Quality Assurance Project Plan

Evaluation of Cool Water Areas on the Lower Yakima River for Thermal Refuge Enhancement Design

Office of Columbia River Contract No.
WRYBIP-2123-BentCD-00030

DEPARTMENT OF ECOLOGY
State of Washington

Benton Conservation District

Publication Information

Each study, funded in whole or in part with Ecology funding, must have an approved Quality Assurance Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. Data for this project are available in the National Water Information System (NWIS) database and linked to Ecology Information Management (EIM) system with Study ID: WRYBIPBentCD00030. This QAPP is valid through May 31, 2028.

This Quality Assurance Project plan is available via Ecology's publications database and upon request. The Ecology publication number for this Quality Assurance Project Plan is 23-12-010.
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- Confluence of Spring and Snipes Creeks in early November – fall Chinook salmon returning to spawn. PHOTO BY MATTHEW BISCHOF, Washington State Department of Agriculture[1]

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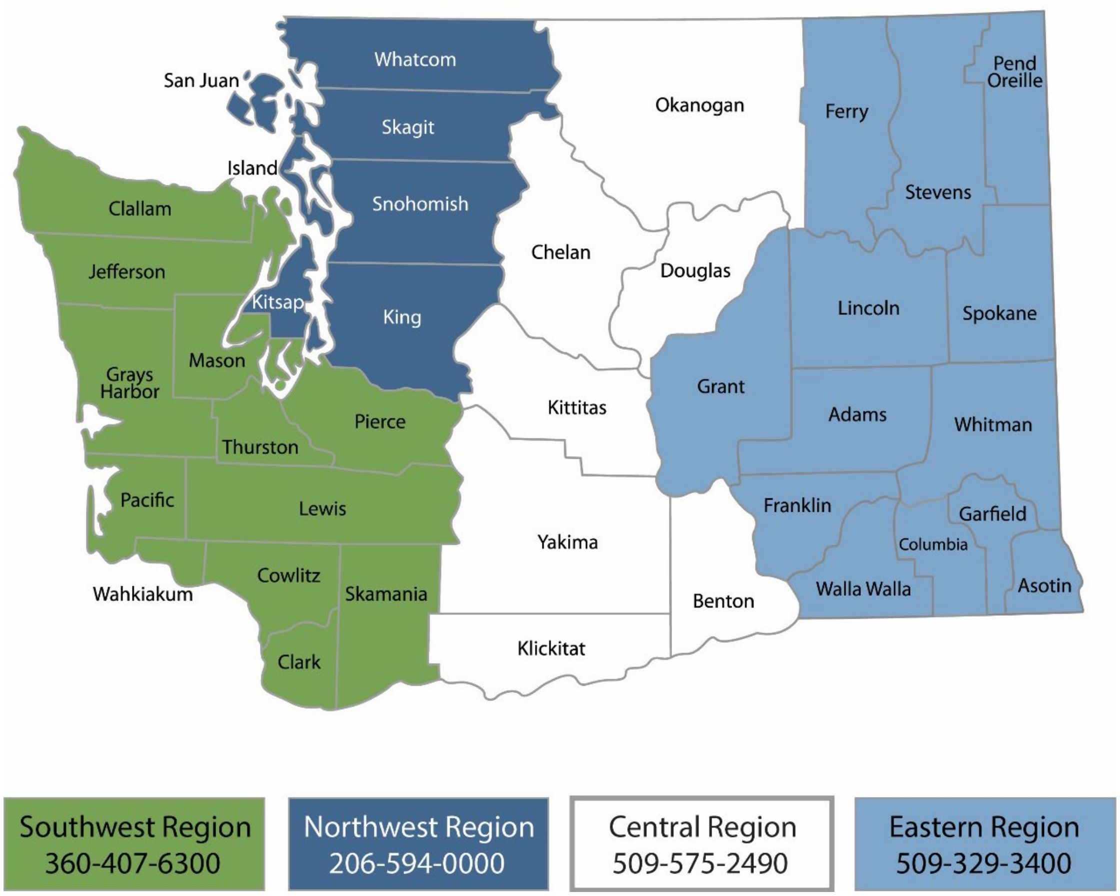

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Published June 2023

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2.0 Abstract

Average daily river temperatures on the lower Yakima River (lower Yakima) exceed the 21 - 23 degree centigrade threshold for salmon survivability during baseflow conditions. Locations along the lower river with incoming seeps, springs, and creeks fed by groundwater provide opportunity to create metabolic rest stops known as cold water refuge (CWR) for thermally stressed migrating salmon. These habitat areas are becoming more widely known as critical habitat to help salmon complete their life cycle and navigate a river system that is otherwise inhospitable during the late spring through early fall. The monitoring conducted under this Quality Assurance Project Plan (QAPP) will help river managers develop projects that enhance and improve existing locations of cool water refuge. Specifically, this project will support the development of 1-2 cold water refuge projects on the lower Yakima through the collection of fish presence data, water temperature, specific conductivity and flow data at four identified cool water areas. The collected temperature data will also provide baseline data for monitoring effectiveness of future implemented cool water enhancement projects pre-implementation. To help build momentum for future projects, we will also investigate multiple cool water habitats that were identified during a 2020 Thermal Infrared Flight of the lower Yakima River to determine suitability for future monitoring and project development. This will build a repository of future sites to develop for enhancement. Continued development of CWR habitat will become increasingly important as the Yakima River basin is identified as highly susceptible for climate change impacts. This project will help mitigate future warming impacts and current in-stream river temperature limitations by developing multiple CWR locations across Yakima and Benton Counties.

3.0 Background

3.1 Introduction and problem statement

The Benton Conservation District in Central Washington State, in cooperation with Mid-Columbia Fisheries Enhacement Group and Yakama Nation Fisheries, is studying and developing cool water refuge enhancement projects on the lower Yakima River (lower Yakima). Years of past research has indicated significant micro-scale temperature variability on the lower river during baseflow conditions (summertime) with cool water patches that may have important implications for migratory fish species (Gendaszek and others, 2021). Areas of cool water habitat, known as cold water refuge (CWR), are thought to provide metabolic rest stops for migrating adult salmon during times when ambient river temperatures are otherwise too warm. Areas of summertime cold water influxes on the lower Yakima are likely to be largely groundwater dominated. Because of the large groundwater influence, the temperature range within these areas of temperature patchiness have less variability between seasons than that of the mainstem Yakima River. As such, they typically become warmer during the winter and cooler during the summer.

Enhancing areas with higher inputs of groundwater influence may provide rearing and growth opportunities for out-migrating juveniles during the wintertime months in addition to cool water refuge for summer adult migrants. Given the critical importance of these sites, this project will monitor temperature and conductivity (as a metric for groundwater input) in multiple locations on the lower Yakima with known cool water inputs. Additionally, flow within each cool water anomaly will be evaluated in the spring, summer and fall. All measurements will be collected during peak salmon migration season when river temperatures are at the threshold temperatures for survival (May – September). Fish presence and absence data will be gathered for the selected monitoring sites through snorkeling surveys and riparian vegetation near the cool water influence will be documented. These data will support selection of 1-2 suitable locations for concept level design development for cool water refuge enhancement projects. Lastly, we will build a repository of future cool water refuge locations by ground truthing possible cool water locations that were identified during a 2020 Thermal Infrared Imaging Flight of the lower Yakima River. These sites will be noted for their presence or absence of cool water using a thermistor and a GPS unit. Final cool water locations will be mapped in ArcGIS for use by other river mangers in the basin for project development.

3.1.1 History of cool water refuge on the lower Yakima

The lower Yakima is a migration corridor for multiple salmon species and historically provided important habitat for spawning fall chinook. During the summer months, the Yakima River in Benton County is the warmest stretch of river with most of its lower 50 river miles inhospitable for adult salmon migration at baseflow (summer) conditions. Specifically, in-stream water temperatures often exceed 21-23°C during baseflow conditions which is limiting for adult migration of sockeye, summer Chinook, and Pacific lamprey. Rapidly warming spring/summer waters can also limit success of late season juvenile out-migration. These challenges are compounded by the fact that warmer water temperatures provide more favorable conditions for invasive predator populations over native salmon stocks and increases their feeding rate on native juvenile species.

Water temperature is critical for fish species as it governs body temperature and metabolism. Water temperature also provides cues for migration timing and controls the amount of available dissolved oxygen in the water for species use. Salmon have a temperature threshold above which conditions negatively impact survival. Excessively warm water temperatures increase salmon's physiological stress, pre-spawn mortality, susceptibility to disease and likelihood of straying, while also decreasing their swimming performance (Carter 2005). Lower Yakima temperatures rapidly warm in late spring and early summer (late May – June) and then cool with the onset of fall between late August and early September (Appel and others 2011). The seasonal timing of river warming coincides with critical migration windows for several Yakima River salmon stocks and can impair migration and spawning success.
In 2008 and 2009, the Benton Conservation District (BCD), identified and documented several locations of "cooler" water on the Yakima River below Prosser Dam. These locations ranged from 0.5°C to 2.0°C cooler than the surrounding mainstem Yakima River water temperatures (Appel and others, 2011). In 2011, Vaccaro found that incoming shallow groundwater and

subsurface flows (likely enhanced or driven by applied irrigation water and overland flows) buffered the daily rise in summer water temperatures in the Prosser reach and may contribute to the complexities of off channel and tributary habitats.

Fish are able to detect water temperature differences to within <0.1 °C (Torgensen 2012). Fish respond to these temperature changes by moving laterally and vertically to areas that are cooler and more favorable in an activity called behavioral thermoregulation. Torgersen and others (2012) summarized the current literature on thermal refuge utilization by fish and discuss the hierarchical river structures that contribute to thermal refuge in a basin. It is noted that on a basin and sub-basin level, cold water refuges are driven by elevation, topography, geology, channel slope, and interactions between the surface and sub-surface hydrology (Torgersen 2012). Utilization of thermal refuge locations by fish is complex. There are oftentimes physiological and biological trade-offs for fish that move to cool water refuges. Although temperatures may be more favorable, the conditions (cover, dissolved oxygen, connectivity) may be less optimal (Torgersen 2012). Species interaction, predation and feeding, all contribute to favorability of a cool water patch. By studying and characterizing potential thermal refuge locations on the lower Yakima, we expect to be able to better-manage, enhance and optimize cool water patches for anadromous species.

While research shows that thermal heterogeneity exists on the lower Yakima (Gendaszek and others, 2021; QSI, 2020, Sheibley and others, 2022), the stability of identified cool water seeps, utilization by migrating and rearing salmonids, and seasonal temperature dynamics still require evaluation and understanding. Additional work to determine the characteristics of a cool water anomaly is critical for supporting management and habitat action decisions to enhance, promote, or utilize these areas for salmon migration and rearing. This grant project will help to fill this data gap by monitoring water quality data and fish utilization in high priority cold water locations. These data will support successful selection of sites to move into project development as enhanced cold water refuges. Building on previously funded grant work, this project will help mitigate future warming impacts and current in-stream river temperature limitations by developing multiple CWR locations across Yakima and Benton Counties. Continued development of CWR habitat will become increasingly important as the Yakima River basin is identified as a highly susceptible basin for climate change impacts. Over the next 30 years it is predicted that the Yakima Basin will undergo an increased likelihood of droughts or floods, changes in peak hydrograph timing and seasonality, and extended summertime warming conditions (Vano and others, 2009). The success of CWR as a mitigation tool for warming mainstem river temperatures will require multiple accessible cold water locations along the 100+ river miles of the lower Yakima to provide “rest stops” for salmonids on their migration journey.

3.2 Study area and surroundings

The lower Yakima River, located in south-central Washington State, flows through two counties: Yakima and Benton (Figure 1). The stretch of river that flows through Yakima County is distinct from that of the lower reaches in Benton County. The stretch of river in Yakima County has an established broad alluvial floodplain with a dynamic river channel and riparian zone. Construction of bridges, dikes, and roads within this stretch, however, have constricted and/or cut off portions of the floodplain (Stanford and others 2002). There are also multiple dams on this stretch of the river used for agricultural water supply. This stretch of river is a mixture of agricultural, conservation and small urban areas and also includes the Yakama Nation Tribal Lands. Significant tributaries entering this stretch of river include Toppenish Creek, Satus Creek, and Sulphur Creek Wasteway.

In Benton County, agriculture is the primary dominant land use, supported by irrigation from the Yakima River and supplemented by wells. Columbia River basalts dominate between Prosser and Benton City, confining the river channel throughout this reach with minimal area for braiding and meander. Alluvial deposits are present between Horn Rapids and West Richland. Alluvial islands formed by Quaternary floods are dispersed throughout this reach and mediate changes in channel morphology. There are no naturally occurring creeks in this reach, but multiple irrigation wasteways drain into the river including Spring/Snipes; Corral/Knox; and Amon (Appel and others, 2011). There are few floodplains and island side-channels on the river in Benton County. The minimal floodplains that exist on the lower river are within West Richland and Richland, WA. The lower Yakima River drains into the Columbia River mainstem at Richland, WA (Gold Star; Figure 1).

The lower Yakima water quality and seasonal flow are predominately influenced by irrigation use for agriculture and growing urban/residential development. The Yakima River is a highly managed system with regulated yearly flow regimes. Water inputs from the area's irrigation enhance subsurface and overland flows to the river. This irrigation derived inflow has largely supplanted the role of the spring flood in creating and maintaining cool water patches. The spring freshet, which has been dramatically reduced in size by river regulation, currently occurs between April and May in the lower Yakima. Low flow contributes to higher water temperatures from June through August (Appel and Others , 2011). Lower Yakima summer temperatures are driven primarily by solar radiation. As such, river temperatures rapidly cool with the onset of fall sometime between late August and early September (Appel and Others 2011). The irrigation season, which draws water from the Yakima River, runs from mid-March to mid-October which coincides with anadromous fish migration timing.

