)	
Location	July Mean Daily Max Temp	Change from Willamette	August Mean Daily Max Temp	Change from Willamette	Summer Mean Daily Max Temp	Change from Willamette
Willamette (USGS 14211720)	23.9	-	23.8	-	23.9	-
Mouth of River Forest Creek (Site 19)	28.3	+4.4	23.4	-0.4	25.8	+1.9
Upstream of River Forest Lake (Site 20)	20.4	-3.5	20.6	-3.2	20.5	-3.4

The logger at Site 19 was located in a pool downstream of the culvert below River Forest Lake. Because flows from River Forest Lake into the creek stopped flowing in August, the pool downstream of the culvert became isolated. At that time, the water in the pool was able to cool which is reflected in the data.

Figure 9 - Average daily maximum temperatures of River Forest Creek as compared with lower Willamette River temperatures.



This data shows that River Forest Creek has the potential to function as CWR habitat if the channel could be disconnected from River Forest Lake. This also supports the findings of the Council’s 2022 Watershed Action Plan, which recommends the disconnection of the River Forest Creek channel from the River Forest Lake impoundment as a priority action. Because the lake is not an in-line impoundment, it’s disconnection from the creek may be possible, and further study should be conducted to determine its feasibility. NCWC is also planning to construct a habitat enhancement project at the confluence that will go to construction this Summer 2024. This project will target winter and spring rearing habitat in the Willamette River as we know River Forest Creek dries up in the summer.

Boardman Creek Confluence

There was one logger installed at the confluence of Boardman Creek with the Willamette River. Site 22 was at the Oak Lodge pump station and the site was selected because the temperatures there are not influenced by the backwater effects of the lower Willamette River.

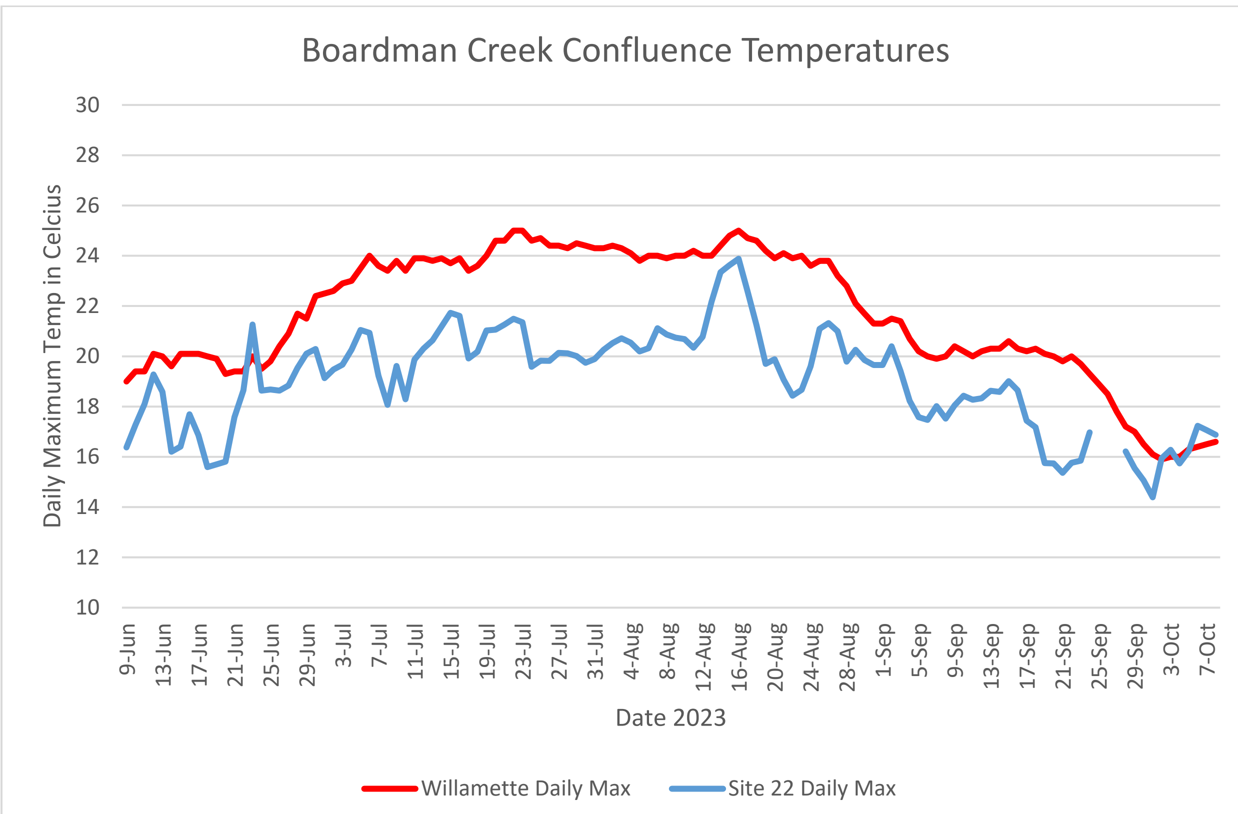
Figure 10 - Location of Boardman Creek confluence temperature loggers.

Summer water temperatures at the Boardman Creek confluence were significantly cooler than the Willamette, and the average daily maximum temperature for the months of July and August was 3.4 °C lower than at Site 22 (see Table 5).

Table 5 - Average daily maximum temperatures of Boardman Creek as compared with lower Willamette River temperatures.

	July 2023 (°C)		**August 2023 (°C)**		**July & August 2023 (°C)**	
Location	July Mean Daily Max Temp	Change from Willamette	August Mean Daily Max Temp	Change from Willamette	Summer Mean Daily Max Temp	Change from Willamette
Willamette (USGS 14211720)	23.9	-	23.8	-	23.9	-
Mouth of Boardman Creek (Site 22)	20.2	-3.7	20.7	-3.1	20.5	-3.4

Figure 11 - Average daily maximum temperatures of Boardman Creek as compared with lower Willamette River temperatures.

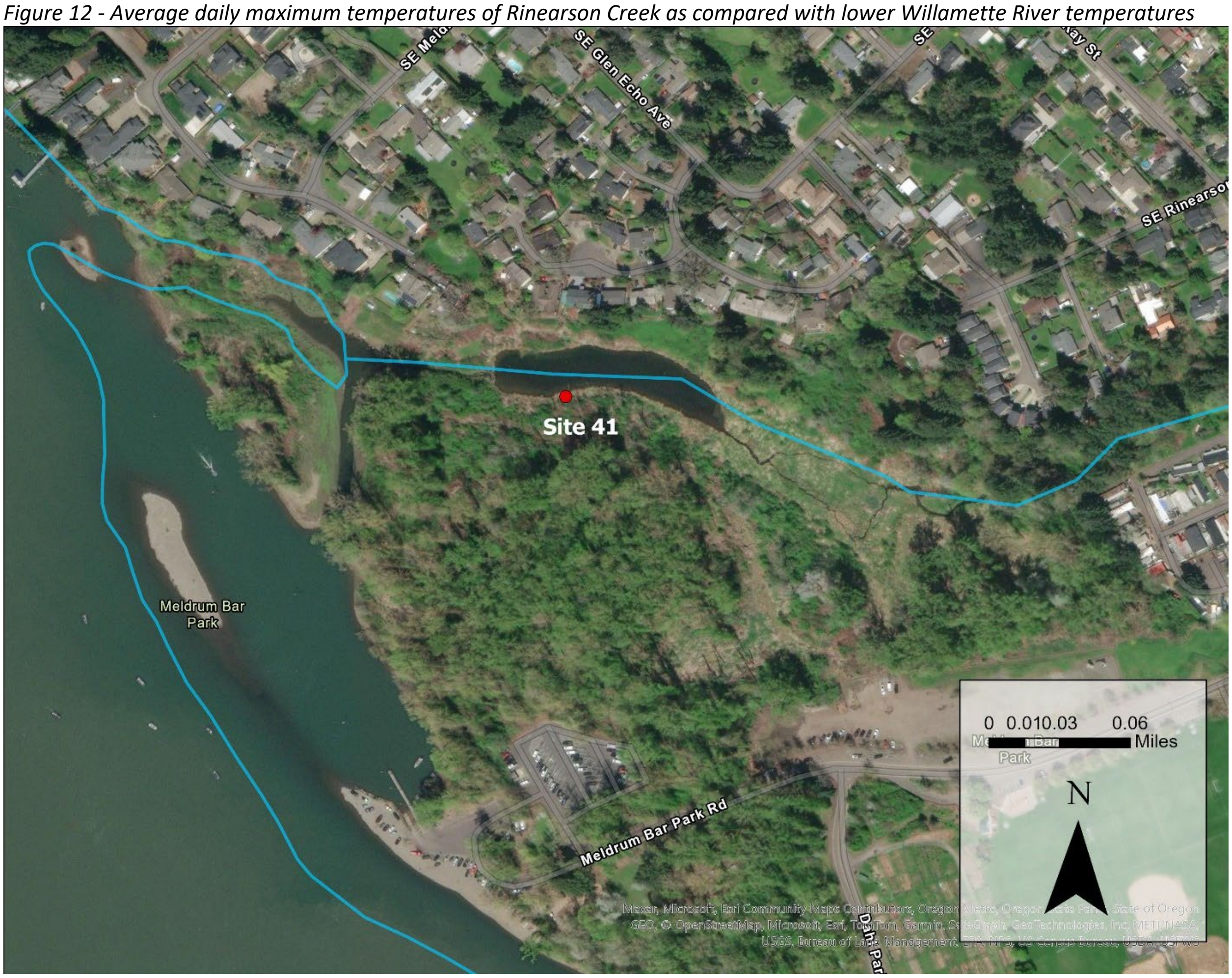


These results from this year and last year (NCWC, 2023) show that Boardman Creek currently functions as CWR habitat in the Lower Willamette in the summer months. Although summer flows out of Boardman Creek are low, they are perennial and the confluence provides thermal refuge for fish. The Council currently is designing a habitat restoration project to create pools and install large wood to provide instream cover at this site. Construction of the project will be dependent on securing landowner agreements.

Rinearson Creek Confluence

This year we installed a temperature logger in the natural area near the mouth of Rinearson Creek. The logger was located at the downstream end of the beaver pond.