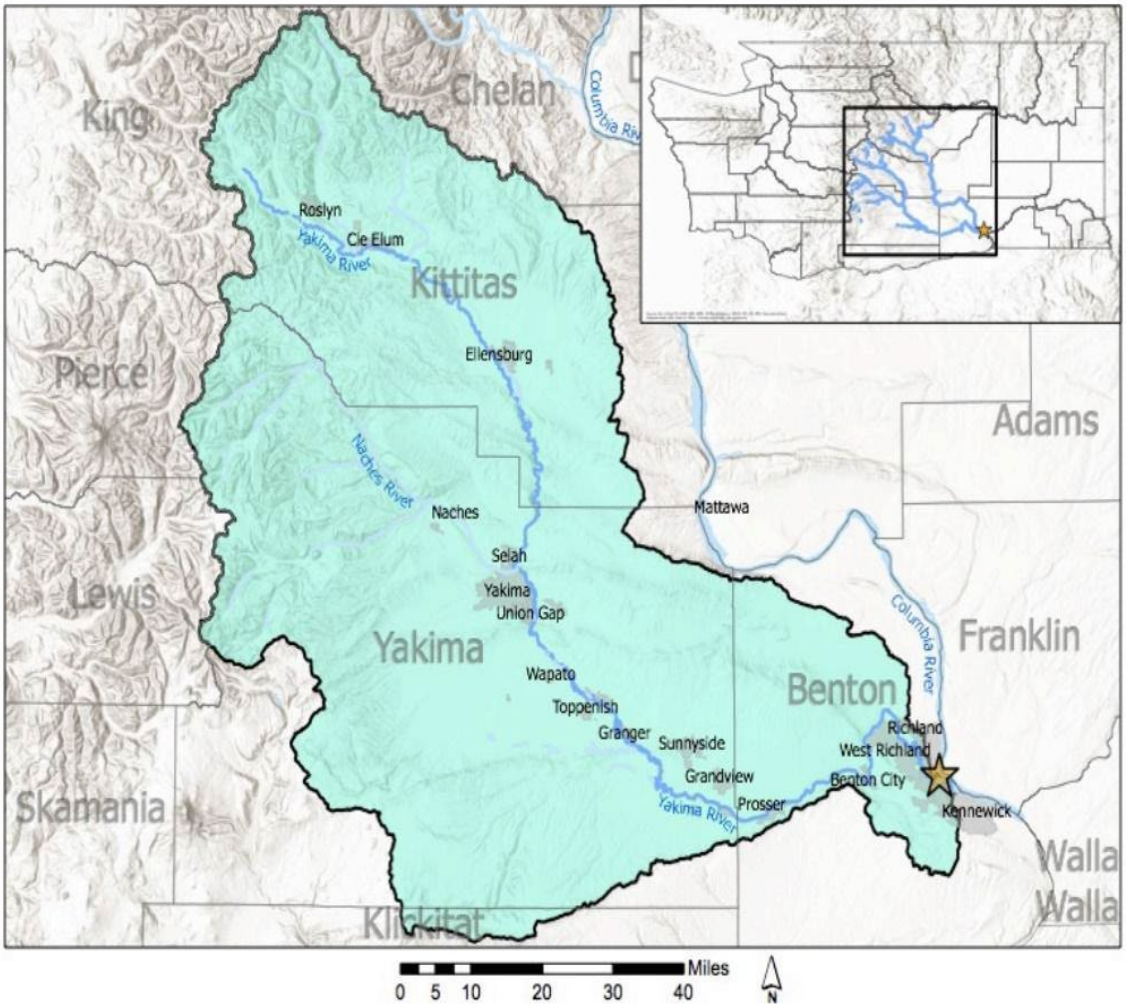

Figure 1. Map of Yakima Basin in Washington State. Study area includes the lower Yakima River from Union Gap to Richland, WA (gold star).

The lower Yakima hosts anadromous runs of Steelhead trout, spring, summer, and fall Chinook salmon, coho salmon, sockeye salmon and Pacific lamprey. Juvenile salmon out-migrate through the lower Yakima to the Columbia River, and adult fish migrate from the Columbia up into the lower Yakima. Historically, the lower Yakima hosted fall Chinook spawning habitat. Abundant water stargrass growth in the lower Yakima has resulted in a shift of fall Chinook spawning to above Prosser Dam into Yakima County. As a result, adult and juveniles must migrate further, decreasing their chances of survival. Thermal refuge enhancement projects provide means for migratory species to survive the inhospitable late spring to early fall conditions that occur as a result of the river's rapid warming.

The data collected from this project will support the development of an additional 1 – 2 new cool water refuge habitat enhancement projects by providing temperature, fish presence, flow, and conductivity data for previously identified high priority sites. These data will be coupled with habitat surveys at the selected locations by Mid-Columbia Fisheries Enhancement Group. Analysis of water quality, flows, fish presence, and site conditions will help elucidate the highest priority sites for future project development.

3.2.1 History of study area

Land use in the lower Yakima valley is predominantly irrigated agriculture that is heavily reliant on the Yakima River for irrigation water supply. For decades, high temperatures and suspended solids, turbidity, DDT, and other pesticides have been documented in the lower Yakima. By the mid-1990s, water quality evaluations by the USGS indicated that some improvements had been made, but beneficial uses were still impaired by sediment and sediment-borne pollutants, like DDT, from irrigation returns (Rinella et al. 1999). As a result, several reaches of the lower Yakima and several of its tributaries did not meet numerous state water quality criteria and federal guidelines.

Water quality issues of concern in the entire Yakima River basin range from fecal coliform bacteria to suspended sediments and turbidity, as well as toxics, pH, nutrients, dissolved oxygen, and temperature. The water quality issues in the basin impact the beneficial uses of the water, potentially making it unsafe for drinking or recreation and threatening the health of aquatic animals and fish living in it.

At this time there are two fish species listed as Threatened under the federal Endangered Species Act: mid-Columbia bull trout and mid-Columbia steelhead. Conley and others (2009) summarized studies in the upper and middle Yakima River that indicated temperature, toxic chemicals, and lack of foraging habitat and refuge from predators were creating obstacles for survival of these species.

To date, the primary water quality improvement projects conducted on the Yakima River are part of the Yakima River Watershed Toxic Reduction Program. These projects have been implemented to decrease the Total maximum daily loads (TMDLs) of toxics, sediment, and DDT. These projects are in various stages of development across the watershed. The primary TMDL projects in the lower Yakima include:

Yakima River: Toxics Reduction Program

- Water quality monitoring of DDT, dieldrin, and other chlorinated pesticides (Johnson et al. 2010).

Lower Yakima River: Suspended Sediment and DDT

- TMDL evaluation report about the amount and sources of several pollutants in the lower Yakima River (Joy and Patterson 1997).

The work related to these TMDL projects can be accessed through the Washington State Department of Ecology Website at:
Toxics Reduction Program: https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Total-Maximum-Daily-Load-process/Directory-of-improvement-projects/Yakima-watershed-toxics-reduction-project

Two cool water refuge enhancement projects are currently in various stages of implementation on the lower Yakima River. A small demonstration pilot project at RM 25, located in Benton County, was constructed in 2019 to connect a degraded side-channel within the floodplain. The project was designed to improve flow, storage capacity and groundwater connectivity. The side-channel provides a source of cooler water to the mainstem Yakima River during baseflow conditions (summer) when the river is otherwise inhospitable for migratory species (Figure 2).

Figure 2. River Mile 25 Pilot Project for Thermal Refuge Enhancement. Photo shows enhanced groundwater channel, installed alcove and mainstem Lower Yakima River.

A second, large scale cool water project is in the final design stages. The RM 2.5 cool water enhancement project will re-route the lower channel of Amon Creek Wasteway, to a new confluence downstream creating a deep, cool water pool off the Yakima River mainstem. The new outlet is in a location on the mainstem Yakima River with deeper bathymetry providing a holding pool with greater depth and cover than the conditions at the existing tributary confluence. Modeling results predict an increased depth of 2.0 meters over existing conditions and a 2000 m^2 cool water refuge holding pool with > 5 degree C cooler water than the mainstem river at peak summer conditions (modeling results are for July 31, 2020; Figure 3).

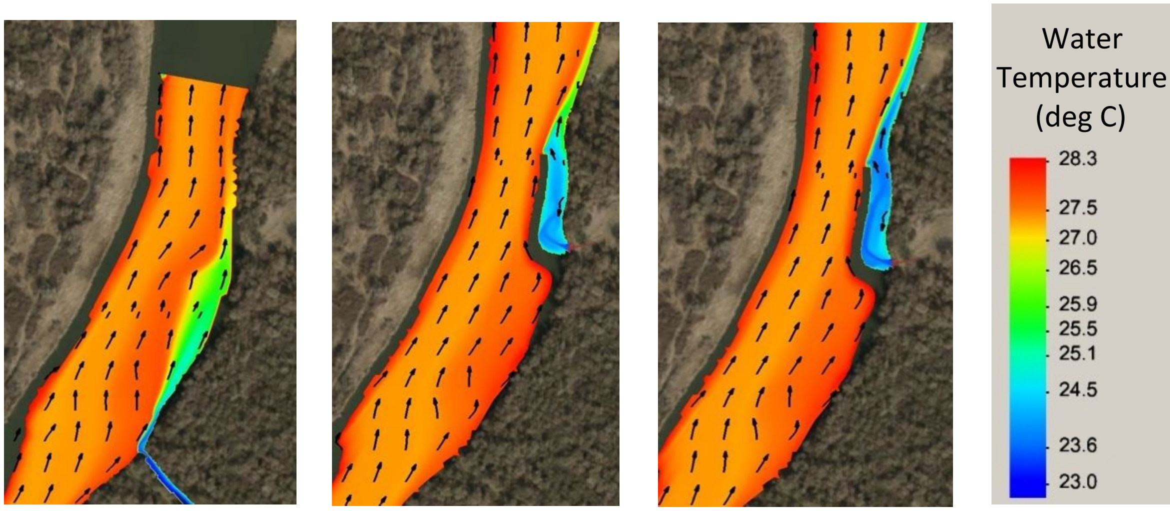

Figure 3. Predicted cool water refuge for the new outlet of Amon Creek on July 31, 2020 left to right: a) Existing Conditions; b) 10 cfs flow conditions; c) 30 cfs flow conditions. Modeling by Northwest Hydraulic Consultants, 2022.

3.2.2 Summary of previous studies and existing data

There is a growing body of literature relating to the water quality and temperature dynamics on the lower Yakima River. Present day concern for the lower Yakima River can be traced back to the 1997 TMDL evaluation report for the lower Yakima (Joy and Patterson, 1997) that noted the poor water quality in the river. Specifically, the report noted the relationship between turbidity, suspended sediment, and DDT. The TMDL work launched significant multi-agency efforts in the basin to improve sediment loadings, and consequently decrease DDT loading the lower Yakima River. This work, while notable, had an unintended consequence of leading to a population explosion of a native aquatic plant known as Water stargrass (*Heteranthera dubia*). Multiple water quality monitoring and research studies began to document the relationships on the lower river between temperature, dissolved oxygen, turbidity, and water stargrass. These studies allowed for installation of longer- term monitoring gages for water quality and temperature. These gages have been operated by both the U.S. Geological Survey and the U.S. Bureau of Reclamation. While temperature is of high concern, there has not been a TMDL drafted for temperature in the lower Yakima River.

BCD, in 2008 and 2009, began what would become a decades long intensive study of lower Yakima River micro-scale temperature dynamics building on work completed by USGS in the early 2000s (Vaccaro 2006). The trajectory of this body of work has led to a deeper understanding of thermal dynamics on the lower Yakima and the delitrious impacts of warm water on migratory species. Results from these studies have resulted in numerous collaborative projects among basin wide river managers (Yakima Delta Causeway Removal, RM 2.5, RM 25, and Crystal Springs Enhancement). Some of the primary contributing studies and existing data for understanding water quality and temperature dynamics on the lower Yakima that are relevant to this QAPP are as follows:

- The Bureau of Reclamation conducted a Forward Looking Infrared (FLIR) flight in 1997 over the lowest 108 miles of the Yakima River to identify cool water inputs and document longitudinal river temperatures (Holroyd 1998). The FLIR imaging provides surficial temperatures, but indicated numerous disconnected or partially connected side-channels in the Wapato Reach floodplain that could be developed and utilized for cool water refuge. It also highlighted the Yakima Delta thermal block caused by the Bateman Island Causeway.
- In 2020, YBIP commissioned an updated FLIR flight of the lower 100 miles of the Yakima River to build on the work completed by the BOR in 1997 and BCD. The work was funded by the Department of Ecology, Office of Columbia River. BCD contracted the work with Quantum Spatial, Inc. and data were collected the last week of July 2020. The thermal imagery indicated several areas of cool water and warm water patchiness along the lower Yakima River. This data set helped guide selection of sites under this QAPP.
- In 2011, BCD summarized two years of lower Yakima River temperature monitoring and habitat assessments in the Assessment of the Lower Yakima River in Benton County, Washington (Appel and others 2011). Expanding on work by Vaccaro and Maloy (2006), BCD conducted thermal profiling of the Kiona Reach at base flows in 2008 and 2009 to identify temperature heterogeneity within the lower river. Appel and others (2011) noted that river summer temperatures were well above 21°C for the 2008 and 2009 summertime floats; however, thermal heterogeneity within the lower reach was identified with "cooler" areas resulting from non-point source seeps, irrigation wasteways, and deeper holes.
- Vaccaro (2011) documented the longitudinal temperature gradient of the Yakima River in 16 reaches covering about 160 river miles. Reaches ranged in length from 5 to 14 miles with a stream gradient range from 0.0002 to 0.0055 ft/ft. Floats were completed in the early 2000s and also included the BCD floats from 2008 and 2009. Vaccaro concluded:

"Thermal gradients ranged from as small as 0.00002 to as large as 0.004°C per mile per minute, and unexpectedly, the smaller gradients were not confined to the upper parts of the basin. Effects of river-aquifer exchanges and surface-water inflows were clearly displayed in the profiles. The thermal regime of the river system impacts the overall biological community in the river system including the different life stages and life history patterns of salmonids. It also leads to a logical progression of the longitudinal gradient of fish assemblages, and invertebrate and algal community structure. The longitudinal gradient, overlaid with the distribution of temperature patches, compose a continuum from the headwaters to the mouth, along which habitat, and thus, species, are arranged (2011)."

- In 2018, BCD collected over 80 miles of thermal profile data in the lower Yakima River from Wapato, WA to Richland, WA during baseflow conditions. This work was part of an Ecology YBIP grant (WRYBIP-1921-BentCD-0004) with results available in Gendaszek and others, 2021. With constantly changing irrigation practices, water management, and water saving practices in the Yakima Basin, these floats were completed to evaluate stability of thermal dynamics between 2008 and 2018. These data identified stable cool water locations on the lower Yakima river at locations over the past decade. It also provided the first comprehensive float conducted in one season, from Union Gap to the mouth. The results of this work are available in Gendaszek and others, 2021.
    - Under this same project agreement (WRYBIP-1921-BentCD-0004), 7 cool water locations were further monitored for two years to examine the spatial and temporal variability of cool water sites. This work was completed in collaboration with USGS. Six sites were located in the Kiona Reach (below Prosser) and 1 site was in the Wapato Reach (above Prosser). The project highlighted the stability of cool water refuge sources, and that the dynamics that cool water sources had thermal warming benefit in the summer and thermal cooling in the summer as compared to the mainstem. This work led to the development of the RM 2.5 project. Spring and Snipes Creek were monitored as part of this study, leading to the further examination of this site, under this QAPP. The full results of this monitoring work is available in Sheibley and Appel, 2021.
- BCD in collaboration with Yakama Nation Fisheries and Mid-Columbia Fisheries deployed continuous temperature loggers at five additional locations in the Mabton to Union Gap reach of the lower Yakima River (WRYBIP-19-21-BentCD-00011). Loggers were deployed from 2020 – 2021. One of the five locations has already been moved into project development by Mid-Columbia Fisheries for riparian enhancement. Sulphur Creek and the RM 92/93 complex which will be further investigated in this study, were initially identified as part of this work. Temperature dynamics indicated potential for cool water refuge at these sites, however additional site characteristics in connection with temperature data are needed to determine feasibility for further cool water enhancement.
- 2018 – 2021: BCD and USGS collected temperature data at three locations on the lower Yakima within Benton County (Prosser, Benton City, and Richland) under a Water Quality Combined Funding grant through Department of Ecology (WQC-2018-BentCD-00065). These temperature data were part of a larger study to investigate water quality parameters, flow and water stargrass dynamics on the Yakima River located within Benton County and provided reach scale temperature data. Data are stored in National Water Information System (NWIS) (https://waterdata.usgs.gov/wa/nwis/rt). These stations continue to be operational seasonally (March – October) under new funding agreements:
    - WRYBIP-BentCD-00033 and WRYBIP-BentCD-00018 currently fund the USGS telemetered data in real-time between March – October at four locations on the

lower Yakima River. These locations are: Van Giesen (West Richland), Kiona (Benton City), Emerald and Union Gap. The Prosser station funded under WQC-2018-BentCD-00065 was picked up for operation through a collaboration between the Pacific Northwest National Laboratory and USGS outside of YBIP funding. Data for the Prosser site are also telemetered in real-time to NWIS. All data are available at: https://waterdata.usgs.gov/wa/nwis/rt.