Figure 12 - Average daily maximum temperatures of Rinearson Creek as compared with lower Willamette River temperatures

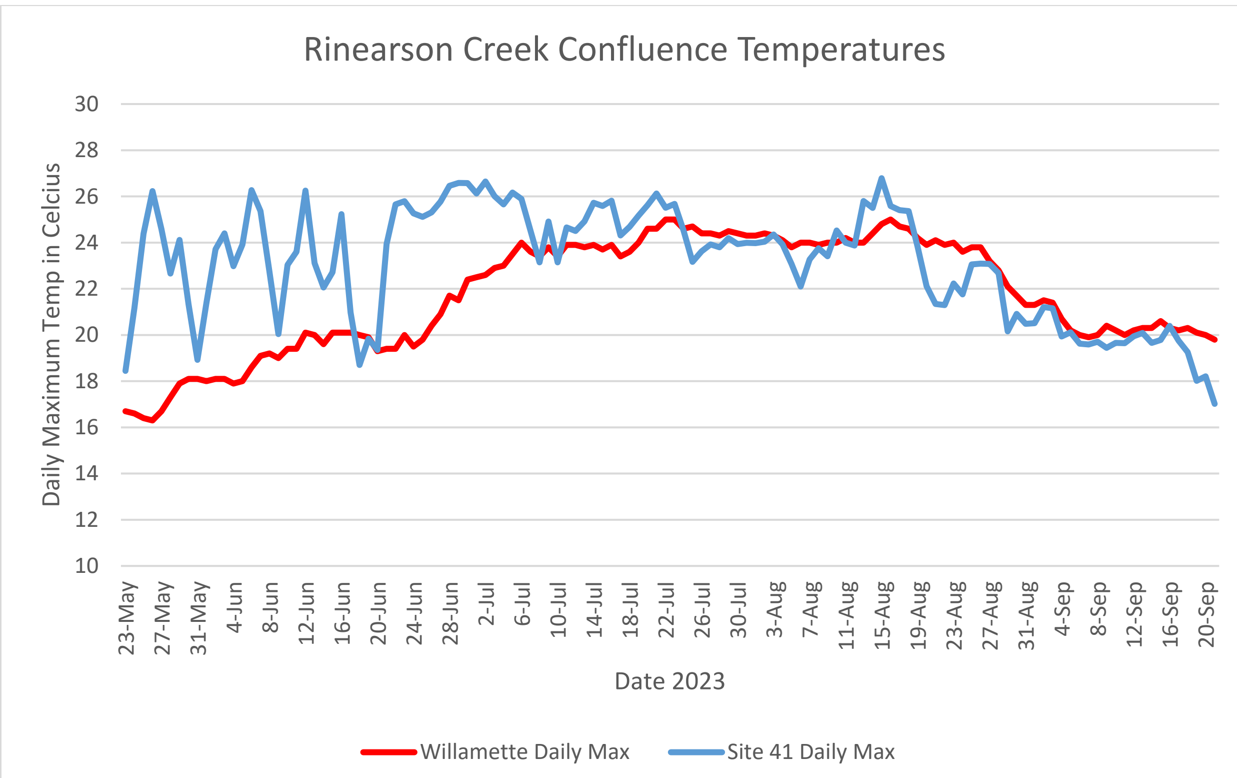


The warm water temperatures coming out of the beaver pond do not allow the confluence of Rinearson Creek to function as cold water refugia for fish in the summer months as seen in Table 6. Any woody vegetation around the pond gets significantly pruned by the beavers, preventing the pond to have much shade from direct sun. The pond is also wide and shallow, which makes it susceptible to warming.

Table 6 - Average daily maximum temperatures of Rinearson Creek as compared with lower Willamette River temperatures.

	July 2023 (°C)		**August 2023 (°C)**		**July & August 2023 (°C)**	
Location	July Mean Daily Max Temp	Change from Willamette	August Mean Daily Max Temp	Change from Willamette	Summer Mean Daily Max Temp	Change from Willamette
Willamette (USGS 14211720)	23.9	-	23.8	-	23.9	-
Mouth of Rinearson Creek (Site 41)	24.9	+1.0	23.4	-0.4	24.1	+0.2

Figure 13 - Average daily maximum temperatures of Site 41 as compared with lower Willamette River temperatures.



Results: Tributary inputs on Kellogg-Mt. Scott

One of the questions posed about the Kellogg-Mt. Scott watershed was how the different tributaries impact water temperatures. This information will help the Council prioritize habitat protection and restoration efforts within the Kellogg-Mt. Scott watershed to target cold water inputs. This year we examined:

2. the confluence of Minthorn Creek with Mt. Scott Creek

3. the confluence of Phillips Creek and Dean Creek with Mt. Scott Creek
4. the confluence of an unnamed tributary in Mt. Talbert with Mt. Scott Creek

During this analysis we are predominately interested in the use of the watershed as rearing habitat as the primary beneficial use, which equates to a DEQ temperature standard of 18°C. As mentioned before, this watershed also has some potential spawning habitat would be accessible to fish once the Kellogg Dam is removed. A future study that places temperature loggers within the potential spawning sites to collect year-round data may be helpful to look at temperatures during the different spawning season for various species. This is particularly relevant for early and late spawners including fall Chinook which spawn in September/October and lamprey which spawn into May.

Minthorn-Mt. Scott Confluence

Thermographs were placed both upstream and downstream of the confluence of Mt. Scott Creek with Minthorn Creek:

- Site 31 - downstream of the confluence of Minthorn with Mt. Scott
- Site 32 - Minthorn Creek upstream of the confluence
- Site 6 - Mt. Scott Creek upstream of the confluence.

Figure 14 - Location of Minthorn-Mt. Scott Creeks confluence temperature loggers.

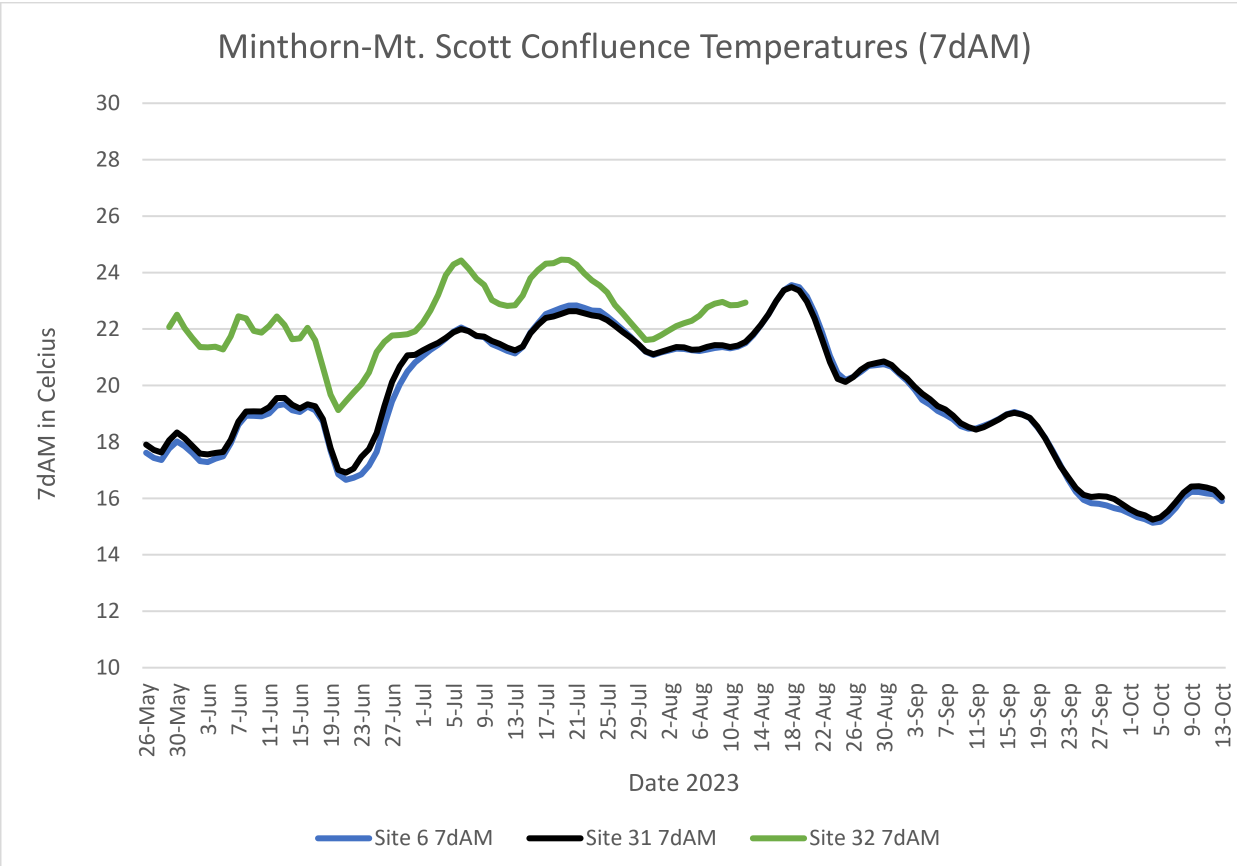
The average 7dAM in July and August was 1.4 °C warmer in Minthorn Creek (Site 32) than Mt. Scott Creek (Site 6):

- Average 7dAM at Site 6 (July -August) = 21.7 °C

- Average 7dAM at Site 32 (July -August) = 23.1 °C
- Average 7dAM at Site 31 (July -August) = 21.7 °C

These results show that these creeks exceed the DEQ standard for rearing habitat (18 °C) during the summer months. Although the temperature of the water coming into Mt. Scott Creek from Minthorn Creek is 1.4 C higher, the flows from Minthorn Creek that time of year are low and have virtually zero impact on the temperatures of Mt. Scott Creek.

Figure 15 - 7dAM temperatures at the confluence of Minthorn and Mt. Scott Creeks.

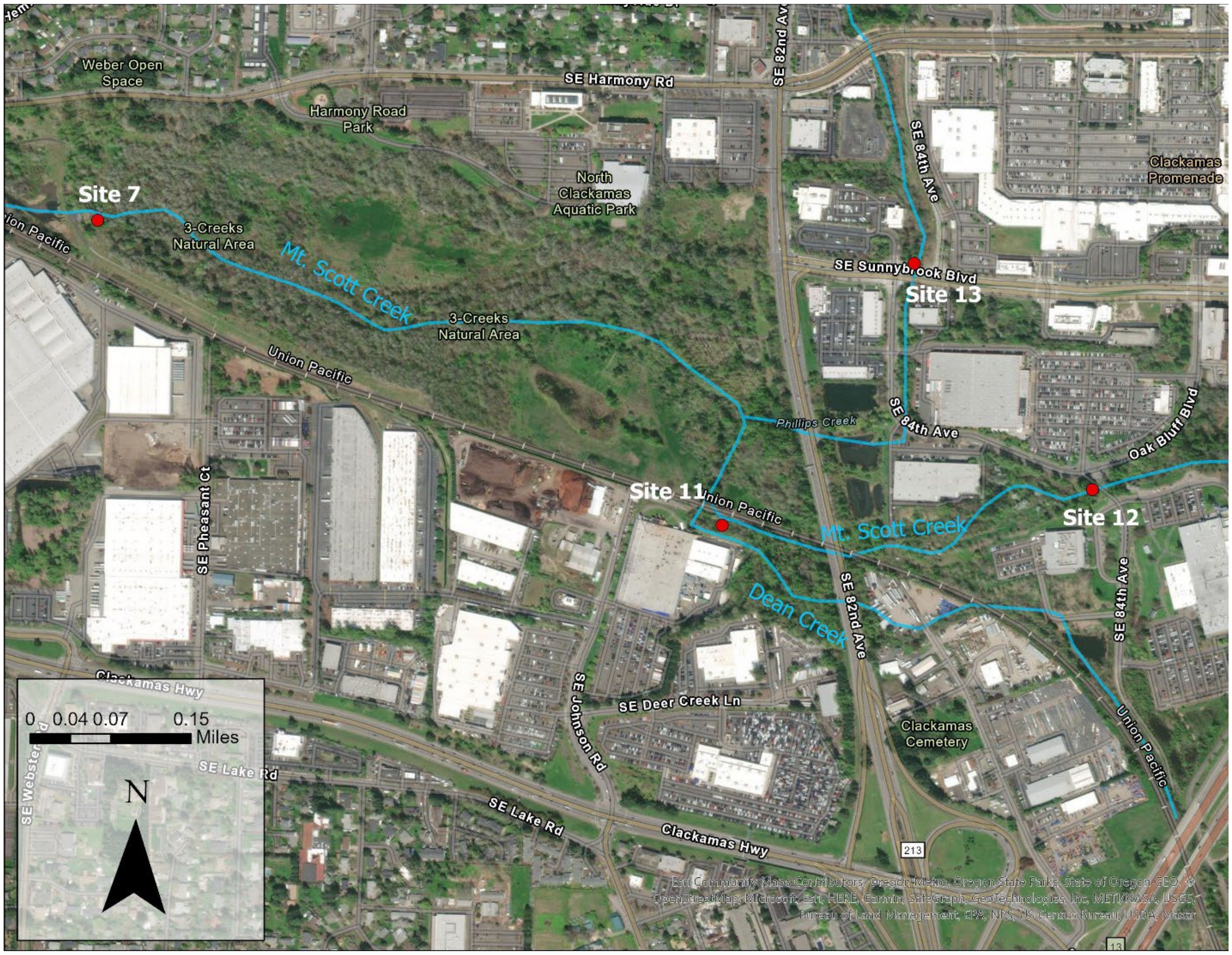


Dean & Phillips-Mt. Scott Confluences

Thermographs were place both upstream and downstream of the confluence of Mt. Scott Creek with Dean Creek and Phillips Creek:

- Site 7 - downstream of the confluences of Mt. Scott and Dean and Phillips Creek
- Site 11 - Dean Creek upstream of the confluence with Mt. Scott Creek
- Site 13 – Phillips Creek upstream of the confluence with Mt. Scott Creek
- Site 12 - Mt. Scott Creek upstream of the confluences with Dean and Phillips Creeks.

Figure 16 - Location of Dean-Mt. Scott Creek confluence temperature loggers.

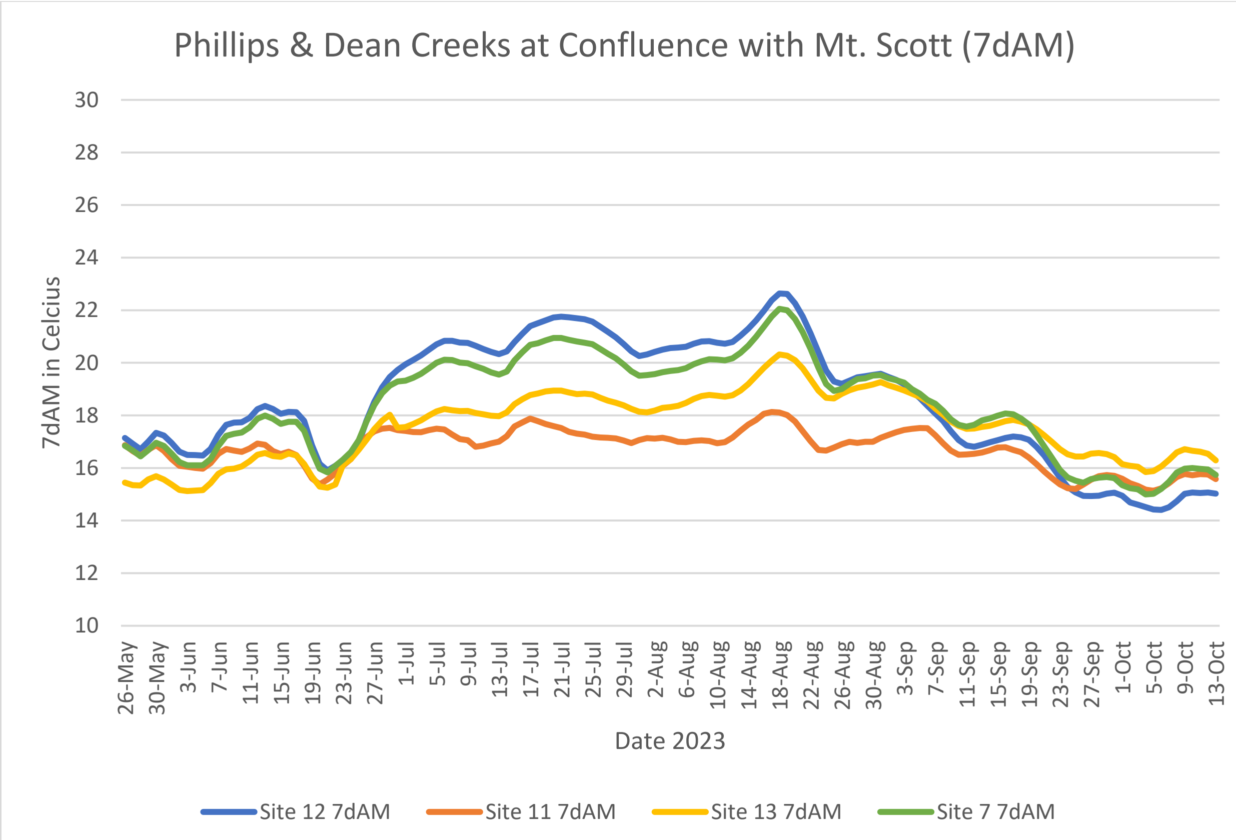


The 2023 temperature data shows that the 7dAM temperature of Dean Creek (Site 11) is an average of 1.9 °C cooler than Mt. Scott Creek (Site 12). Phillips Creek (Site 13) is an average of 1.0 °C cooler than Mt. Scott Creek:

- Average 7dAM at Site 12 (July – August) = 18.6 °C
- Average 7dAM at Site 11 (July – August) = 16.7 °C
- Average 7dAM at Site 13 (July – August) = 17.6 °C
- Average 7dAM at Site 7 (July – August) = 18.3 °C

The cooler water coming from Phillips and Dean Creek, seems to have some small impact on downstream water temperatures at Site 7, dropping stream temperatures 0.3 °C between Site 12 and Site 7. This impact is relatively small because of the low flows coming out of Dean and Phillips Creek. This stretch of riparian corridor through 3 Creeks Nature Area is also well shaded by trees and shrubs, which helps keep the water temperatures cooler.

Figure 17 - 7dAM temperatures at the confluence of Dean and Mt. Scott Creeks.



Unlike Mt. Scott Creek, Dean Creek summer temperatures meet DEQ's temperature standards for rearing habitat (18 °C). This means the Dean Creek is most likely a temperature refugia for fish rearing in this watershed during the summer. Because of this, the Council will prioritize protection, restoration, and research efforts in Dean Creek. During a 2023 fish passage barrier assessment (NCWC, 2023) a culvert was identified at the mouth of Dean Creek that functions as a partial barrier to fish.

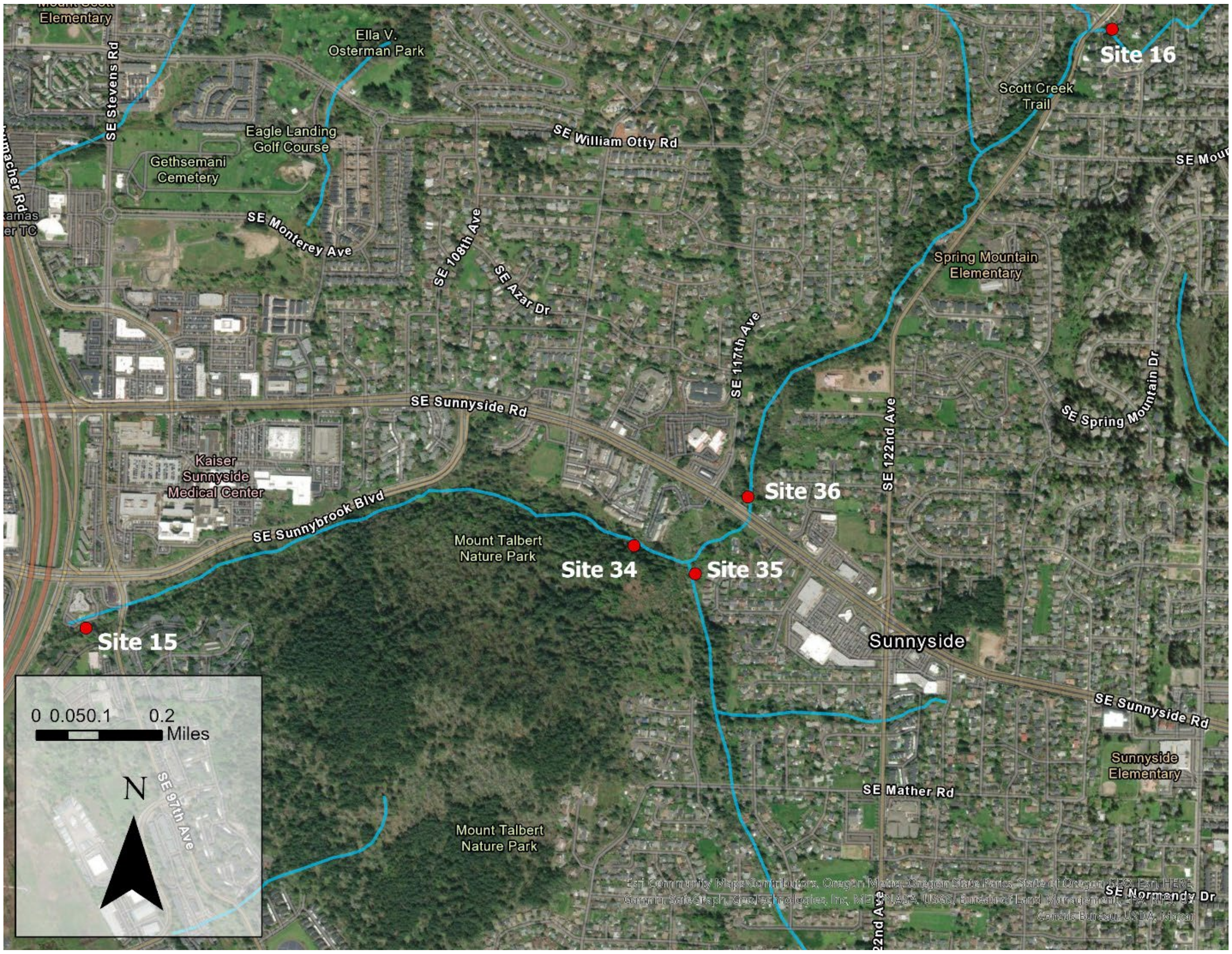
Unnamed Tributary-Mt. Scott Confluence

Thermographs were place both upstream and downstream of the confluence of Mt. Scott Creek with an unnamed tributary in Mt. Talbert Nature Park.:

- Site 34 – downstream of the confluence of the unnamed tributary with Mt. Scott Creek
- Site 35 – an unnamed tributary in Mt. Talbert Nature Park
- Site 36 – upstream of the confluence of the unnamed tributary with Mt. Scott Creek

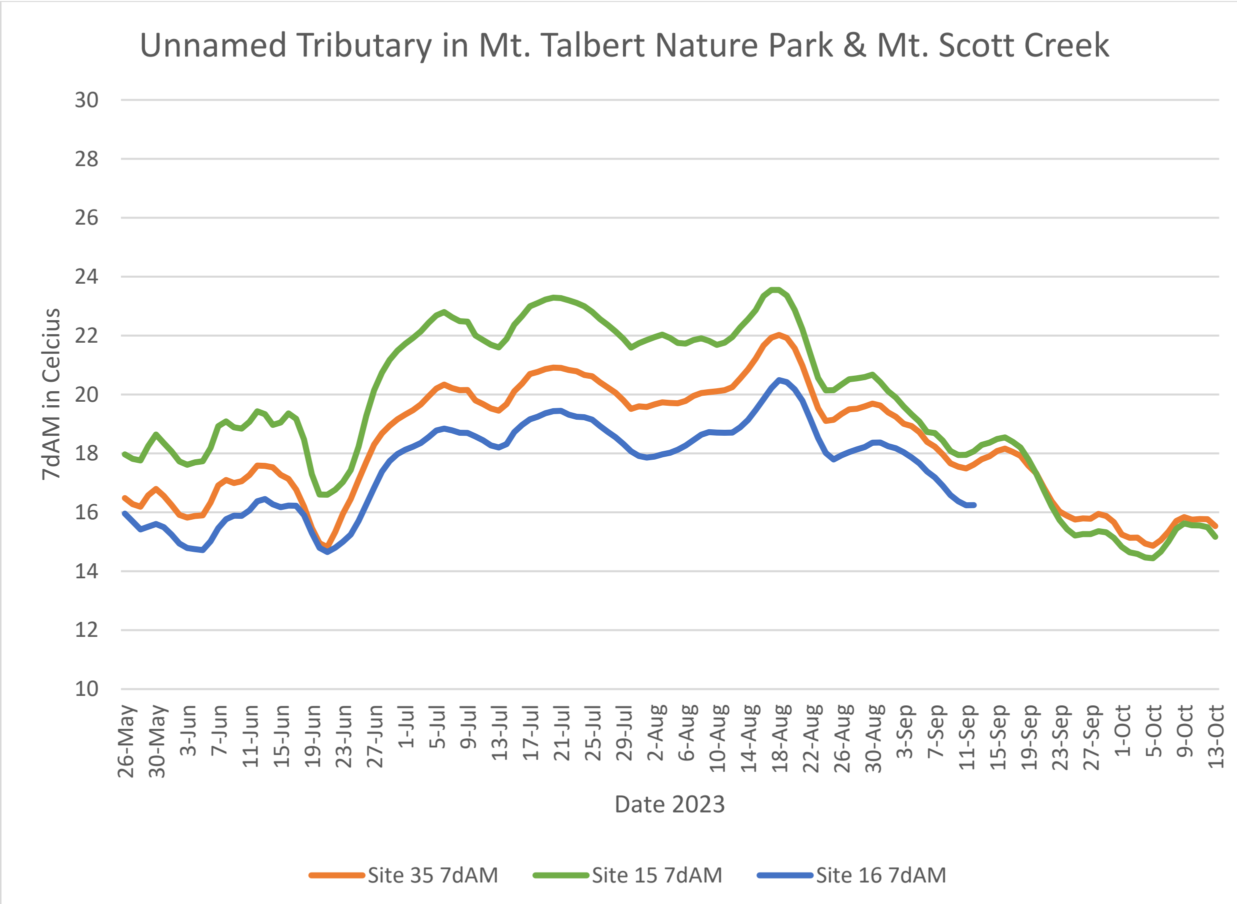
This tributary was chosen as a study site because during last year's temperature monitoring (NCWC, 2023) we found significantly warming in Mt. Scott Creek through the Sunnyside corridor. Unfortunately, the logger at Site 34 was stolen and the data was unrecoverable from the logger at Site 36. However, we still analyzed the data at Site 35 and compared it with the temperatures at Site 15 and Site 16 to see if the unnamed tributary is contributing significantly hotter or cooler water. Site 15 and Site 16 are each approximately one mile from the confluence of the unnamed tributary, so we are just looking for any significant anomalies.

Figure 18 - Location of Mt. Scott Creek temperature loggers near an unnamed tributary in Mt. Talbert Nature Park.



Although Site 35 is a distance from Site 15 and 16, the tributary temperatures appear to be in the expected range. There were not significant cold or warm water coming from that drain, and water temperatures were actually cooler than those found at Site 15. However, because of the loss of the thermographs directly up and downstream of this tributary, the temperature study at this site should be repeated in 2024. It should be noted in Figure 19 that we once again saw a dramatic increase in water temperatures between Site 16 and Site 15, with an average increase of 3.4 C in the summer months (July-August).

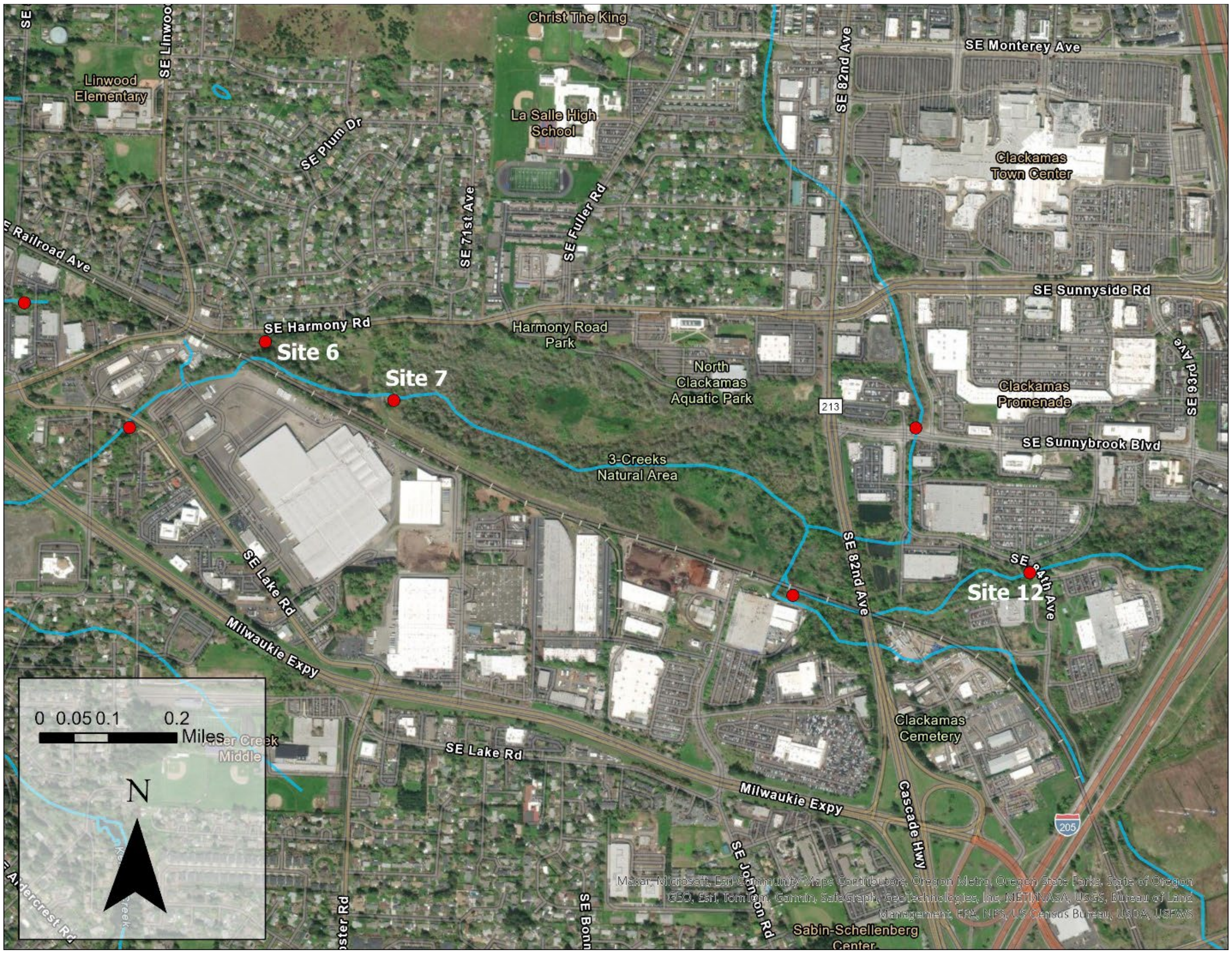
Figure 19 - 7dAM temperatures upstream and downstream of the confluence of an unnamed tributary with Mt. Scott Creeks.



Results: 3-Creeks Natural Area

The 3-Creeks Natural Area is approximately 89 acres of streams, wetlands, and upland habitat that encompasses Mt. Scott Creek and its confluences with Phillips and Dean Creeks. The site is wedged in between industrial and commercial properties, a set of active railroad tracks, and private homes. The site is also owned by Clackamas Water Environment Services (WES) and is home to a flood control facility which stores water during the heaviest rains to protect businesses and infrastructure. There were two thermographs installed in 3-Creeks Natural Area and one just upstream at Site 12. The temperature study of the confluences of Phillips Creek and Dean Creek with Mt. Scott Creek is discussed in the previous section, and shows how those two tributaries contributed colder water to the Mt. Scott mainstem.

Figure 20 - Location of 3-Creeks Natural Area temperature loggers.