    - Specific conductance on the lower Yakima has been monitored by USGS since 2018 as part of the water stargrass dynamic grant and subsequent grant agreements. Values at Prosser, Benton City and West Richland were below 350 uS/cm for 2018-2021 and mean values were similar across the sites (Sheibley and others, 2022). Increased flows in the mainstem dilute specific conductance. Mainstem Yakima River values ranged between 100 uS/cm and 320 uS/cm across the seasons and years of monitoring.

- Mid-Columbia Fisheries in coordination with BCD, installed a thermal refuge demonstration project at RM 25 on the lower Yakima River in 2019. The project included installation of two check gates in a relic oxbow channel on the Yakima River floodplain for cold water storage, and an alcove with large woody debris at the confluence of the floodplain channel and mainstem river for enhanced thermal refuge. Temperature data have been collected at this site 2016 – 2018; and from 2019 - present in the side-channel and mainstem Yakima River. All data are available in EIM.
- BCD monitored 7 locations within Prosser Canyon reach of the Yakima River (River Miles 52 – 57) for temperature dynamics in July through September of 2022 and data will be monitored again in 2023. These temperature locations provide information on mainstem warming prior to the Prosser Pool and reservoir and inform difference in mainstem temperatures for the river above and below Prosser. These data are available in EIM and were collected as part of grant WRYBIP-2123-BentCD-00033.

3.2.3 Parameters of interest and potential sources

The main parameter of interest for this monitoring study is water temperature. Flow, specific conductivity, and fish presence will also be monitored to help evaluate the utilization of the site by fish and current conditions at each potential cool water site. Site vegetation will also be examined to document current riparian species.

The source of high extreme temperatures in the lower Yakima (over 21°C) is the large expanse of slow moving, shallow water, exposed to full sunlight (Snyder and Stanford, 2001). Water stargrass dominance exasperates the warming in the lower river. Shading and cover will not greatly impact the mainstem river temperatures, however, improved plantings that provide shade to the cool water inputs may help protect these micro-habitat areas.

3.2.4 Regulatory criteria or standards

Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC (Ecology 2011) established beneficial uses of waters and incorporated specific numeric and narrative criteria for parameters such as water temperature, DO, pH, and turbidity. The criteria define the level of protection necessary to support the beneficial uses. Washington Administrative Code (WAC) 173-201A-600 and WAC 173-201A 602 list the use designations for specific areas. The state has not yet established regulatory criteria for river nutrients.

For the lower Yakima, the designated uses of the waters include the following:

- Primary Contact Recreation.
- Water Supply Uses (Domestic Water, Industrial Water, Agricultural Water, Stock Water).
- Wildlife Habitat.
- Commerce/Navigation.
- Boating.
- Aesthetics.
- Aquatic Life.

Chapter 173-201A WAC defines the aquatic life for the lower Yakima as Salmonid Spawning, Rearing, and Migration. The key-identifying characteristic of this use is salmon or trout spawning and emergence that only occur outside of the summer season (September 16 - June 14). Other common characteristic aquatic life uses for waters in this category include rearing and migration by salmonids.
Table 1 summarizes the criteria that apply for temperature in the lower Yakima, which we further discuss below. There is no state criteria for specific conductivity or flow.

Table 1. Water quality criteria for the study area.

	Dates	Temperature[a]
Yakima River from Cle Elum River to the mouth	Annual	21°C 1-day maximum. No human-caused increase of more than 0.3 °C if natural conditions exceed criteria.

[a] These criteria are not currently in effect for Clean Water Act purposes as a result of EPA's 2021 reconsideration and disapproval of Washington’s natural conditions criteria in the water quality standards. These criteria remain in effect for other statewide water quality actions. Ecology has initiated rulemaking to revise the natural condition provisions that will respond to EPA’s concern and will again meet Clean Water Act approval. For more information, please visit

Ecology's website (https://ecology.wa.gov/Regulations-Permits/Laws-rules-rulemaking/Rulemaking/WAC-173-201A-Natural-Conditions).

3.2.4.1 Temperature Criteria

Chapter 173-201A WAC defines the aquatic life for the lower Yakima as Salmonid Spawning, Temperature levels fluctuate over the day and night in response to changes in climatic conditions and river flows. Since the health of aquatic species is tied predominantly to the pattern of maximum temperatures, most of Washington temperature criteria are expressed as the highest 7-day average of the daily maximum temperatures (7-DADMax) occurring in a waterbody.

However, WAC 173-201A-602 (Ecology 2011) provides the following special criteria for the Yakima River from mouth to Cle Elum River (river mile 186).
Temperature shall not exceed a 1-DMax of 21.0°C due to human activities. When natural conditions exceed a 1-Dmax of 21.0°C, no temperature increase will be allowed which will raise the receiving temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t = 34/(T+9).

3.3 Water quality impairment studies

Not Applicable

3.4 Effectiveness monitoring studies

Not Applicable

4.0 Project Description

In order to better understand the temporal (time), spatial extent, and stability of identified cool water refuge locations, BCD in partnership with Mid-Columbia Fisheries, and the Yakama Nation (YN) will continue to monitor four cool water inputs on the lower Yakima River. Through previous project development at RM 25 and RM 2.5, we have a better understanding of the metrics that help guide evaluation for project enhancement. Sites must have a) persistent cool water source, b) sufficient flow to support the site, and c) suitable groundwater connectivity for cooling. As such, the combination of temperature, flow, and specific conductivity will be evaluated along with site features. These site features include vegetation, fish monitoring to evaluate current assemblages and usage, and project feasibility (site access and landowner willingness). These assessments help identify sites with the highest potential for success in the next stage of project development. Future site enhancement options may include adding off-season watering, shading, pool scour, and physical barriers to prevent mixing between the thalweg and cool water. The design goals would be to increase cool water influences and holding capacity for salmonids.

The monitoring sites covered under this QAPP were identified using the 2018 thermal profile data results collected under a separately funded YBIP Grant Project (Gendaszek and others 2020), coupled with Forward Looking Infrared (FLIR) flights (Holroyd 1998; QSI 2020), and temperature data collected under previous grant work (WRYBIP-BentCD-00011; WRYBIP-BentCD-0004). Multiple temperature loggers will be deployed at each of the four sites in late spring, so that the spatial variability of the cool water inputs can be further investigated. Temperature data will be collected and evaluated every 3-5 weeks in order to minimize data interruptions from sensor malfunction and to identify and replace lost or damaged equipment. Alongside temperature measurements, synoptic flow and specific conductivity will be monitored to better evaluate water conditions for migrating salmonids. Riparian vegetation structure will be assessed at each site following Ecology's Watershed Health Monitoring (WHM) Program guidelines where the types of vegetation within each layer (the canopy, understory, and groundcover) are qualified. This will provide an assessment of shade potential and opportunities for improvements at the site. Snorkel surveys will be performed to directly detect fish presence and provide information about the usage of these sites by both anadromous and predatory fish species.

Temperature sensors will be deployed after the spring freshet in May and maintained during baseflow conditions through September. Monitoring will take place at the following locations: The Sulphur Creek confluence at River Mile 61, Spring and Snipes Creek Confluence at River Mile 42, the floodplain complex at River Miles 92-93 and the side-channel at River Mile 95 (Figure 4). Site specific location details are provided in Section 7. The data collection effort under this QAPP will provide understanding of the dynamic nature of thermal water gradients at these locations and provide the data necessary for successful concept level designs to enhance habitat.

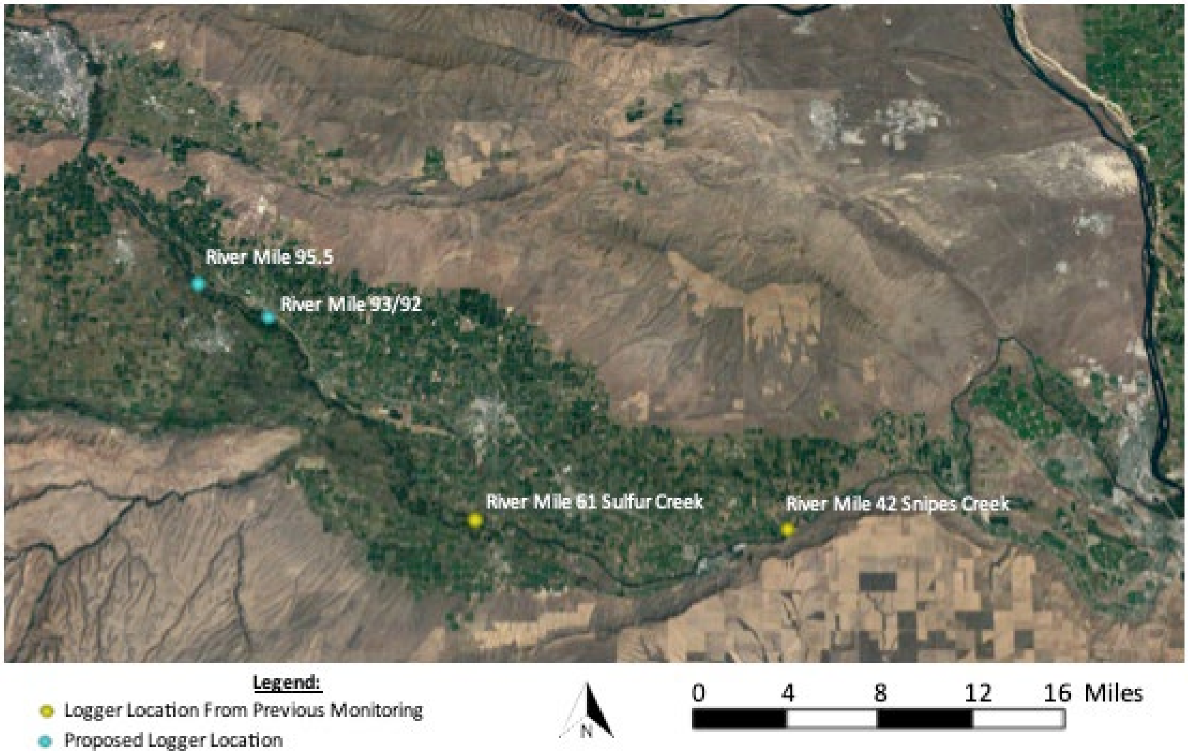

Figure 4. Map showing boundary of project study area. The 4 cool water refuge locations are between RM 42 and RM 93 on the lower Yakima River.

Snorkel surveys are set to be performed on three consecutive Wednesday and Thursday evenings during a three week period during each of the months of June, August, October, and February.

Lastly, this project will develop a repository of additional sites for future cool water refuge development. Several cool locations were identified in the 2020 TIR Flight (QSI, 2020) that had not been previously monitored or studied. This project will groundtruth 8 - 12 of the identified 2020 TIR sites. BCD staff will seek landowner permission, visit the identified sites and check for cool water inputs with a handheld thermistor. Any sites that have a confirmed cool water location suitable for fish use (connectivity to mainstem) will be marked by GPS. These sites will then be mapped in ArcGIS and added to a list of potential future long-term monitoring locations.

4.1 Project goals

The primary project goal is to gather additional data at four potential CWR enhancement locations where feasible improvements exist in order to direct future project design efforts. We will evaluate the collected site data for fish utilization, temperature, specific conductivity, and flow for at least one migration season when mainstem temperatures are limiting (late May – September). These metrics are known to be important for both design selection and concept level design development. A secondary project goal is to collect high quality data sufficient to support decision making in moving 1-2 CWR projects forward for concept level design. The data collected in previous efforts combined with current project data and fish habitat potential assessments at each site, will further develop, refine and prioritize projects for thermal refuge enhancement in the lower Yakima. The final goal, is to develop a repository of additional future cool water monitoring sites by groundtruthing cool water anomalies identified by TIR flight data.

4.2 Project objectives

The project objectives include:

- Collection of continuous measurements of temperature every 15 minutes at 4 sites previously identified for potential CWR enhancement from June – September 2023.
- Comparison of continuous temperature data collected at the cool water refuge sites to established USGS stations on the mainstem Yakima River for evaluation of cool water refuge potential. Sites utilized for comparison are:
    - Union Gap at Ahtanum, USGS Station 12500450 (https://waterdata.usgs.gov/nwis/uv?site_no=12500450).
    - Emerald (RM 73.8), USGS Station 12507573 (https://waterdata.usgs.gov/nwis/uv/?site_no=12507573&PARAmeter_cd=00065,00060,00062,72020)
    - Kiona (Benton City), USGS Station 12510500 https://waterdata.usgs.gov/nwis/uv?site_no=12510500)
- Collect synoptic measurements of specific conductivity at the 4 cool water refuge sites every 5 - 6 weeks from June – September, as feasible with river flows.
- Measure cross-sectional streamflow velocities and depth within the cool water anomaly just above the confluence of the four selected site locations. Cross sectional flow data will be collected at least three times during June – September monitoring window, as feasible given river flows and safety. An effort will be made to collect cross-sectional flow measurements under differing hydrologic regimes (spring, summer, and fall), as feasible.
- Measure fish presence at four selected CWR sites using snorkel surveys conducted on consecutive weeks during three week periods in June, August, October, and February.
- Document riparian vegetation structure for at least one riparian plot for each identified CWR site.
- Groundtruth the presence of 8 – 12 cool water anomalies located along the 100 miles of the lower Yakima by collecting synoptic temperature measurements and documenting location with a handheld GPS.

4.3 Information needed and sources

BCD and project partners will conduct continuous temperature monitoring for the migration season during baseflow (June – early September) in 2023. Multiple temperature loggers will be deployed in four potential CWR enhancement locations. We will also collect synoptic specific conductivity measurements every 5-6 weeks and measure cross-sectional flow up to three times during the monitoring period. Site specific conductivity data will be collected within each cool water location above the confluence with the mainstem Yakima River at the location of the deployed loggers. Data will also be collected from the mainstem Yakima River above the cool water influence, as feasible. Specific conductivity data for the mainstem Yakima River is collected by USGS at multiple locations on the lower Yakima and available through NWIS. These data will be used as a comparison for the the conductivity data collected at each cool water location and as a secondary data check, especially when flows in the Yakima are prohibitive to safely collect in stream measurments. Input of groundwater data is assumed if specific conductivity measurements in the cool water anomaly are higher than the mainstem Yakima River conductivity values.

In order to determine cool water refuge potential, we will also need temperature data from the mainstem Yakima River. We will utilize USGS monitoring stations located at Benton City, WA, Emerald, WA and Union Gap for mainstem river comparisons. Loggers will also be deployed in the mainstem Yakima River above the cool water influence for temperature comparisons.