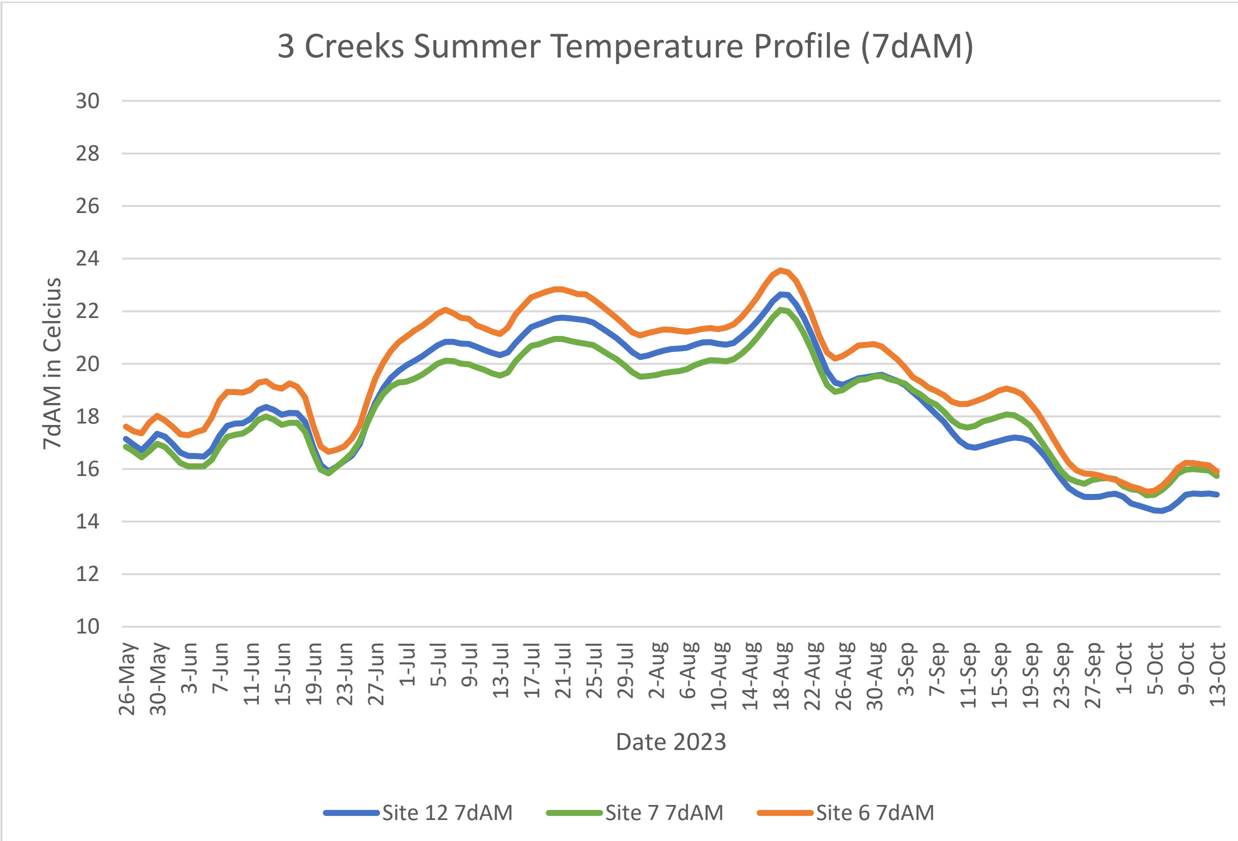


As discussed in the tributary study previously, when we compare those upstream temperatures coming into 3 Creeks (Site 12) with the temperatures collected downstream at Site 7 we saw a drop in water temperatures related to the cooler flows coming out of Phillips and Dean. The 3-Creeks Natural Area contains some good riparian canopy, however the channel is significantly incised preventing the creek to flow out into the floodplain and allowing for the cooler late season hyporheic flow. WES is currently designing a restoration project that will allow for the creek to interact with the floodplain more, and it will be interesting to see how that affects summer temperatures.

Between Site 7 and Site 6 we did see a 1.5 °C increase in the average 7dAM in the months of July and August.

- Average 7dAM at Site 6 (July -August) = 21.7 °C
- Average 7dAM at Site 7 (July -August) = 20.2 °C
- Average 7dAM at Site 12 (July -August) = 20.8°C

Figure 21 - 7dAM temperatures in 3-Creeks Natural Area.



We saw this heating effect between Sites 6 and 7 in 2022 as well (NCWC, 2023). It is potentially the result of the wide and shallow pond that exists downstream of the water control structure. As WES considers management of their flood control structure, design considerations should take into account the potential heating that occurs in that pond. Consideration should also be given to looking for other potential warm water inputs through that stretch of creek to ensure that significant commercial or industrial inputs are not occurring.

Results: Longitudinal Study of Minthorn Creek

The Wetlands Conservancy Urban Wetlands State-of-the-Catchments Summary (Labbe and Scully-Engelmeyer, 2016) noted that the water quality in Minthorn Springs Wetland is considered poor. For this investigation, we assessed the difference between water temperatures coming directly out of the spring seep at the inlet of the wetland (Site 18), versus water temperatures exiting the wetlands into Minthorn Creek (Site 17). Then we assessed how the water temperatures changed as flows came down Minthorn Creek into Site 33 and 32. The location of these four temperature loggers can be seen below.

Figure 22 - Location of Minthorn Springs temperature loggers.

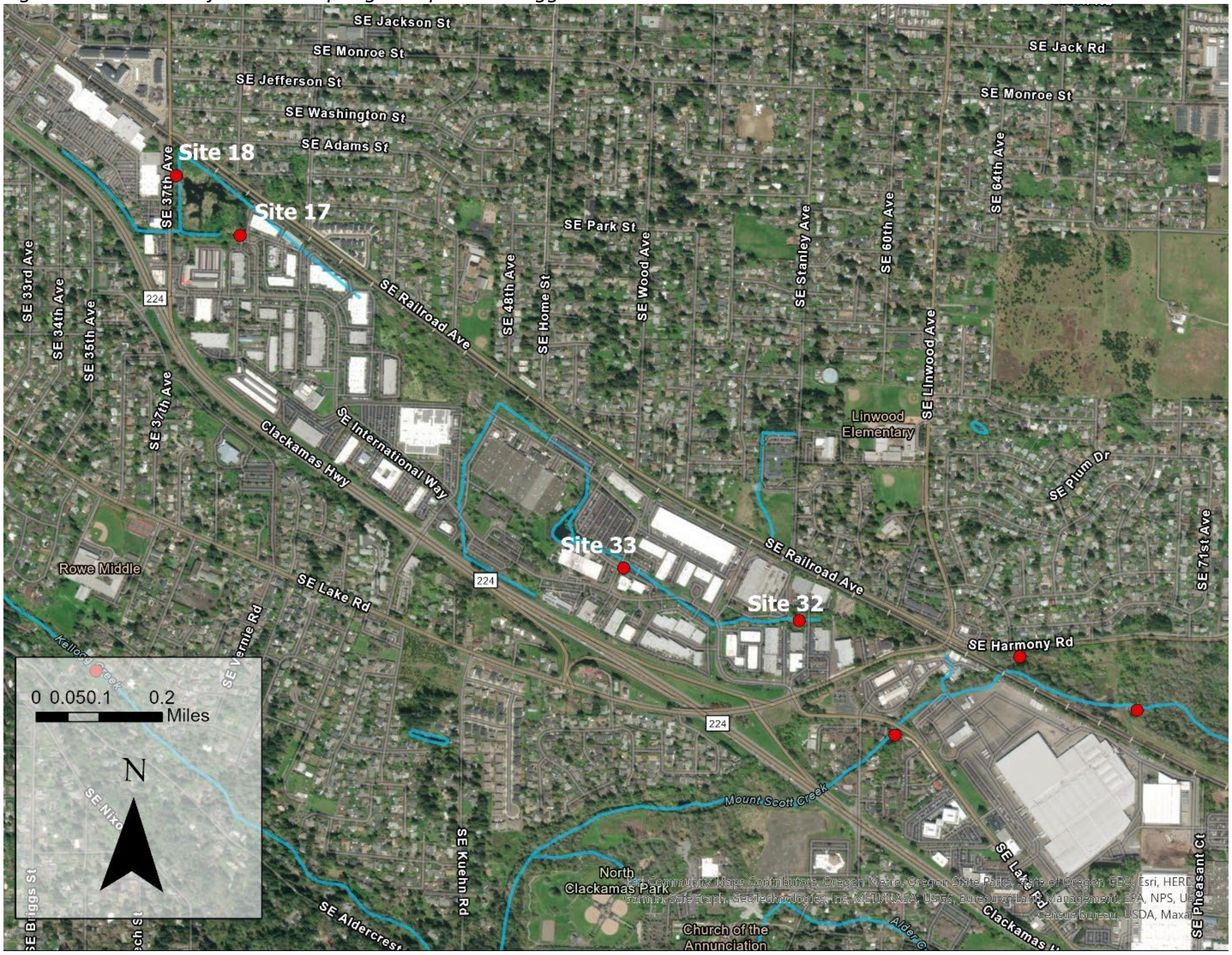
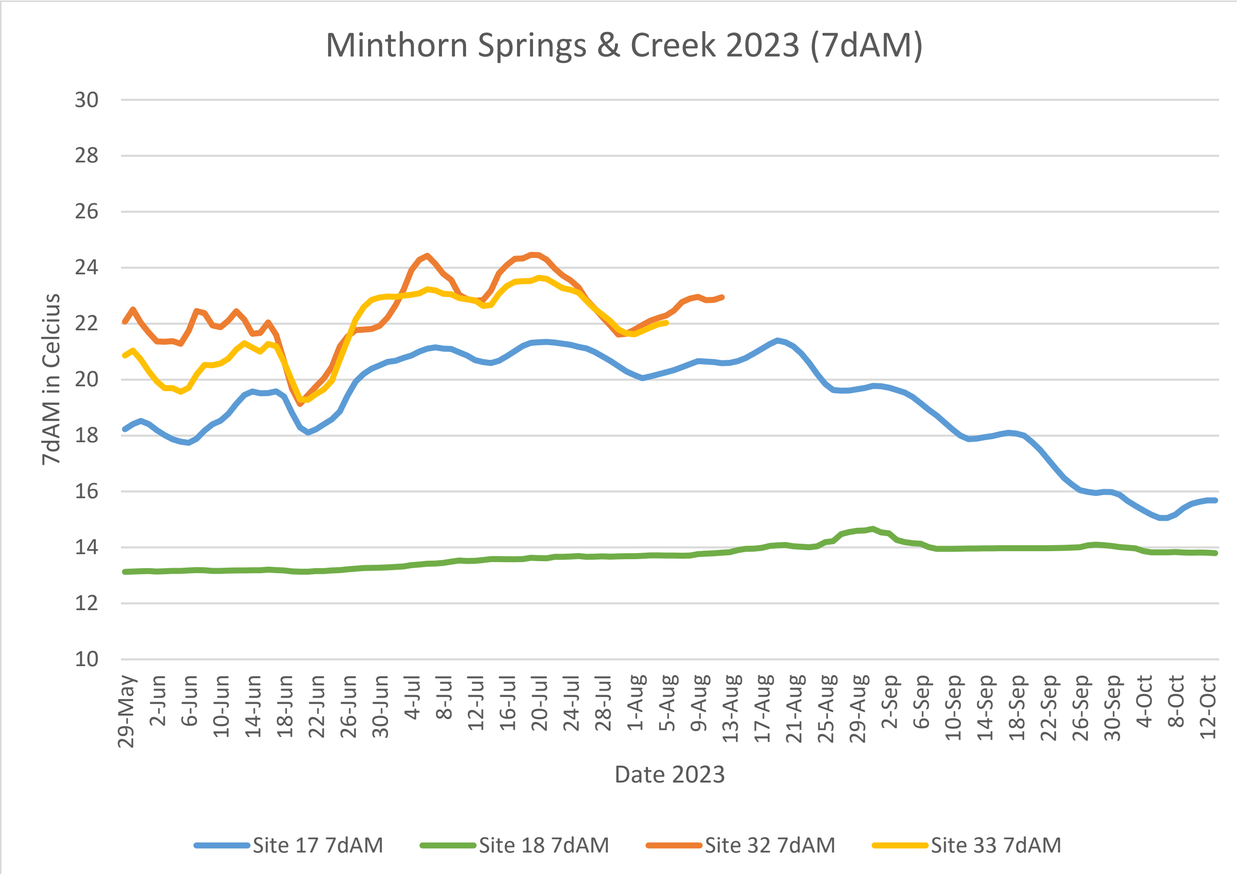
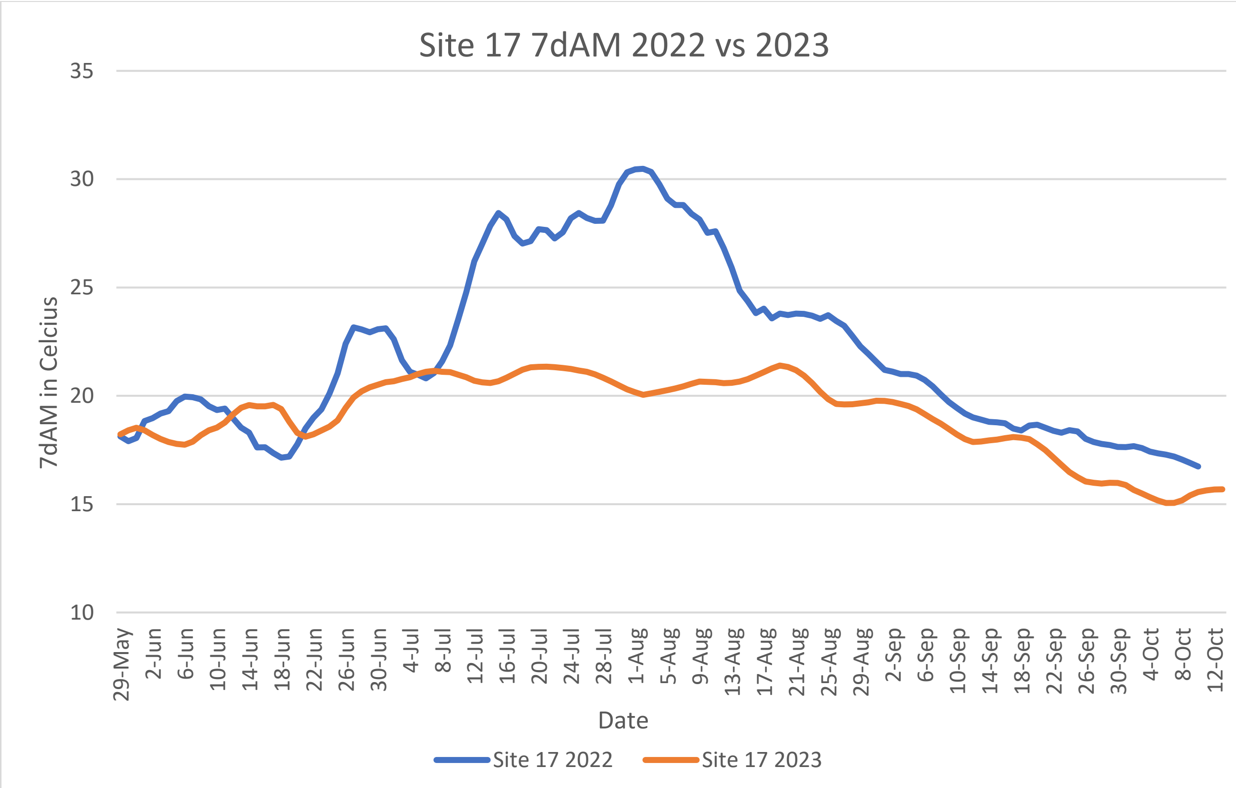