This project will address data gaps regarding the thermal heterogeneity and thermal refuge potential on the lower Yakima. While we know where potential thermal refuge sites are located, conceptual design development requires temperature data evaluating spatial and temporal characteristics. We also need flow data as sites with lower to moderate flows may not provide sufficient volumes of water for usable habitat development. Four monitoring sites were selected by BCD, Mid-Columbia Fisheries, and Yakama Nation (YN) and outlined in Section 7.0 of this Project QAPP. The monitoring locations were determined by analyzing the collection of thermal profile data and results analysis collected during the 2020 TIR Flight Data (QSI, 2020), 2018 thermal profiling floats (Gendaszek and others 2020), the 1997 FLIR flight data (Holroyd, 1998) and previous cold water monitoring work under YBIP Grant WRYBIP-1921-BentCD-00011. Sites were selected based on meeting the following criteria: a) already measurable cool water flows as compared to surrounding mainstem temperatures at baseflow, b) potential to develop, protect or enhance the cool water at the site for increased salmonid functionality, c) suitable site accessibility for equipment deployment and d) landowner permission for property access. We anticipate data for comparison and analysis of the results may be used from the following sources to help support this project:

- USGS Surface-Water Data for Washington (https://waterdata.usgs.gov/wa/nwis/rt).
- Thermal Profiles for Selected River Reaches in the Yakima River Basin (Vaccaro, J.J. and others, 2001) https://pubs.usgs.gov/ds/342/.
- Assessment of the Lower Yakima River in Benton County, WA (Appel, M. and others, 2011).
- Current GIS layers for Benton County compiled by BCD
- Ambient air temperature data from the Washington State University AgWeatherNet stations will be used for the project dates (https://weather.wsu.edu).

- Flow data at Parker for the Wapato Reach located on Bureau's Hydromet System at: https://www.usbr.gov/pn/hydromet/yakima/yakwebarcread.html
- Flow and stage data for Benton City (Kiona) and Mabton located on the USGS NWIS database at: https://waterdata.usgs.gov/nwis.
- Temperature and Specific conductivity data for Union Gap, Emerald, Prosser, and Kiona located on the USGS NWIS database at: https://waterdata.usgs.gov/nwis.
- 2020 Lower Yakima River TIR data, provided as ArcGIS files stored on Benton Conservation District's server (QSI, 2020).
- Washington State Department of Agriculture (WASDA) monitors Spring/Snipes Creek during irrigation season as part of their pesticide monitoring network. Data collected includes flow and specific conductivity. WASDA has agreed to share their data of Spring/Snipes with Benton CD during the duration of this project.
- Spring/Snipes creek was monitored by USGS under a separate QAPP (Appel 2019) that was completed in 2020. Data for this project are stored on the BCD server and located in EIM for long term storage and retrieval.
- Sulphur Creek Wasteway and RM 93/92 were monitored by BCD from 2020 – 2021 under a separate QAPP (Appel 2020). The data collected for this project are stored on the BCD server and located in EIM for long term storage and retrieval.

4.4 Tasks required

The tasks required to complete this project include:

- Build logger casings and deploy temperature sensors to monitor spatial and temporal characteristics of 4 cool water sites to support cold water habitat enhancement
- Check deployed temperature equipment every 5-6 weeks to ensure accurate and continuous data collection.
- Evaluate the cross-sectional flow in each of the 4 cool water locations during late spring, summer, and early fall
- Collect synoptic measurements of specific conductivity at 4 sites every 5-6 weeks from June – early September, as feasible with river flows.
- Conduct snorkel survey's twice weekly during three consecutive weeks in June, August, October, and February.
- Measure assessments of riparian vegetation structure during midsummer at each of the identified sites.
- Select 8 – 12 cool water anomalies from the 2020 TIR Flight ArcGIS data set for additional groundtruth monitoring and obtain landowner permission for access to any sites that are located on privately owned land.

Ensure quality of data collected with temperature loggers:

- Conduct Pre-and post-calibration checks on temperature loggers using a two point steady state calibration bath
- Collect temperature field checks for temperature using a National Institute of Science and Technology (NIST) calibrated thermistor
- Perform Quality Assurance checks of the collected temperature data
- Perform calibration on YSIProDSS for conductivity measurements
- Maintain Field Record Notebooks
- Data Entry for continuous temperature data into EIM for long term storage and management

Ensure quality of data collected during snorkel surveys:

- Include survey methods that allow observation of conditions that all life stages of salmonids use
- Survey the same area of each site through each survey period
- Ensure repeatability and comparisons by calculating the area surveyed
- Classify fish species based on size, life stage, and whether predatory.
- Minimize water disturbance to improve accuracy of species and size determination
- Capture spatiotemporal complexity of the thermal units within the lower river mosaic in order to collect robust habitat variables

4.5 Systematic planning process

This QAPP represents the systematic planning process.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 2 shows the responsibilities of those who will be involved in this project.

Table 2. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Marcella Appel Benton Conservation District Phone: 509-786-6000	Lower Yakima River Project Manager	Clarifies scope of the project. Arranges and oversees agreement with Mid-Columbia Fisheries. Responsible for grant reporting and communication with Ecology. Oversees data review and EIM upload.
Thomas Sexton Benton Conservation Disrict Phone: 509-786-6000	Resource Conservationist	Will provide technical coordination of field sampling; quality assurance, calibration and mobilizing of equipment. Supports data review, storage and EIM upload.
Zac Zacavish Mid-Columbia Fisheries Phone:	Project Manager/Fisheries Biologist	Perform snorkel surveys. Provide evaluation of the fish and riparian suitability of the sites for cool water refuge, technical coordination with BCD staff for field sampling, equipment deployment and field checks.
Chris Perra, LHG Yakama Nation Fisheries	Lower Yakima River Habitat Coordinator	Coordinates with BCD and Mid-Columbia Fisheries on evaluation and interpretation of the data, support data collection on Yakama Nation land, and provide technical assistance for field work.
Scott Tarbutton Washington Department of Ecology, Office of Columbia River Phone: 509-867-6534	Ecology OCR QAPP Coordinator	Provides initial review and feedback of QAPP, approves QAPP.
Kevin Haydon Washington Department of Ecology, Office of Columbia River	Ecology OCR Project Manager	Coordination of QAPP development and finalization. Coordinate with project on completion of deliverables, timelines, and budget.

QAPP: Quality Assurance Project Plan
NEP: National Estuary Program
WQX: Water Quality Exchange

5.2 Special training and certifications

The field lead and assistants for each logger deployment will be trained in and have experience with the SOPs being used for this QAPP. BCD, Mid-Columbia Fisheries and YN fisheries staff are trained in ArcGIS for mapping and data evaluation. Mid-Columbia Fisheries has extensive experience with fish identification and snorkel surveys.

5.3 Organization chart

BCD, Mid-Columbia Fisheries and YN will work collaboratively on this project. Ms. Appel, Mr. Zacavish, Mr. Perra will communicate about the project every six to eight weeks depending on seasonality. BCD, Mid-Columbia Fisheries, and YN will collaborate to determine the most suitable thermal refuge monitoring locations to move into the project phase of development. YN will provide support as in-kind match. Mid- Columbia Fisheries and BCD have a Memorandum of Understanding for the contracted project work. Responsible project staff and lines of communication are demonstrated in Figure 5.

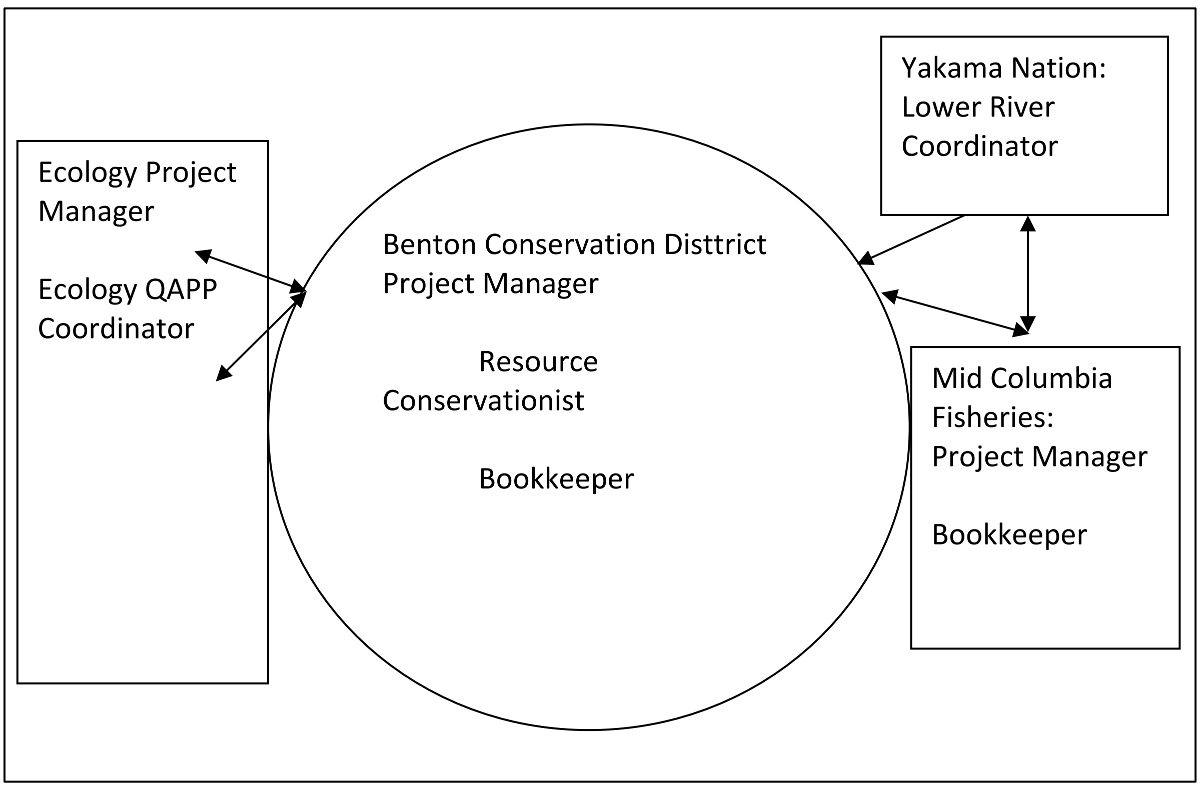

Figure 5. Organizational chart for project communication.

5.4 Proposed project schedule

Table 3 lists key activities, due dates, and lead staff for this project.

Table 3. Schedule for completing field work

Task	Due date	Lead staff
Collection of data and field checks	June – September from 2023	Thomas Sexton BCD
Collection of snorkel survey data	June, August, October, and February, 2023 - 2024	Zach Zacavish Mid-Columbia Fisheries
Data Processing, Data QA/QC and EIM Upload	November – March, 2023-2024	Thomas Sexton BCD
Quarterly PRPR reports	Quarterly from 2023 through 2024	Marcella Appel BCD
Collaborative Summary Report	December 2025	Marcella Appel BCD

5.5 Budget and funding

This project is funded by a Department of Ecology grant through the Yakima Basin Integrated Plan (WRYB-1921-BentCD-00030). The project funding was awarded to Benton Conservation District. Mid-Columbia Fisheries will be a contract partner through a contracted memorandum of understanding. The funding allocation for the part of the grant covered under this QAPP is provided in Table 4. Yakama Nation is providing in-kind support for meetings, field planning, and cold water refuge selection.

Table 4. Project budget and funding

Cost Category	Cost ($)
Salary, benefits, and indirect/overhead	41,242
Equipment	2,500
Travel and other	580
Contracts (Mid-Columbia Fisheries)	34,911

6.0 Quality Objectives

6.1 Data quality objectives

The primary data quality objective (DQO) for this project is to collect continuous temperature data at 4 cool water locations on the lower Yakima River (site descriptions provided in Section 7.0) from June through September. Observations of fish presence will be determined from snorkel surveys during the same time period and qualitative observations will be made of the riparian vegetation structure assessment by a qualified plant biologist familiar with local desert upland and riparian vegetation. Additionally, periodic measurements of specific conductivity and flow will be collected at the sites to help evaluate suitability for cool water enhancement projects. The data collected should be of sufficient quality and quantity to support decision making in the selection of 1-2 sites for further concept level design. Ground-truth data for an additional 8 – 12 cool water monitoring sites will be collected, with data of sufficient quality to confirm with certainty the presence of a cool water influence. This study will use previously developed methods that meet the measurement quality objectives (MQOs) described below and are comparable to previous study results.

6.2 Measurement quality objectives

Measurement quality objectives (MQOs) for continuous water quality monitoring, specific conductivity and flow described here are to obtain high quality data to meet the goals and objectives of this project. MQOs for fish usage and vegetetation assessments are not provided as these measures are qualititative and subjective in nature. The snorkeling surveys are collected as fish presence and absence data and the vegetation assessements are a percent estimate. These assessments are included to provide additional data for the cool water locations, but are not critical for site selection. Data quality indicators for the MQOs for all other parameters include precision, bias, sensitivity, representativeness, comparability, and completeness (as defined in Appendix B).

6.2.1 Targets for precision, bias, and sensitivity

The MQOs for project results, expressed in terms of acceptable precision, bias, and sensitivity, are described in this section (Table 5).

This project will use Onset Pendant temperature loggers for continuous temperature measurements. To ensure the data quality of all continuous temperature data, field staff will perform field visits for maintenance, cleaning, and field checks at each cool water site every 5-6 weeks. Manual collection of temperature data to check calibration of pendant temperature loggers will be performed with a NIST certified handheld digi-sense 20250-94 data logging thermistor meter. Latitude and longitude will be determined using a Garmin GPSMAP 64s hand held GPS unit and imported into ArcGIS.

Specific conductivity data will be collected with a YSI ProDSS, every 5 - 6 weeks in conjunction with temperature logger deployment and field checks. The meter will be calibrated per the

Standard Operating Procedure (Ward 2022; Section 8.2). Flow measurements will be calculated using cross-sectional average velocity measurements collected by an OTT MF Pro, electromagnetic flow meter with depth sensor as per Standard Operating Procedure (Shedd 2017, Section 8.2).

The precision and instrument bias measurement quality objectives (MQOs) described below for each of the continuously deployed temperature loggers are verified through both pre- and post-deployment calibration checks following the procedures described in the Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams (Nelson and Dugger, 2022). The procedures require that the temperature loggers be tested in controlled water temperature baths that bracket the expected monitoring range (near 0ºC and near 20ºC) with side by side field checks during deployment, maintenance and retrieval. The results are then compared to those obtained with a NIST certified reference thermometer.

Table 5. Measurement quality objectives for field meter measurements.

MQO →	Accuracy	Bias	Precision (Relative percent Difference)	Sensitivity
Temperature (Onset Pendant, UA-001-64)	Within ±0.6 °C of field meter[1]	Within ±1.13 °C of NIST calibrated thermistor[2].	≤ ± 20%	Between 0 and 35°C, resolution ±0.1 °C
Temperature (InnoCal Digisense Meter and probe) – NIST calibrated	±0.5 °C	NA	NA	Between 0 and 35°C, resolution ±0.1 °C
Specific Conductance YSIPro DSS	± 0.5% or 1 µS/cm	Within ±2 µS/cm of calibration standard	≤ ± 15%[3]	Between 0 and 200,000 µS/cm, resolution 0.001 – 0.1 µS/cm
Flow OTT MF Pro, electromagnetic flow meter with depth sensor	Within ±2% of reading (±0.05 ft/s) at 0 – 10 ft/s; Within ±4% of reading (±0.05 ft/s) at 10– 16 ft/s	Within ±2% (or ±0.05 ft/s) for measured reference zero stability	≤ ± 10%[3]	Range, 0 – 20 ft/sec, 0.01 value less than 100
Garmin GPSMAP 64s	±12 ft[4]	NA	NA	0.00001 decimal degrees

1. The manufacturer's stated accuracy for the field meter is the combined accuracy for the NIST traceable InnoCal Digisense meter and EW-20250-94 probe. The meter has an MSA of ±0.5 °C and the probe has an MSA of ±0.1°C giving an accuracy of. ± 0.6 °C
2. The Bias is the combined manufacturer's stated accuracy for the NIST traceable meter (± 0.6 °C) with EW-20250-94 probe and the Onset Temperature Logger (± 0.53 °C).

3. RPD from Washington State Department of Agriculture (WASDA) Ecology approved QAPP (Bischof, 2022) utilizing same instrumentation to maintain comparability for Spring/Snipes Creek.
4. This is the manufacturer's accuracy. However, experience with the unit demonstrates accuracy to ±1 – 2 feet.

NIST: National Institute of Standards and Technology

6.2.1.1 Precision

Precision is a measure of variability between results of replicate measurements that is due to random error. It is usually assessed using duplicate field measurements from two separate samples (1-replicate and 1-routine). Table 5 above provides the MQOs for comparison of data between the replicate samples, which should fall within the same criteria as those used during calibration. Precision for field replicate measurements will be expressed as the replicate median Relative Percent Difference (RPD) as outlined in Equation 1.

Equation 1. Relative percent difference (RPD) defined as:

$$RPD = \frac{ABS(R1 - R2)}{(R1 + R2)/2}$$

ABS = Absolute Value

R1 = Logger Temperature or Sample Measurement

R2 = Deployment Check Temperature 2 or value of replicate measurement

Side-by-side temperature measurements using a NIST certified temperature thermistor will be collected in the field for the continuously deployed temperature loggers at an interval of every 5 – 6 weeks. The field readings will correspond to the times the deployed meter is recording (15 minute intervals) and used to calculate RPD values.

The RPD limit for flow replicates is listed in Table 5, with a second replicate measurement collected immediately following completion of the first cross-sectional measurement. Replicate velocity measurements are also collected within each vertical of a cross-section using fixed period averaging and follows guidance from SOP EAP056 Measuring and Calculating Stream Discharge, Version 1.3 (Shedd, 2017). The RPD limit for specific conductance is listed in Table 5 and follows guidance from SOP EAP 032, V. 23 (Ward 2017) where a duplicate sample is collected 15 – 20 minutes after the first sample and used as the replicate measurement.

If the mean relative percent difference (RPD) is equal to or greater than the precision criteria, then a second check should be performed. If field RPD's regularly fall outside of the range outlined in Table 5, BCD will evaluate the equipment and methods to determine a course of action.

6.2.1.2 Bias

Bias is the closeness of agreement between an observed measurement value to the expected value or to the most-probable value. Bias is usually addressed by calibrating field and laboratory instruments. Tables 5 list targets for bias.

For continuous temperature, sample bias can be evaluated during the pre- and post- deployment calibration checks by looking for consistent differences between the NIST referenced thermometer and the temperature logger. Sample bias in deployed thermistors is estimated by comparing the temperature deployed temperature loggers to the NIST calibrated field check thermometer during field visits.

Staff will perform calibration checks on all continuous loggers prior to deployment and perform in the field side-by-side calibration checks during deployment, maintenance, and retrieval. If the loggers are within the calibration parameters listed in Table 5, a second calibration check is not required. If the loggers are not within the calibration parameters listed in Table 5, and are still not within the parameters for a second calibration check, the logger will not be deployed.

Accuracy of field measurements for specific conductivity will be addressed by calibrating the ProDSS at the start of each sampling week. Accuracy of the instrument will be evaluated each field day by checking instrument readings against known standard values. If the difference between the meter value and the standard are outside the MQOs, the meter will be re-calibrated. Once opened, reference calibration stock solutions must be used within 1 month to maintain stock solution integrity. Field staff will ensure accuracy in field measurements by strictly following equipment calibration, measurement and sampling protocols. For the ProDSS the calibration procedures are found within the online manual: https://www.ysi.com/file%20library/documents/guides/w89_ysi_prodss_calibration_guide.pdf.

The OTT Flow Meter will be calibrated at 0.0 cfs as outlined by the manufacturer's specifications (https://www.fondriest.com/pdf/ott_mf_pro_manual.pdf) prior to field use. A second post -calibration check is not warranted for the flow meter.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as the detection limit and the instrument range of operation. This project is not detecting contamination so sensitivity measurements for the equipment used for this project will be used. These sensitivity levels for the instruments are listed in Table 5.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

To ensure comparability, field measurements will follow approved Environmental Assessment Program (EAP) SOPs. These are listed in section 8.2.

For all continuous temperature monitoring, we will also follow standard USGS techniques and methods for temperature (Wagner et al. 2007) to keep consistency with the USGS monitoring in the lower Yakima River. For cool water sites that have previously been monitored, temperature loggers will be deployed in the same sites and locations for consistency.

For the flow and specific conductivity measurements, we will follow the procedures outlined by Washington State Department of Agriculture (WASDA) in their approved QAPP (Bischof, 2020) so that measurements in Spring/Snipes Creek are comparable to measurements collected by WASDA.

6.2.2.2 Representativeness

Representativeness expresses the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. The study is designed to have enough monitoring sites and sufficient monitoring frequency to meet study objectives of characterizing the temperature regime in the target areas to meet the project goals and objectives. Flow measurements between spring, summer, and fall will provide representative data across various flow conditions during the sampling periods. Similarly, multiple specific conductivity samples between June and September will help evaluate the influence of groundwater relative to mainstem surface water.

Multiple temperature loggers (3 – 6) will be deployed from June - September within each identified thermal refuge locations in order to help capture the temperature variability in the target areas. The loggers will be submerged near the streambed (typically 6 inches above the bed) and distributed to capture the spatial variability and extent of the cool water influence.

To ensure the continuous temperature monitoring at thermal refuge locations are representative, we will:

- Follow the QAPP protocols for data accuracy for installation, operation, and maintenance of all sensors.
- Check continuous data against field measurements for all parameters.
- Select logger locations that are well mixed, and representative of the thermal conditions within the cool water anomaly.

Making consistent repeated measurements during snorkel surveys will be made by defining the areas to be surveyed. The outer most edge of the a unit will be defined as the boundary that the unit shares with the mainstem Yakima River. Since each unit is discretely identifiable as a confluence site, side channel terminus, or pool location; each of the sites is only flanked by the Yakima on one side. Starting at the outer most edge, the snorkel surveyor proceeds on an upstream transect line orienting with the mainstem Yakima. The perimeter transect line was established based upon thermal profile of the feature and extends at least 50m beyond the feature.

Within the thermal unit, there will be two transects established based upon the feature. Based upon the features characteristics, established transect lines are set to best survey each site without jeopardizing re-counts, minimizing disturbances, and ensuring repeatability. In confluence sites, locations and survey lines will be set to best observe fish (i.e pools, bends, banks). Some instances may require additional upstream monitoring or modification to original survey line, this could include lost/gained connection with the mainstem Yakima. Regardless of snorkel surveyors present, area observed will be calculated based upon survey line length and estimated visibility. This will ensure that correlations in fish encountered can be compared between and among sites. Best effort will be made to survey approximately the same area of each site through each survey period. Below is locations and diagrams of how survey lines may look in these discrete unit locations.

Decreased visibility may lead to increased survey transects to ensure area observed remains consistent, however it should be noted when this occurs. During spring run-off and potential for fall precipitation, a concerted effort will be made to adhere to area surveyed. However, the decrease in visibility from the snorkeler could warrant additional effort at each site.

6.2.2.3 Completeness

The completeness is a measure of the amount of acceptable analytical data obtained from a measurement system compared to the amount expected under normal conditions. Target completeness values will be considered acceptable if 95% of the data are complete for the critical migration period of June through September. Data are considered usable if they meet the quality assurance and quality control standards as outlined in this QAPP.

Potential problems during data collection that need to be avoided if possible include: loss of temperature loggers due to theft, flows, or sedimentation or loss of data due to loggers being removed from water (shallow areas, changes in river level).

6.3 Acceptance criteria for quality of existing data

Potential data sources for this study are listed in Section 3.2.2, however, during the course of the project additional data sources may be identified. The project will use the best data available, assess the quality of that data and then assess the effects of data quality on the project. A process of quality assessment will be followed:

1. The source of the data will be investigated for documented data quality procedures.
2. Any qualifications associated with the data will be documented and evaluated.
3. The data will be evaluated for outliers or unusual trends that may suggest data quality problems.
4. Based on the evaluation of the data, suspect data may be censored, qualified, or accepted.

If available, other documents that already contain this information may be cited.

6.4 Model quality objectives

Not Applicable.

7.0 Study Design

7.1 Study boundaries

The study area is located in WRIA 37 (Lower Yakima). BCD staff will collect continuous water temperature data at 4 locations along the lower Yakima River from June – September from RM 93 to RM 42. Snorkel surveys will be completed twice weekly for three consecutive weeks in June, August, October, and February. Additionally, synoptic sampling for specific conductance will take place every 5-6 weeks at each logger location. Cross-sectional flow measurements will be collected three times at each site in the spring, summer, and fall above the confluence of the cool water influence and the mainstem Yakima. Riparain vegetation structure assessments will describe habitat conditions within the riparian area. Lastly, water temperatures will be collected from 8 – 12 newly identified sites by 2020 TIR imaging – these sites will have synoptic temperature measurements collected with a handheld temperature sensor and the corresponding gps locations will be logged.

Previous monitoring of cool water refuge locations was conducted under grant WRYBIP-1921-BentCD-00011 and WRYBIP-VER1-BentCD-0004 at 3 of the 4 locations (Figure 4, Section 4.0). These sites include the RM 92/93 complex, Sulphur Drain (RM 61), and Spring and Snipes Creek (RM 42). These sites were selected from previous monitoring efforts as having the highest likelihood of cool water enhancement. The fourth site, RM 95 side-channel, was selected based on 1997 and 2020 TIR imaging along with Yakama Nation data supporting the site is a cool water side-channel that is in a critical area for riparian restoration and fish spawning. This site is near the Wanity Slough groundwater recharge project planned by the Yakama Nation. Multi-project efficiencies may be realized if monitoring indicates possibility for enhancement of CWR. The selected monitoring sites are further detailed in Section 7.2.

7.2 Field data collection

7.2.1 Evaluation of 4 sites for CWR Enhancement – Sampling locations and Frequency

7.2.1.1 Water Quality and Vegetation Evaluations

Multiple continuous temperature loggers (3 – 9) will be deployed strategically at each of the 4 selected sites to capture spatial differences within the individual thermal refuge locations and capture the thermal contrasts resulting from cooling inputs at each site. As the sites are directly cooled or influenced from floodplain inputs (side-channels, creeks, drains, subsurface flows), the installation of loggers in the Yakima River will be near the mainstem river bank margins and at confluences of any incoming cool water seeps (not in the thalweg). Longer term monitoring stations (Identified in Section 4.3) will be used for mainstem river temperature comparisons. Loggers will also be deployed in the Yakima River (along the edge margins) upstream and downstream of the incoming cool water sources to capture the change in mainstem temperature resulting from the cool water inputs.

Because the nature of the identified cool water locations varies greatly from site to site, logger installation and specific locations is based on field conditions, river bed type, river flows and the extent of the cool water input. Field sites can have a range in vertical river depths from approximately 2 feet to 8 feet during baseflow conditions. For most sites, loggers will be deployed using previously established methods developed in the lower Yakima River by the project team and have been used successfully in monitoring similar thermal refuge sites on the lower Yakima River. Loggers will be cable tied to an anchor (such as rebar). The loggers will be at or near the riverbed for all sites other than RM 61. For RM 61 (Sulphur Creek Wasteway) which is a deeper site, the loggers will be deployed from the bank by anchoring the logger with a cable to a fixed point on the bank (using rebar, cables, or sturdy tree roots. All deployed loggers will be housed within a PVC protective casing. GPS coordinates will be collected for each logger location after deployment along with field photos that triangulate the logger locations. Anticipated logger deployment locations and site specific details are provided in Figures 7 – 10, along with specifics for each sampling site.

Figure 6. Examples of probe deployment casings.

All deployed loggers will be set to record at 15 minute intervals for the duration of the monitoring season. This interval is selected to capture diurnal variations in temperature and to compare readings to the data collected by USGS at the lower Yakima gage stations. Loggers will be checked and downloaded every 5-6 weeks. Loggers that are missing due to theft will be replaced. Field checks will include calibration, maintenance, and cleaning. The final site coordinates for the logger locations and maps will be provided in the final project report and notes will be made if logger locations deviated from previous logger deployment locations. Specific conductivity measurements will be collected with the handheld YSI ProDSS at the locations of the deployed temperature loggers and measurements form the cool water anomalies will be compared to Yakima River temperatures. These measurements will be collected at a frequency of every 5 -6 weeks when temperature loggers are deployed, downloaded, and retrieved.

Cross sectional discharge measurements will be calculated three times for each site. These measurements will be collected during temperature logger deployment (spring), mid-summer, and retrieval (fall). The discharge measurements will be collected in the cool water refuge site along a transect above the confluence of the cool water input with the Yakima River. If the cool water influence is disconnected from the mainstem Yakima River during low flows, as is likely at the RM 92 location, then a measurement will be collected as feasible within a representative, flowing section of the cool water area. Point velocity measurements will be collected using an OTT MF Flow Pro meter, with wading rod, following procedures outlined in the SOP EAP056, v 1.3 (Shedd, 2017). This method is designed for calculating streamflow discharge. There may be times, especially in June or September, that cross-sectional flow measurements may not be feasible due to safety concerns from higher flows, as such an alternative cross-sectional flow measurement will be made at the soonest possible date where flows safely allow data collection.

Riparain vegetation structure assessments are determined following SOP EAP117, Version 1.2, where protocols for transects extend 10 m perpidicular from bankful. Assements will be performed mid summer at each site within the measurement window. This assessment will be done beginning at the mouth of side channels or inputs into the Yakima use a wide protocol that extend 10 m upstream and downstream of the transect. Transects will be located at the position of the most upstream temperature logger. This work will be done by Benton CD staff, Thomas Sexton, who holds a PhD in plant biology and is qualified in riparian and upland plant identification.

7.2.1.2 Snorkel Monitoring Evaluation

Snorkel monitoring surveys will be conducted above, below, and within side channels or inputs to the Yakima River in June, August, October and February. Corresponding collection of temperature data will be captured in order to better characterize the conditions across each transect per each site and flow data will also be evaluated on the days of the surveys, as feasible. Collection of temperature data will be performed with a handheld digi-sense data logging thermistor lowered into the water to determine temperature. Simultaneous collection of latitude and longitude will be determined using a Garmin GPSMAP 64s hand held GPS to geographically identify the measurements of water temperature. This collection will be cross referenced with georeferenced aerial photos on a tablet to ensure location data appropriately saved. This method also allowes for quick geospatial transport into ArcGis.