Figure 23- 7dAM temperatures at Minthorn Springs Wetland.



The spring-fed inlet to the wetlands maintained a consistent 13-15 °C all summer long, providing some of the coolest water seen during this study. Last year, the logger placed at the outlet of the wetlands showed the highest water temperatures seen, tracking just below air temperatures above 20 °C all summer and peaking over 30 °C in the beginning of August (NCWC, 2023). This year, although the temperatures leaving the wetland were much warmer at the outlet, we did not see those extreme high temperatures (see below in Figure 24). This was an interesting result and it makes us question what was different with the management of the wetland this year to effect that change. Because of the interesting temperature dynamics in Minthorn Wetlands, this site has been selected to collect infrared drone imagery. This will help us determine if point-source heating is an issue or if the water warms simply due to incidental solar radiation. If we can determine a way to capture and maintain the cold water coming out of the springs and filling the wetland, then Minthorn Creek may become a more valuable target for restoration improvements.

Figure 24 – Comparison of temperatures at the outlet of Minthorn Springs from 2022 to 2023.



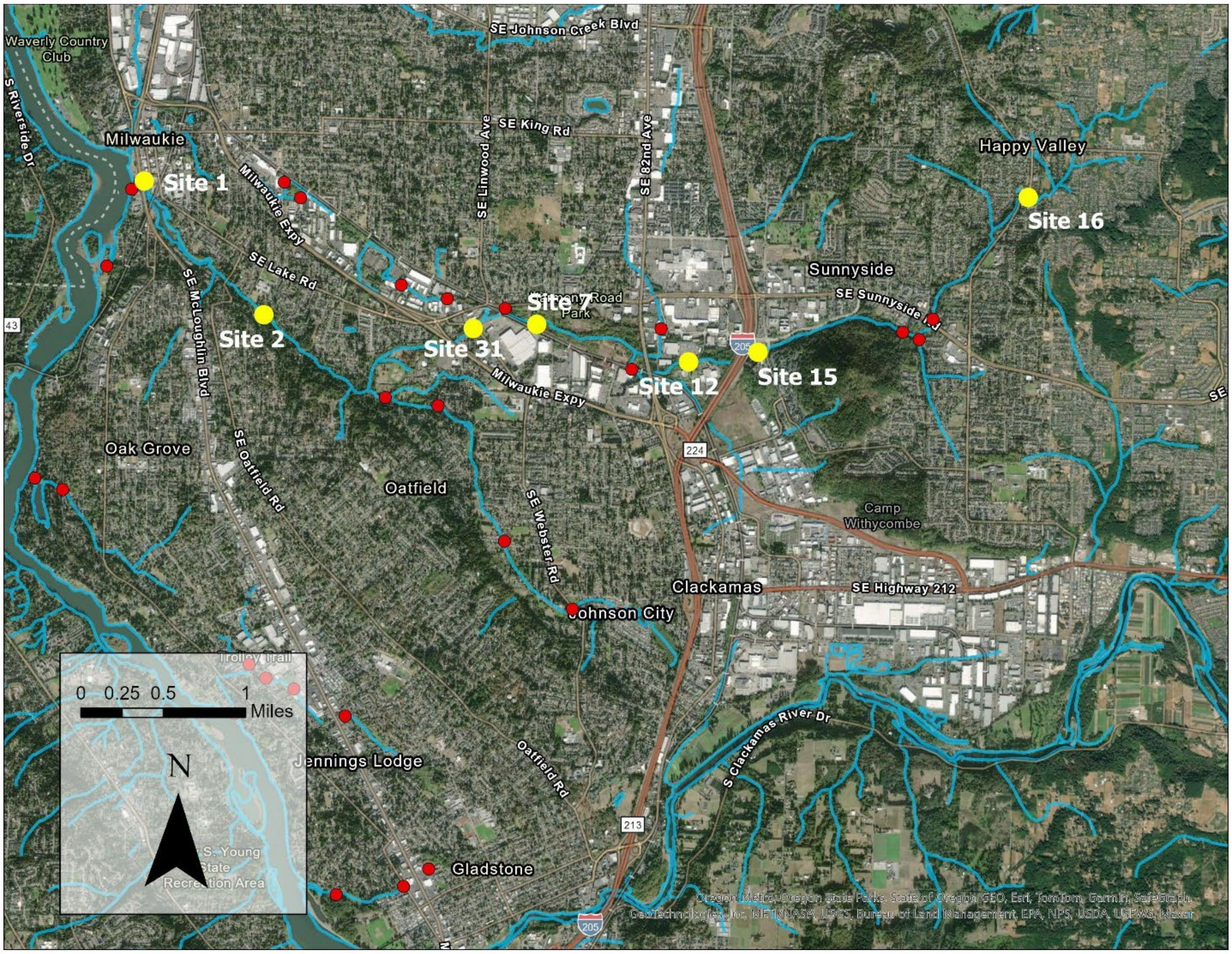
Results: Longitudinal study of Mt. Scott Creek into Lower Kellogg

There were many loggers installed throughout the Kellogg-Mt. Scott watershed and we wanted to conduct a longitudinal study of water temperatures from Mt. Scott Creek down to confluence of Kellogg Creek with the Lower Willamette River. For this study we pulled data from the following locations:

- Site 1 – Kellogg Creek at the dam
- Site 2 – Kellogg Creek upstream of impoundment
- Site 31 – Mt. Scott Creek at SE Lake Road
- Site 6 – Mt. Scott Creek upstream of flood structure in 3-Creeks Natural Area
- Site 12 – Mt. Scott Creek at SE 84th Avenue
- Site 15 – Mt. Scott Creek at SE 97th Avenue
- Site 16 – Presumed end of anadromy at 129th Avenue bridge

These locations were selected because the other loggers either had corrupted datasets, were stolen, or showed no temperature variations to nearby loggers.

Figure 25 - Location of Kellogg-Mt. Scott loggers used for longitudinal study (shown in yellow).



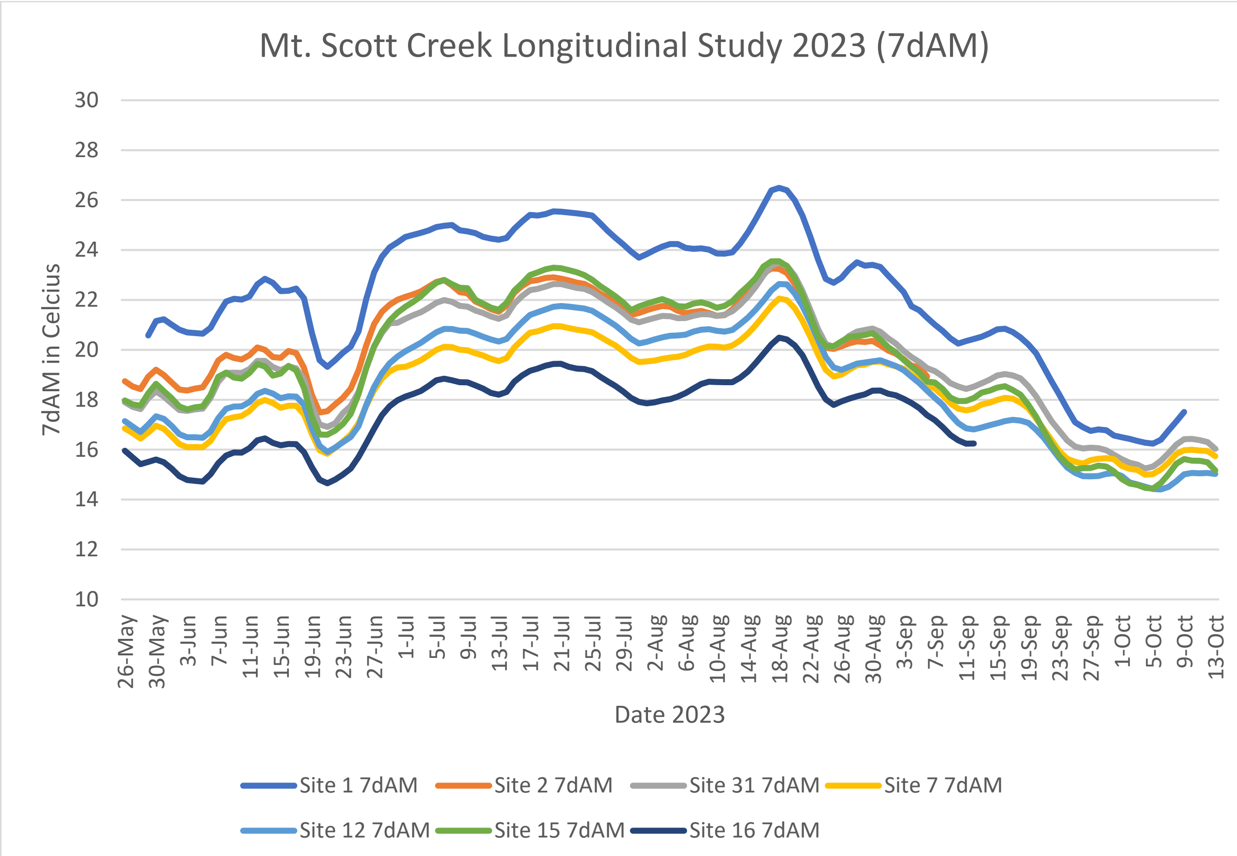
Looking at the mean summer 7dAM in July through August, we see a gradual warming of temperatures as we move from the upper parts of Mt. Scott Creek down to the outlet into the Willamette River.