Fish will be classified and enumerated by life stage and species. All salmonids observed will be separated into two major groups: juveniles and adults. This is based upon size to discern in-migrants, out-migrants, and rearing categories. All salmonids will be estimated to the nearest 10mm, however it should be noted that salmonids under 100mm are challenging to discern in large fast moving water so they will be grouped as “zeros or YOY”. Fish species observed outside of salmonids would be classified by size class. For estimates in low visibility or in areas of high density; Small mouth bass and pike minnow >150cm will be considered predators, whereas <150cm will be classified as non-predators (Pearson 2004). Fish species such as the carp, dace, and chiselmouth will be documented but no size class estimations will be actively taken due to projects goals. Data on these non-game species will be taken opportunistically when available, in order to maintain spatial and temporal scope of the project.

The spatiotemporal complexity of the thermal units within the lower river mosaic allows for robust habitat variables to be collected. These variables will selected based upon standardized stream survey methodology; additional variables were selected in order to rank thermal unit’s characteristics that could be driving fish usage, spatial and temporal assemblage found in sections of the lower Yakima River.

After the snorkel surveys are completed (as to not disturb fish counts), crew members will collect measurements needed to calculate surface area of the thermal refuge. Along the perimeter transect line, temperatures will be taken every 10m at surface and riverbed to accurately estimate thermal profile of the feature as it relates to the mainstem. Mainstem thalweg temperatures will be for comparison amongst sites with adjacent mainstem temperature. Discharge will also be measured at each discrete site following the fish snorkel surveys following SOP EAP056, v 1.3 (Shedd, 2017) and mainstem discharge will be taken from the nearest USGS or USBR gauge.

Along the perimeter line and any other upstream transects taken, the stream habitat classifications will be assessed following Platts et al. (1983) methodology. This will help to better describe the gradient and heterogeneity in riverbed depths found in transects measured in the lower river (Table 6). Bedrock depressions will also be identified in the habitat classifications.

Table 6. Methodology describing habitat types as related to hydrology (from Platts and others, 1983).

Relative Velocity	Description	Habitat Type
Slow Water	With hydraulic control at downstream transition.	Pool
	No downstream transition, but distinct area of increased depth.	Depression
Mixed	Numerous boulders or other obstructions small pools in an otherwise fast water reach.	Pocket Water
Fast Water	Little surface turbulence	Run
	Abundant surface turbulence	Riffle

The area of each unit will not be estimated due to the size of the Yakima River. However to better correlate fish usage and habitat, area will be estimated as a function of visibility. Prior to snorkel survey, estimates will be made of visibility using the snorkelers approximation of accurate visual identifiable distance. For example, if a surveyor had 2m of visibility (1m on each side of snorkeler) and had a transect of 50m on the perimeter line, then 100 square meters were observed along this transect. This allows scalability, repeatability, and correlations to be made.

7.2.1.3 Temperature logger and snorkel survey locations by site

7.2.1.3.2 RM 95 - Side Channel

RM 95, Side Channel (right bank): RM 95 is located on Yakama Nation tribal lands, and is an approximately 2 mile long cool water side-channel. This side channel was identified by 2020 TIR flights (QSI 2020) and confirmed as a source of cool water by Yakama Nation staff in 2021. This location is adjacent to an ongoing Yakama Nation project for ground water recharge (Wanity Slough). The side-channel cools as it nears a pool at the bottom of the side-channel prior to its confluence with the mainstem river. For RM 95, 2-3 loggers will be deployed at the lower end of the side-channel where the water is coolest and fish are most likely to congegrate. Additionally, 2 loggers will deployed above and below the confluence of the side-channel within the Yakima mainstem for comparison purposes (Figure 7).

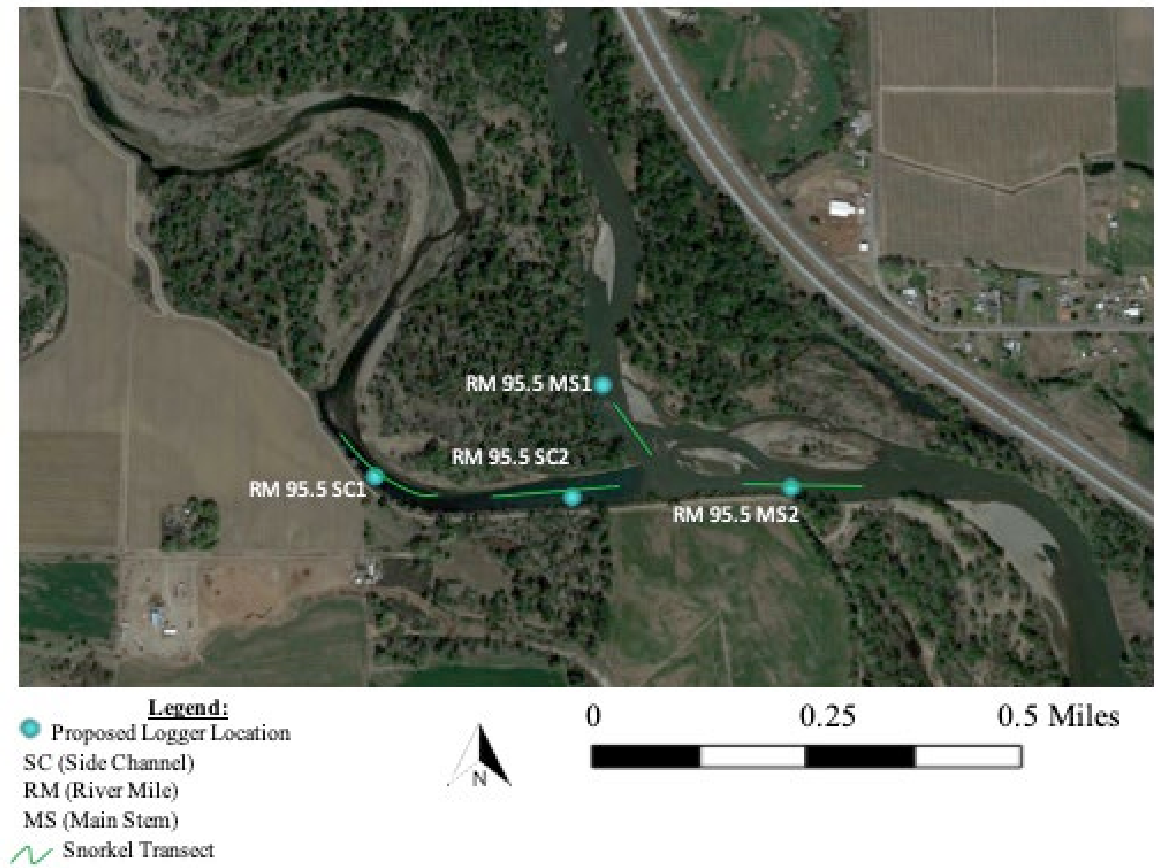

Figure 7. RM 95 Floodplain Complex with proposed logger locations shown.

7.2.1.3.1 RM 93/92 – Floodplain Complex

The RM 93/92 Floodplain Complex (left bank): This floodplain complex is located on Yakama Nation property and has a long cool water side channel at RM 93 that is partially connected at high-flow to the mainstem river channel but disconnected during baseflow. Natural river meander leads to a partially disconnected side channel at RM 92. This complex is likely to have larger restoration opportunities given the underlying hydrology of this area (Gendaszek and others, 2021) and as such the sites are coupled together as one larger potential refuge enhancement project. This site was previously monitored by BCD in 2020 – 2021 as part of YBIP grant WRYBIP-1921-BentCD-00011. The RM 93/92 complex was identified during the 1997 and 2020 FLIR flights and monitored in previous studies. Location of deployed loggers during the previous studies are shown in Figure 8, and will be the locations for logger re-deployment under this QAPP.

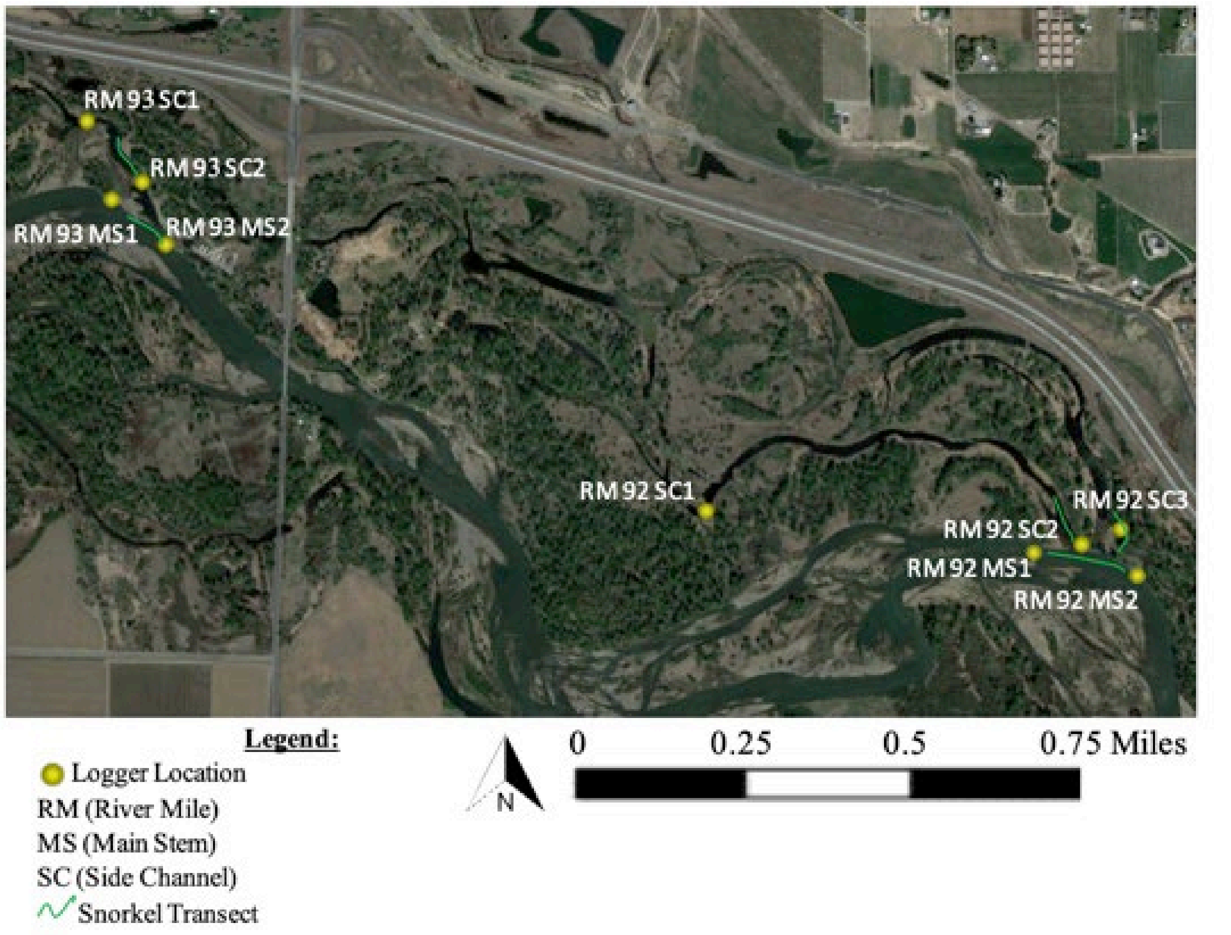

Figure 8. RM 93/92 Floodplain Complex with logger locations shown from previous monitoring shown.

7.2.1.3.3 RM 61 - Sulphur Creek Wasteway

RM 61, Sulphur Creek Wasteway (Left Bank): This identified cool water location is a wasteway/ overflow drain that is operated as part of the Sunnyside Valley Irrigation District Operations. Access to the site is located on easements owned by Sunnyside Valley Irrigation District. Loggers will be deployed within the confluence and upstream and downstream of the wasteway discharge located within the lower river mainstem (Figure 9). This site is a higher traffic area and loggers are more susceptible to theft and need to be adequately hidden. Loggers are deployed and anchored by cabling to the bank as the mainstem Yakima River is deeper at this site. Loggers have remained at the site with good success during previous studies. This site was previously monitored in 2020 – 2021 by BCD as part of YBIP grant WRYBIP-1921-BentCD-00011.

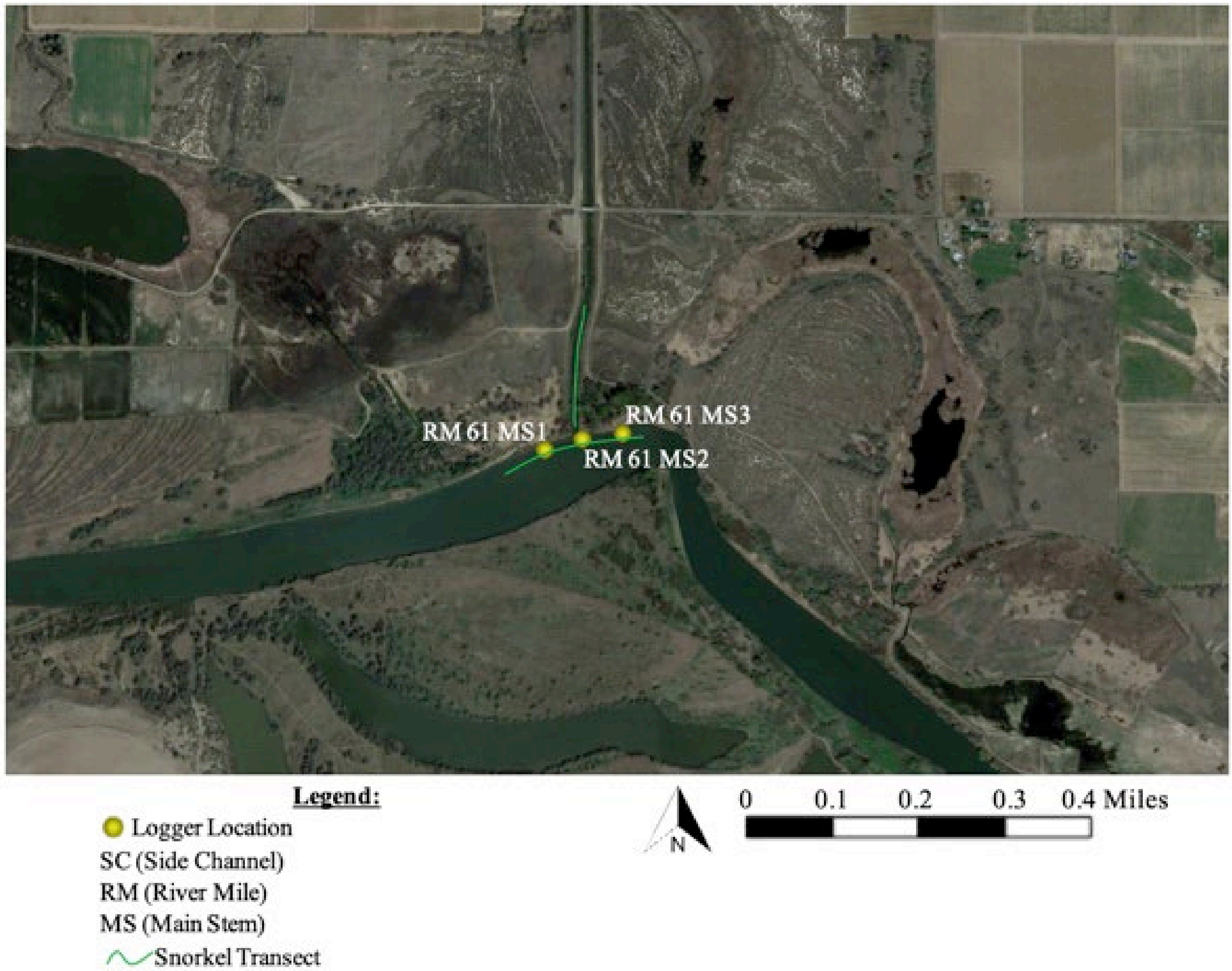

Figure 9. RM 61, Sulphur Creek Wasteway with logger locations from previous monitoring shown.

7.2.1.3.4 RM 42 - Spring/Snipes Creek

Spring and Snipes Creeks are part of the Roza Irrigation District system and is used for return irrigation flows. Located near river mile 42, Spring and Snipes Creeks enter the Yakima River along the left bank of the mainstem (Figure 10). The Spring Creek tributary joins Snipes Creek, at approximately 175 m above the joint confluence with an island side-channel on the Yakima River mainstem. Spring Creek begins near the Roza Canal and ends with its junction into Snipes Creek. There is an easement owned by the Roza Irrigation District along the creek length that can be used for access, in addition to permission from property owners at the confluence. This site was previously monitored for water quality metrics by USGS in 2019-2020 (Sheibley and others, 2021).

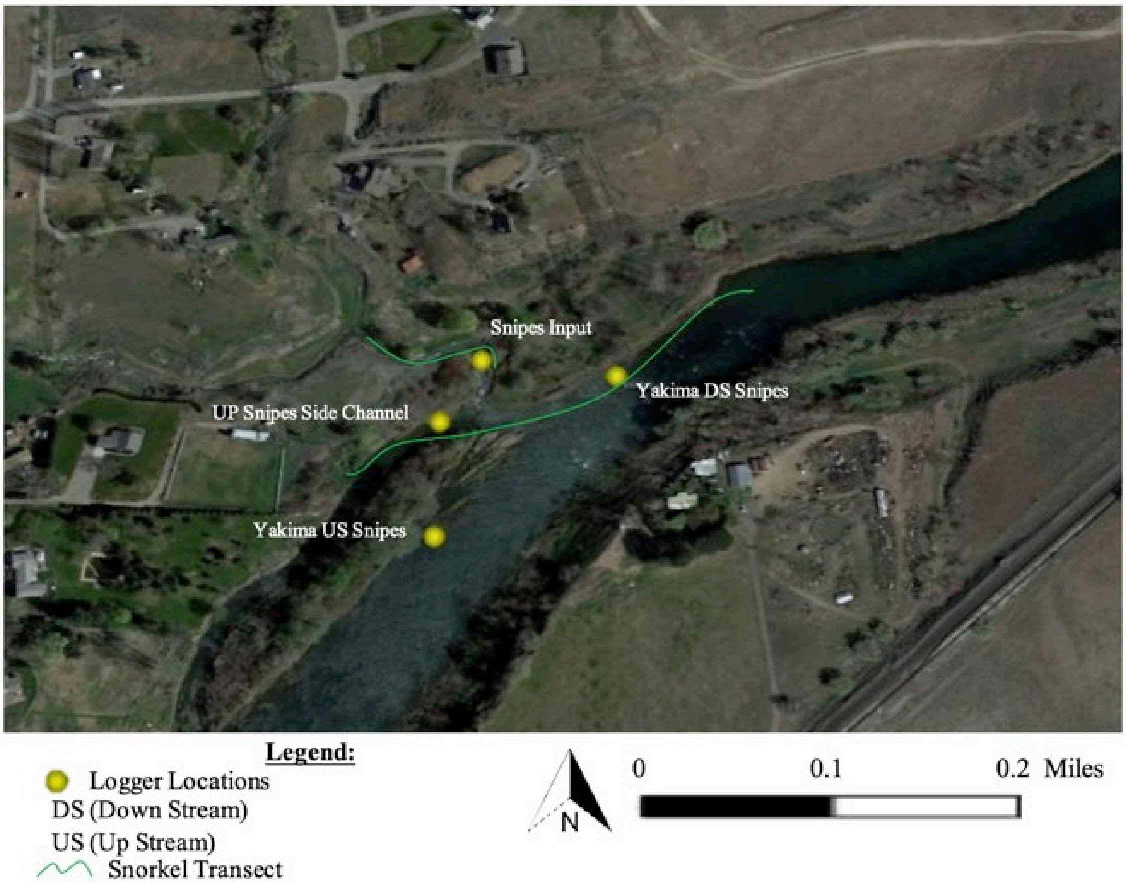

Figure 10. RM 42, Spring/Snipes Creek with logger locations from previous monitoring and planned snorkel survey transects shown.

7.2.2 Ground-Truth of Newly Identified Cool Water Locations – Sampling location and frequency

To develop a repository of future cool water refuge enhancement project sites, BCD Staff will visit cool water anomalies in the Summer of 2023 and 2024 as identified in the 2020 TIR flights, that have not been previously identified by either thermal profiling work, or the 1997 TIR Images. The 2020 TIR flights identified additional cool water analmolies that had not previously been identified through project work, either due to shifts in the alluvial floodplain, greater sensitivity of 2020 TIR flight data over the 1997 TIR flight images, or cool water anomalies were in areas that the boats could not access during profiling floats. All of the TIR 2020 temperature anomalies (known and unknown) are shown in Figure 11.

Data collected from 2020 TIR flights (July 31 – August 4)

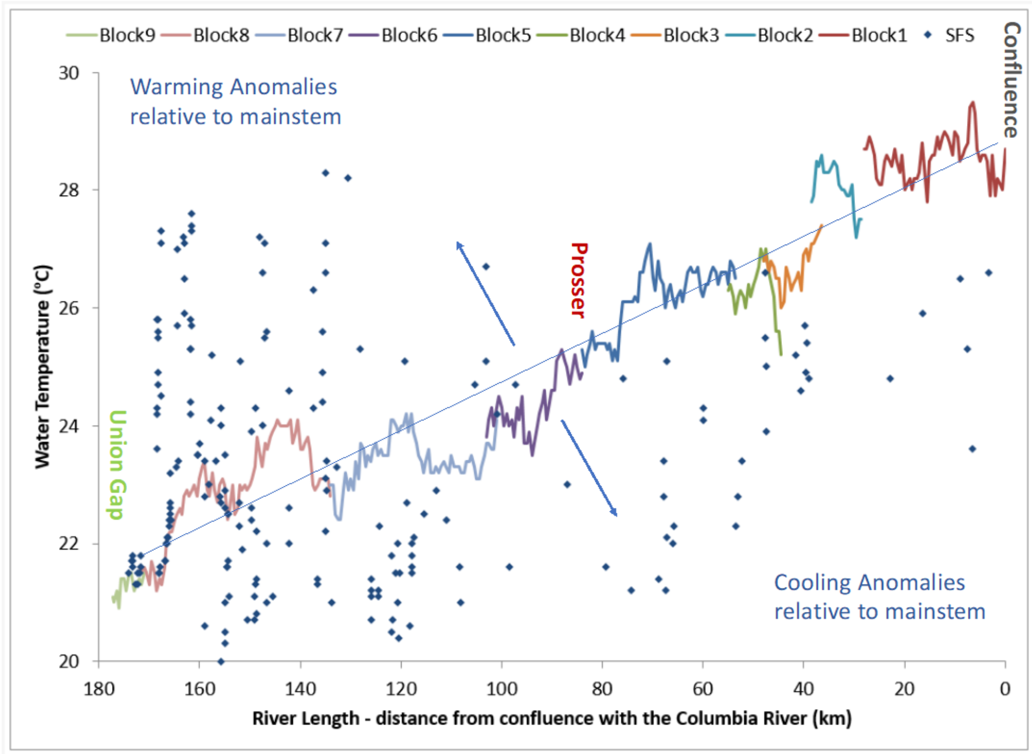

Figure 11. Warm and Cool temperature anomalies on the lower Yakima River as relative to mainstem river temperatures. Anomalies below the center (mainstem line) are cool relative to mainstem river (QSI, 2020 with modifications by BCD).

To evaluate the cool water refuge locations, BCD will identify new locations from the 2020 TIR ArcGIS images that have not been previously studied and visit once during the summer of 2023 or 2024. Sites will be selected based on site accessibility, whether the sites have previously been identified, and landowner permission. BCD staff will visit the selected sites at peak baseflow conditions when temperature extremes between cold water anomalies and mainstem river temperatures are the greatest. This is typically the last two weeks of July and the first two weeks of August. BCD staff will a) evaluate temperatures within the identified anomaly (if present) using the handheld NIST certified temperature thermistor and b) collect GPS coordinate locations for the temperature measurements. These points will be compared to mainstem Yakima River temperatures from the nearest USGS station gages. These data will be provided in a final ArcGIS map. Potential locations for the ground-truthing project are shown in Figure 12.

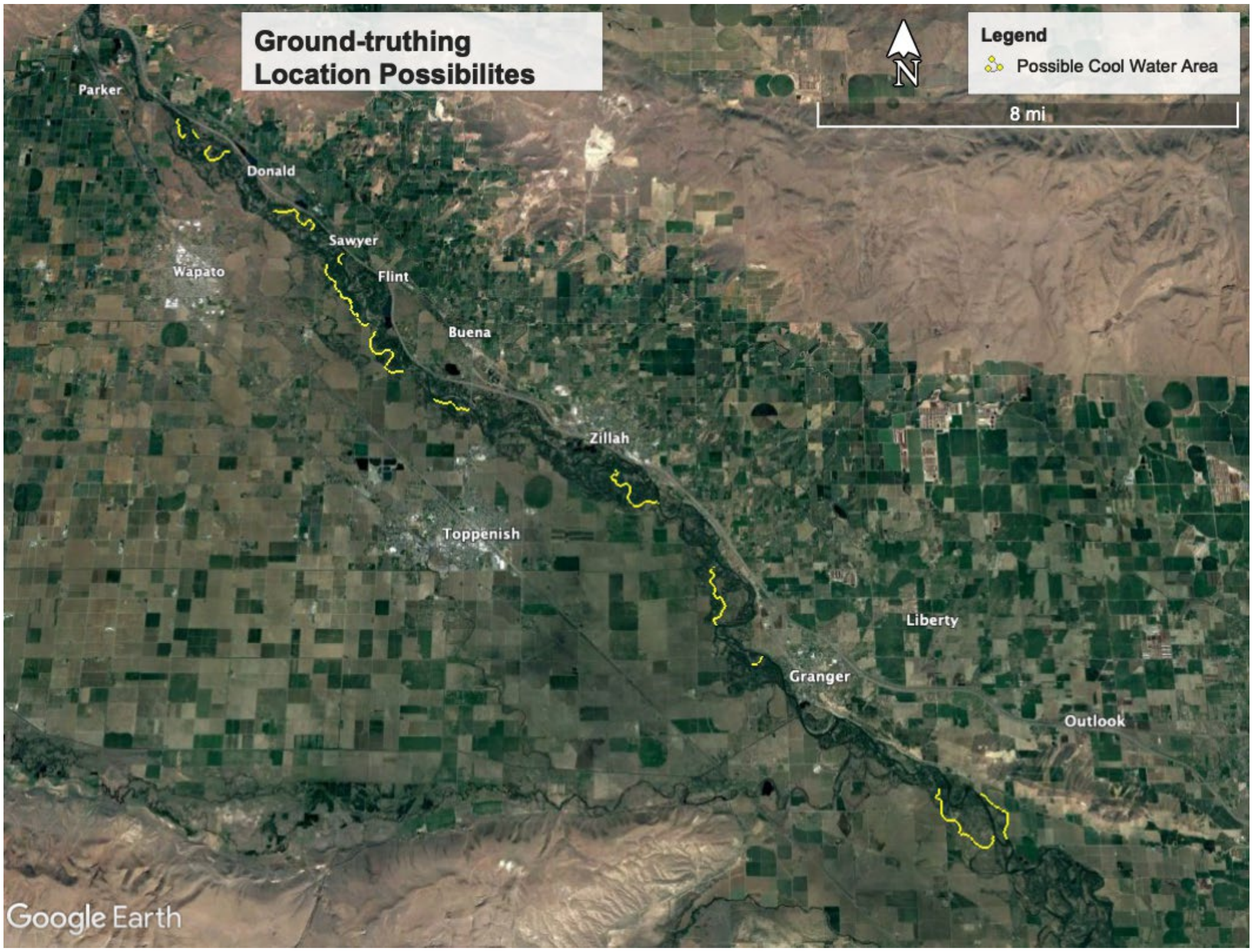

Figure 12. Identified reach sections of probable cool water anomalies on the lower Yakima River as identified by the 2020 TIR images (QSI, 2020).

7.2.3 Field parameters and laboratory analytes to be measured

Continuous and instantaneous water temperature data will be measured along with conductivity, flow, average velocity, wetted width, depth, GPS coordinates, vegetation, and fish presence.

7.3 Modeling and analysis design

Not Applicable

7.3.1 Analytical framework

Not Applicable.

7.3.2 Model setup and data needs

Not Applicable.

7.4 Assumptions of study design

Assumptions are made that the study design and sampling locations will adequately meet the outlined project goals and objectives. We are also assuming that we will be able to adequately measure the spatial changes within a cool water location using multiple sensors in a way that will help inform future management decisions for enhancing or improving the thermal refuge. Moreover, it is assumed that the data collected during June - September will help inform the seasonal temperature pattern within a normative water year. Excessive water stargrass growth, sedimentation, flood or drought conditions, or human interference with the loggers may interfere with the project design. Sediment levels and flows may impact fish snorkel surveys.

7.5 Possible challenges and contingencies

There are several logistical problems that may arise for deployment of continuous temperature monitors for cool water inputs and monitoring of thermal refuge. As with any environmental monitoring there is always a possibility of unusual weather conditions, extreme river events (flooding or drought), or site access that can cause challenges with deployment, sampling, retrieval or result in the loss of equipment. Furthermore, interference from the public with deployed equipment can be problematic. The logistical problems, practical constraints, and schedule limitations specific to this QAPP are discussed further in the following sections.

7.5.1 Logistical problems

Landowner permission and/or site access (heavy vegetation, steep banks, swift flows) can be challenging for some of the thermal refuge locations that the project intends to monitor. Some of the sites have water that is too deep to access at baseflow, and other sites have highly variable conditions from June – September. The loggers will be deployed near the streambed which may range from sediment to cobble. Depending on the streambed conditions, it may be challenging to drive posts or rebar into the bed for attachment of the loggers. Some of the sites have higher public access and interference with the loggers by public recreationists may be an issue. High water or swift spring flows may dislodge loggers, alter timing of snorkel surveys, or carry high amounts of sediment and bury loggers. Technical field staff will try to mitigate these issues as much as possible during deployment and with regular field checks during the summer to help the project gauge any problems that may occur due to theft, flow conditions, and sedimentation.