- Average 7dAM at Site 1 = 24.6 °C
- Average 7dAM at Site 2 = 21.9 °C
- Average 7dAM at Site 31 = 21.7 °C
- Average 7dAM at Site 7 = 20.2 °C
- Average 7dAM at Site 12 = 20.8 °C
- Average 7dAM at Site 15 = 22.1 °C
- Average 7dAM at Site 16 = 18.7 °C

As mentioned previously, we saw the same increase in temperatures between Site 16 and Site 15 through the Sunnyside corridor that we saw in 2022, with a 3.4 °C increase in average 7dAM in 2023. Unfortunately, the loggers installed between those two points were either stolen or the logger data was unretrievable. This warming trend should be looked at closer in 2024, with more loggers installed between these points.

We also saw a 1.5 °C increase in temperature between Site 7 and Site 31. This is a relatively short stretch of creek that runs through an industrial park with lots of impervious concrete adjacent to the creek.

Figure 26 - 7dAM for loggers included in Kellogg-Mt. Scott longitudinal study.



There was a hail storm event on June 18, 2023 and the graph of 7dAM reflects the sudden drop in water temperature resulting from that weather.

Unfortunately, most sites exceed DEQ's 18 °C temperature standard for rearing salmonids during the summer months. For this reason, protection of cold-water inputs into this watershed such as Kellogg Creek and Dean Creek is even more important. We also see that when we removed the probes in October all the sites were still over 15 °C. This is notable considering the temperature standard for spawning fish is 13 °C. Coho typically spawn in November in colder snowmelt dominated systems. However, coho will spawn earlier in warmer tributaries since water temperatures impact maturation to spawning (Todd Alsbury, personal communication). Therefore, in areas with potential spawning gravels, a year-round temperature study is recommended. These areas have been identified in the Council's Rapid Bio-Assessment conducted in 2020.

Results: Longitudinal study of Kellogg Creek upstream of confluence

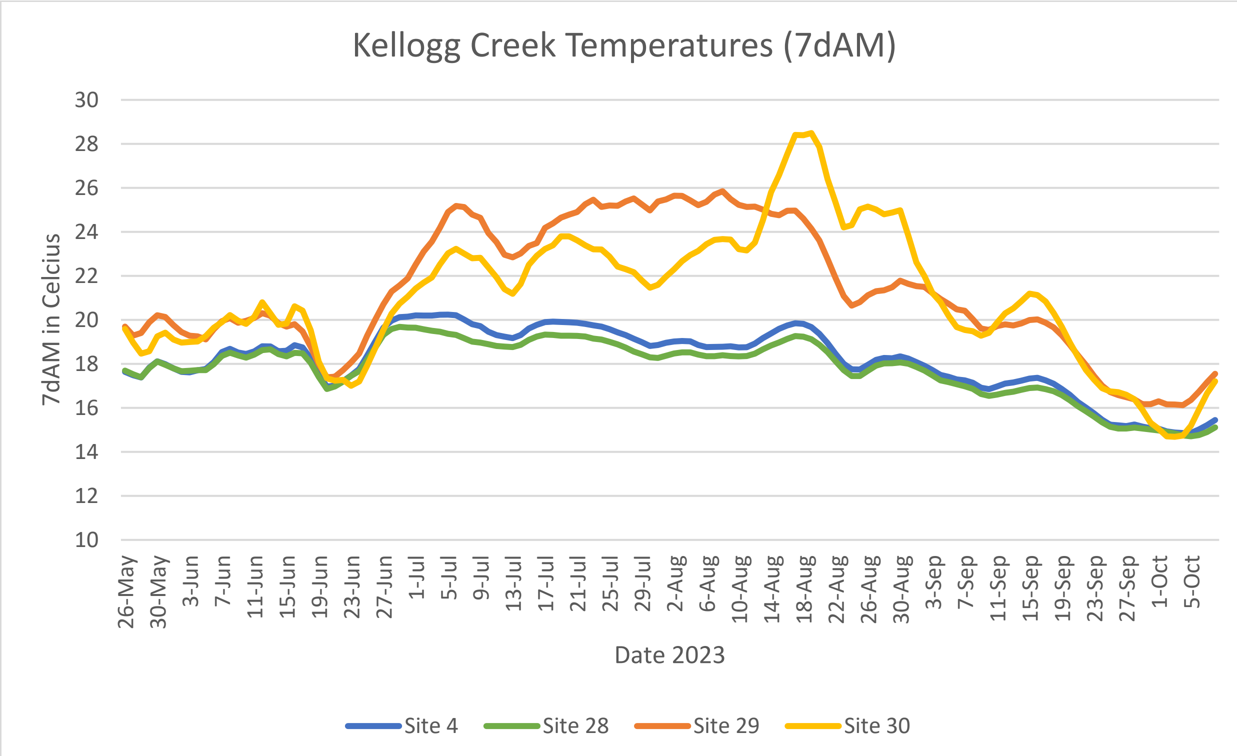
Last year's temperature study (NCWC, 2023) showed some cold water coming from Kellogg Creek at its confluence with Mt. Scott Creek. This year, temperatures in Kellogg Creek were investigated further to look at the temperature profile of Kellogg upstream of the confluence with Mt. Scott Creek. Four temperature loggers were deployed along its length:

- Site 4 – Kellogg Creek above confluence (private property)
- Site 28 – Kellogg Creek at SE Rusk Road
- Site 29 – Kellogg Creek at SE Clackamas Road
- Site 30 – Kellogg Creek at SE Webster Road

Figure 27 - Location of Kellogg Creek loggers used for longitudinal study (shown in yellow).

The cooler water seen coming from Kellogg Creek in 2022, was evident this year at both Site 4 and 28. These two sites are located downstream of Parmenter Wetland, a beaver wetland that appears to be fed by Lovawalla Spring. Parmenter Wetland also has good connectivity to the floodplain, allowing for floodplain storage in the wet season and increased cool water availability in the summer. Further study should look at Parmenter Wetland to confirm that it is the source of cool water that we see between Site 28 and 29. The wetland would be a good candidate for imagery using the infrared drone.

Figure 28 - 7dAM for loggers included in Kellogg Creek longitudinal study.



Results: Longitudinal Study of Rinearson Creek

Temperature loggers were installed in Rinearson Creek in three locations. Site 41 was a new monitoring location in the pond located at the Rinearson mitigation site. Site 26 was located on the west side of River Road and Site 27 was located upstream adjacent to Olsen Wetlands (see Figure 29).

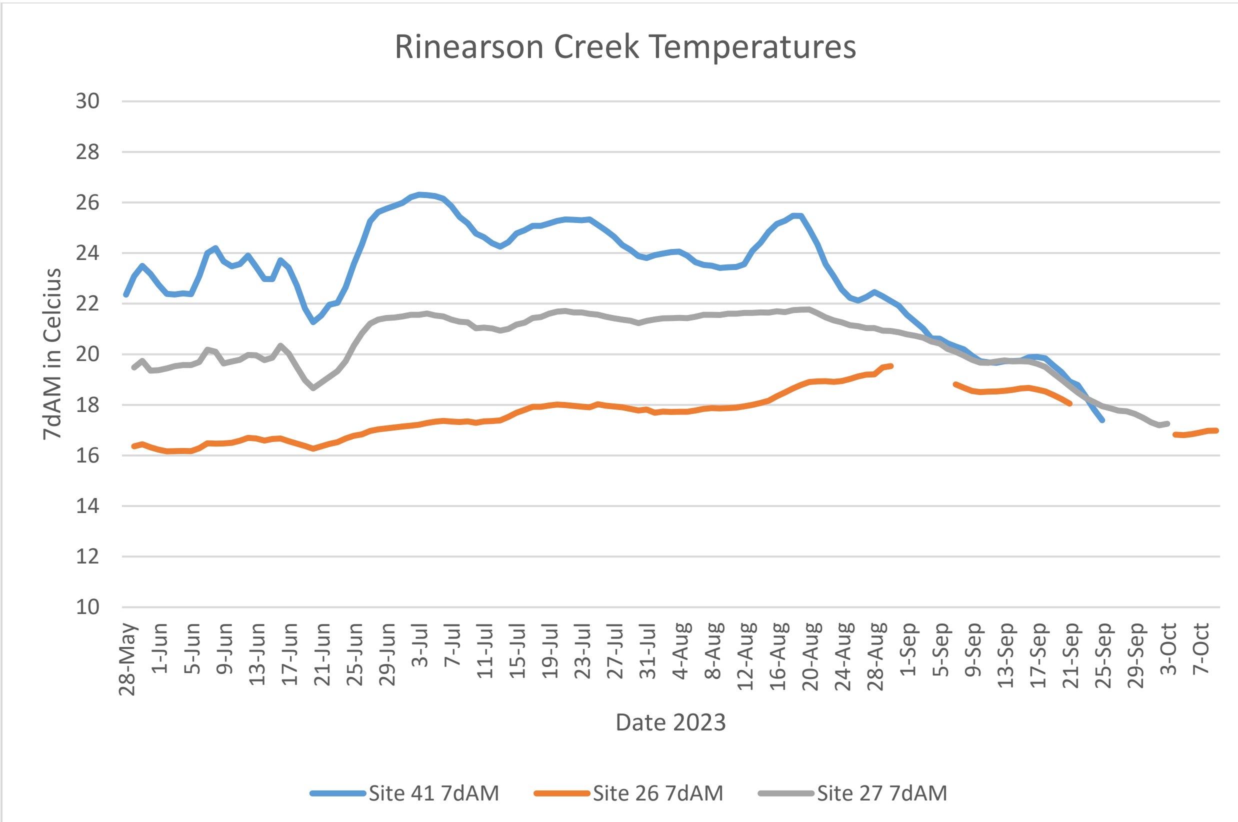
Figure 29 - Location of Rinearson Creek temperature loggers.

In 2022 we saw a significant temperature increase as water flowed from Site 27 to Site 26 (NCWC, 2023). We did not see that heating through the McLoughlin corridor this year, and in fact the average summer 7dAM (July-August) decreased 3.4 °C between these sites. This shows the importance of collecting multiple years of data over successive years.

- Average 7dAM at Site 41 (July – August) = 24.4 °C
- Average 7dAM at Site 26 (July – August) = 18.0 °C
- Average 7dAM at Site 27 (July – August) = 21.4 °C

We also saw significant warming between Site 26 and Site 41, with an increase of average summer 7dAM (July-August) of 6.4 °C. This increase in temperature is probably due to the large beaver pond at this mitigation site. This result is also consistent with what was found in the Rinearson Natural Area Restoration Year 5 (2023) Monitoring Draft Report (Waterways Consulting, Inc, 2023). That report showed that the pond temperatures increased significantly over those recorded just upstream in the emergent marsh. This site may also be a good candidate for imagery collection utilizing the infrared drone.

Figure 30 - 7dAM temperatures in Rinearson Creek.



Results: Longitudinal study of Boardman Creek

Five temperature loggers were installed in Boardman Creek, one of which (Site 24) we were unable to retrieve due to the creation of a large beaver pond.

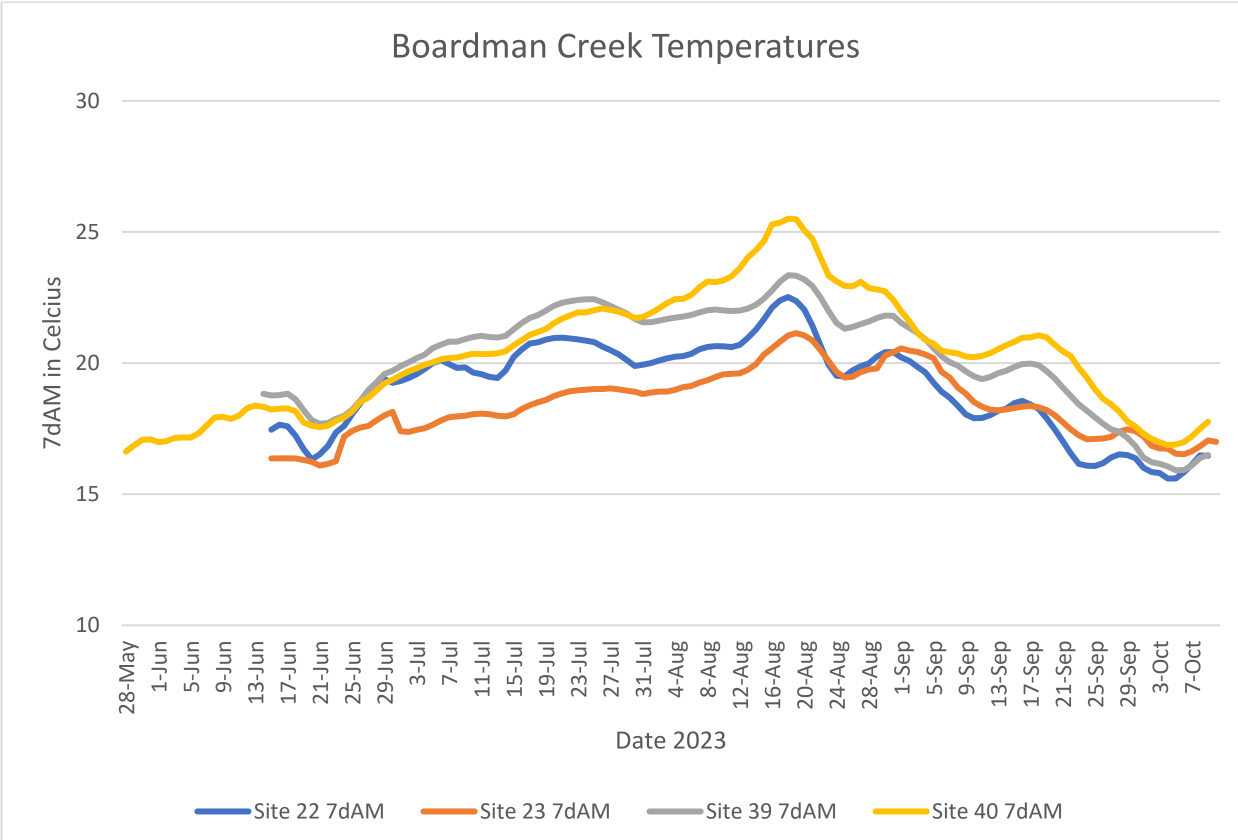
- Site 22 – confluence of Boardman Creek with the Willamette River
- Site 23 – North Fork of Boardman Creek
- Site 24 – Boardman Creek at Stringfield Park (unretrievable)
- Site 39 – Boardman Creek at Roethe Road
- Site 40 – Boardman Creek at Boardman Avenue

Figure 31 - Location of Boardman Creek temperature loggers.

Similar to last year's finding, we see that the coolest water in this watershed was recorded in the North Fork of Boardman Creek (NCWC, 2023).

- Average 7dAM at Site 22 (July -August) = 20.4 °C
- Average 7dAM at Site 23 (July -August) = 19.1°C
- Average 7dAM at Site 39 (July -August) = 21.7 °C
- Average 7dAM at Site 40 (July -August) = 22.2 °C

Figure 32 - 7dAM temperatures in Boardman Creek.



Conclusions and Recommendations

Findings

There are several key findings that we can surmise from this year's temperature monitoring data.

1. *Several Willamette River confluences are potential cold water refugia*
   Boardman Creek was identified as CWR. Both Kellogg Creek and River Forest Creek were warmer than the Lower Willamette River. However, loggers placed above Kellogg and River Forest Lakes showed that those impoundments significantly increased water temperatures. If Kellogg Dam and its associated impoundment could be removed then the mouth of Kellogg Creek would function as CWR habitat. And if River Forest Lake could be hydraulically disconnected from River Forest Creek, that confluence could also function as CWR habitat. Rinearson Creek however does not seem to be functioning as CWR because of the warm water in the beaver pond.

2. *Kellogg Creek, Dean Creek, the North Fork of Boardman Creek, and Minthorn Springs provide cold water*
   We were able to identify several cold-water sources in the North Clackamas watersheds. The water flowing from Dean Creek and Kellogg Creek upstream of its confluence with Mt. Scott Creek was significantly cooler than Mt. Scott Creek. Phillips Creek was also slightly cooler than Mt. Scott Creek. The upper reaches of Mt. Scott also appears to be quite cool; however, our logger at that location

stopped working early in the monitoring season which will require another year of monitoring to confirm this finding. The coldest water found was at Minthorn Springs, however, this water warmed significantly to become the warmest water studied as it travelled through Minthorn Springs Wetland. In Boardman Creek, the temperatures in the North Fork of Boardman Creek were significantly cooler and may function as a thermal refuge in the summer.

3. *Water heated up through the Sunnyside corridor of Mt. Scott Creek, and through water impoundments.*
   There were several areas where we recorded significant increases in water temperatures. Wide shallow impoundments of water allowed water to heat up, including Kellogg Lake, Minthorn Springs Wetland, River Forest Lake, the pond in Rinearson Creek Natural Area, and the pond downstream of the diversion structure in 3-Creek Natural Area. We also saw increases in water temperatures along major urban arteries such as McLoughlin Boulevard and along Sunnyside Road.

4. *The south fork of Kellogg Creek seems to be significantly cooler due to the presence of springs and beaver wetlands at Parmenter Ponds.*
   Parmenter Ponds seem to have a significant cooling effect on the south fork of Kellogg Creek.

Implications for Restoration, Protection, and Management

The Council is utilizing these results to prioritize their restoration, protection, and management efforts in the watersheds in our service area.

1. *Fix heat-loading effects at impoundments*
   Water temperatures increased significantly through water impoundments. Potential treatments vary at each site:
   - When Kellogg Dam is removed, the associated impoundment will be dewatered and the channel will be restored to a sinuous flowing creek.
   - River Forest Lake could potentially be disconnected hydraulically from River Forest Creek, while maintaining the lake for its surrounding residents. Further study should be conducted to determine the feasibility of accomplishing this.
   - Minthorn Springs Wetland heats up considerably in the summer and restoration of that wetland should focus on controlling summer temperatures.
   - As Clackamas WES plans restoration of their 3-Creeks property, consideration should be given to the pool downstream of the water diversion structure to determine how best to mitigate the temperature impacts at that site.
   - The pond in the Rinearson Natural Area was maintained in the mitigation project at the request of adjacent landowners who wanted to be able to see the open water. However, the heat loading that occurs in this pond during the summer is problematic. Consideration should be given to restoring this area to a beaver-managed wetland complex that would allow the creek to access the floodplain.

2. *Target cold water areas for protection and fish access*
   The cold-water areas (Boardman/Willamette Confluence, Dean Creek, Upper Kellogg Creek below Parmenter Ponds, North Fork Boardman Creek) should be prioritized for protection and fish access. These areas will provide thermal refuge for fish in the summer, and the Council will focus on removing any barriers to fish accessing these reaches, especially during summer low flows. There are two large passage barriers upstream of the Boardman Creek confluence at Walta Vista and River Roads that currently block passage of anadromous fish past that point.

3. *Identify solutions for reducing heat loading through urbanized corridors with large heat island effects*
   Significant temperature increases occur where streams pass through industrialized and urbanized corridor, such as the upper reaches of Mt. Scott Creek down to Mt. Talbert Nature Park. Projects should be explored that reduce the heating effect such as reducing impervious surface area, improving stormwater inputs, or preventing point-source inputs of warm water from businesses.

Further Study

As with any research project, this study has generated several more questions that need answering. Future monitoring years should study the following in more depth:

- Repeat temperature monitoring in the upper reaches of Mt. Scott Creek to verify potential cold-water sources and determine why it heats up so much as water flows down to Mt. Talbert.
- Continue long-term trend monitoring to track changes in watershed temperature impacts from climate change, development, and restoration actions.
- Compare the results of this study with the Council's fish passage barrier and eDNA studies to better understand fish utilization.
- Conduct a year-round study of temperatures in areas that have potential spawning habitat in the Kellogg Creek watershed.
- Utilize drone technology mounted with an infrared camera to look at temperature dynamics such as point-sources for heating and cooling, and the management of these impacts in restoration sites.

Despite the association between warm summer water temperatures and reduced salmonid survivorship, there is often little consistent long-term temperature data collected year after year in smaller streams. The Council plans on continuing our temperature monitoring program annually. Funding for repeated annual monitoring programs can be difficult to secure, and it is our hope that granting agencies recognize the importance of utilizing empirical data to inform our protection and restoration efforts. We currently are funded to complete five years of temperature monitoring.

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