7.5.2 Practical constraints

Accessibility to RM 93/92 and RM 95 can be challenging when there is dense vegetation later in the summer. These field sites with heavy riparian vegetation could result in alterations of the sampling plan for timing of field checks. In-stream flows, high summer heat or unsafe air conditions (fire season), and availability of field staff during the busy summer field season may dictate logger deployment and field check schedules. Early field work planning and scheduling will take place to help offset staff and internal work load challenges.

7.5.3 Schedule limitations

It is important loggers are deployed during base flow when the river is accessible by wading. However scheduling of personnel for fieldwork due to severe weather or air conditions (fire season) may also delay field activities a few days or weeks but this will likely not impact the overall proposed data collection. Schedule limitations due staff isolation after positive Covid-19 tests may impact timing of logger deployment and provide constraints on personnel for sampling windows. Timely completion of the QAPP and approval may also create schedule delays.

8.0 Field Procedures

8.1 Invasive species evaluation

Field staff will follow the procedures described in Ecology SOP EAP070 – Minimizing the Spread of Invasive Species (Parsons et al. 2018). While the study area for this project is not located within areas of extreme concern, the boat is carefully inspected for invasive species after each sampling event and washed before stored. Loggers, the thermistor and the handheld YSI and flow meter are washed after each deployment to ensure invasive species are not spread from site to site.

8.2 Measurement and sampling procedures

This study will adhere to the appropriate techniques and SOPs published by Ecology:

- EAP080, V2.2 – Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams (Nelson and Dugger, 2022).
- EAP011, V2.1 – Standard Operating Procedure for Instantaneous Measurements of Temperature in Water (Dugger, 2022).
- EAP117, Version 1.2 – Standard Operating Procedure for Watershed Health Monitoring: Assessing Riparian Vegetation Structure (Hartman, 2018).
- EAP056, V 1.3 – Measuring and Calculating Stream Discharge (Shedd, 2017)
- EAP032, V2.2 - Collection and Analysis of Conductivity Samples (Ward, 2022)
- EAP070 – Standard Operating Procedures to Minimize the Spread of Invasive Species (Parsons et al. 2018).

The relevant SOPs can be found on the Ecology Website at: https://ecology.wa.gov/About-us/How-we-operate/Scientific-services/Quality-assurance, and https://apps.ecology.wa.gov/publications/SummaryPages/1803203.html.

BCD will also follow the Standard Operating Procedures (SOPs) for the collection of water quality data provided in the National Field Manual (US Geological Survey, variously dated) to keep consistency with other monitoring sites being maintained by U.S. Geological Survey staff. Field technicians will deploy continuous sensors in secure and representative areas of the river at each selected field site. During field maintenance visits, staff will check the sensors for fouling or sedimentation and clean as appropriate. A separately calibrated field meter will be used for quality assurance to ensure data are accurate as detailed previously in this QAPP.

8.3 Containers, preservation methods, holding times

Not Applicable.

8.4 Equipment decontamination

Field staff will follow the procedures described in Ecology SOP EAP070 – Minimizing the Spread of Invasive Species (Parsons and others, 2018). Boats and equipment used will be inspected after use on boat ramps and cleaned accordingly.

8.5 Sample ID

Not Applicable.

8.6 Chain of custody

Not Applicable.

8.7 Field log requirements

Field technicians will record all field-sampling activities in a field logbook. Field log will be maintained by each sampler that will contain any additional information. This field log will be a bound, waterproof notebook used with permanent, waterproof ink for entries. It will use a single strikethrough (one line) to correct information and staff will initial and date all corrections. The field log will include: Information recorded includes (but is not limited to):

- Name and location of project.
- Environmental conditions.
- Date, time, location, logger number, and description of parameter measured.
- GPS coordinates for deployed logger
- Instrument calibration procedures.
- Field measurement results.
- Transect length (channel width)
- Distance for each transect measurement
- Point velocity measurements
- Depth for field velocity measurement
- Identity of field QC samples.
- Unusual circumstances that may affect interpretation of results.
- Field personnel.
- Sequence of events.
- Any changes to plan.

- Field observations and observable environmental conditions will be noted including any conditions that may impact temperature of the recording logger (shade, direct sun, etc.)

8.8 Other activities

Not Applicable.

9.0 Laboratory Procedures

9.1 Lab procedures table

Not applicable.

9.2 Sample preparation method(s)

Not applicable.

9.3 Special method requirements

Not applicable.

9.4 Laboratories accredited for methods

Not applicable.

10.0 Quality Control Procedures

Field QC procedures for measurements of temperature, specific conductivity, and streamflow velocity will follow the SOPs listed in Section 8.2. We will operate monitoring of the continuous water quality sites as described within Section 7.0 (Study Design) including inspection and calibration of monitors as frequently as required to obtain as complete a record as possible. Section 6.2 details side-by-side checks of deployed sensors to field meters.

Prior to deployment, the temperature loggers will be calibrated following procedures recommended by Nelson and Dugger (2022). Each logger will be pre-set for a delayed start so that each logger starts recording at the same pre-set time prior to calibration and continues to log temperature every 1 minute for 10 -15 minutes at 20°C and 20 minutes at near 0.0 °C. A separate watch will be synchronized with the computer start time so that calibration readings would be simultaneous with the watch.

Loggers are placed into two separate water baths with a high and low temperature of 20 and near 0 degrees Celsius (°C), respectively, and allowed to equilibrate prior to recording temperatures. Calibration will be performed using a NIST certified digi-sense 20250-94 Thermistor meter. Mean differences calculated from the logger calibration procedures are added or subtracted as appropriate from field data prior to use.

The YSI ProDSS will be calibrated the week of field work and checked each day of the field procedures to ensure accurate specific conductivity measurements.

10.1 Table of field and laboratory quality control

Table 7 provides the field QC procedure required for this study. Detailed side-by-side checks of deployed Onset Hobo loggers to the NIST certified field thermistor, conductivity and flow will occur as described in Section 6.2.

Table 7. Quality control samples, types, and frequency.

Parameter	Field Mid-deployment Check
Temperature	1 measurement collected per temperature logger per field check[1]
Conductivity	1 duplicate measurement collected per sample[2]
Flow	1 replicate discharge measurement is collected immediately after completion of first discharge measurement.

[1]Temperature checks will be collected using a NIST certified field thermistor every 5 – 6 weeks.

[2]Duplicate conductivity samples will be collected every 5 – 6 weeks at the time of sample collection.

10.2 Corrective action processes

Review of data is an ongoing process throughout the project and we will reject data or qualify it as needed. Quality control results may indicate problems with data during the course of the project. Options for corrective actions might include:

- Recheck pre- and post-calibration checks.
- Qualify or reject results.
- Clean, repair, or replace loggers if evidence of mid-deployment failures or issues.
- Adjustments for logger drift based on field check data along with pre and post check data
- Convene project personnel to decide on the next steps we will take if persistent quality control problems arise.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

Staff will record all field data in a field notebook. Before leaving each site, staff will check field notebooks for missing information. Staff will electronically record data as soon as practical after returning from the field.

All continuous data will be entered into and analyzed with Microsoft Excel® spreadsheets, GIS, and R statistical software. After data are downloaded from the deployed loggers, the project will check that instantaneous water temperatures collected with the NIST certified field thermistor are within the specified criteria as compared to recorded values by the loggers. Data that do not meet criteria will be flagged, removed, or qualified as appropriate. Once QA/QC is completed, data will be uploaded to EIM using Study ID: WRYBIPBentCD00030.

Vegetation data will be recorded in an Excel Spreadsheet and stored on the BCD server. Snorkel survey data will be recorded by Mid-Columbia Fisheries and emailed to BCD to be stored with the project files on the BCD server.

11.2 Laboratory data package requirements

Not Applicable

11.3 Electronic transfer requirements

Not Applicable

11.4 Data upload procedures

Data will be transferred to Ecology's EIM system annually per online submittal guidelines. The EIM data coordinator will be consulted if data submittal problems arise.

11.5 Model information management

Not Applicable

12.0 Audits and Reports

12.1 Audits

Not Applicable.

12.2 Responsible personnel

Not Applicable.

12.3 Frequency and distribution of reports

Grant progress reporting for this project will be completed according to the requirements outlined in WRYBIP-2123-BentCD-00030 between BCD and Ecology. Quarterly progress reports will be completed and submitted with each payment request.

A final project report will be completed by BCD by October 15, 2024. A draft report will be available for review prior to this date.

12.4 Responsibility for reports

Marcella Appel with BCD will be responsible for all quarterly progress reports, annual environmental reports, and the final environmental monitoring report.

13.0 Data Verification

Data verification is the process for evaluating completeness and correctness of the collected data set against the method and contractural requirements. At completion of this project we will have data for one field season with continuous temperature, conductivity, flow, and one vegetation assessment and snorkel surveys. Project staff will oversee data verification as described further below.

13.1 Field data verification, requirements, and responsibilities

The field data will be verified by both field and management staff overseeing the project. BCD Staff will ensure that the applicable procedures described in the Standard Operating Procedures provided in Section 8.2 are followed for temperature collection, flow, vegetation assessment and conductity. Snorkel surveys will be overseen by MCF project management and field staff. Snorkel suveys will use 2 – 3 field observers with cross validation using Yakama Nation predator surveys. Additional field data verification details are provided below:

- Instrument calibration checks and field procedures will be documented on appropriate forms.
- Data will be checked for entry errors and completeness
- Pre- and post-calibration check results and field measurements will be reviewed to ensure the data quality objectives were met.
- Results will be verified using data plots, field measurements, and stream height/flow information (if available).
- Detected data errors will be corrected, flagged with data qualifiers, or deleted. For non-continous measurements, the field lead will verify initial field data before leaving each site. This process involves checking the data sheet for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be repeated.

BCD and MCF project staff will upload field parameters recorded on field sheets into Excel Spreadsheets within 48 hours of returning from the field with verification by the BCD project manager. Project staff will also:

- Review continuous recording data within 48 hours of download to ensure correct sensor operation and identify possible problems early.
- Upload and store data in the EIM or WRM database for long term storage and retrieval.
- Approve records, including the primary data collector rectifying anomalous data, dates and times and applying any corrections that are needed
- Plot all data and comparing continuous data to field check data and GPS coordinates within ArcGIS for verification

13.2 Laboratory data verification

Not applicable.

13.3 Validation requirements, if necessary

Not applicable.

13.4 Model quality assessment

Not applicable.

13.4.1 Calibration and validation

Not applicable.

13.4.1.1 Precision

Not applicable.

13.4.1.2 Bias

Not applicable.

13.4.1.3 Representativeness

Not applicable.

13.4.1.4 Qualitative assessment

Not applicable.

13.4.2 Analysis of sensitivity and uncertainty

Not applicable.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

After all field data are verified, the project manager will examine the data to determine if all the criteria for MQOs, completeness, representativeness, and comparability have been met. If the criteria have not been met, the project manager will decide if affected data should be qualified or rejected.

14.2 Treatment of non-detects

Not applicable.

14.3 Data analysis and presentation methods

Data collected from the continuous temperature loggers will be analyzed utilizing Microsoft Excel®. BCD will investigate each thermal refuge site separately to look for cool water temperatures as compared to the mainstem river data, and provide corresponding data for flow and specific conductivity. All data will be compiled and presented within the final project report. No presentations are anticipated as part of this project.

14.4 Sampling design evaluation

It is anticipated that the sampling designs outlined in Section 7.0 will be adequate to meet the project goals based on prior thermal refuge monitoring. The data collected during this project will be evaluated to determine thermal refuge potential for the lower Yakima. Identified thermal refuge locations will be further evaluated by fisheries biologists and habitat restoration professionals for future thermal habitat enhancement, protection, or creation.

14.5 Documentation of assessment

The data collected will be documented in accordance with the grant reporting requirements and in accordance with Ecology requirements.

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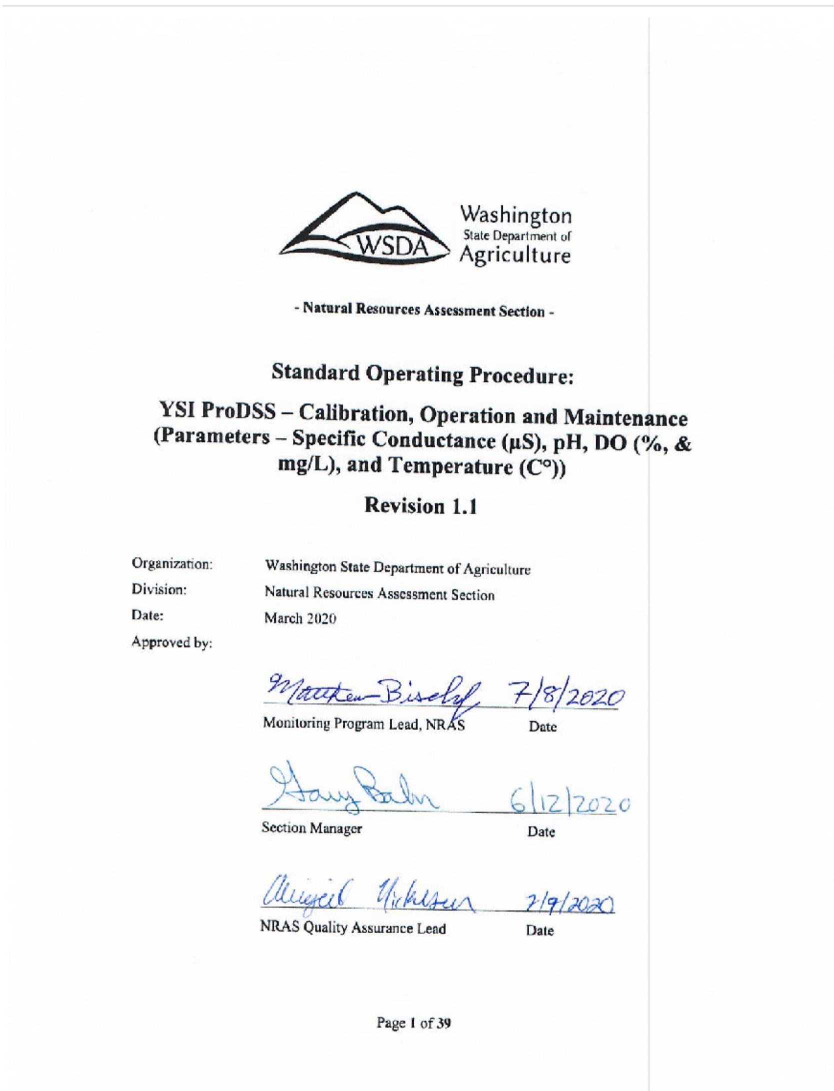
16.0 Appendices

Appendix A. WASDA Standard Operating Procedures YSI ProDSS Title Page

Attached is the title page for the WSDA SOP for documentation. This SOP is followed for YSI operation and consistency with sampling by WSDA at Sulphur and Spring/Snipes Creek operation.



Washington State Department of Agriculture

- Natural Resources Assessment Section -

Standard Operating Procedure:

YSI ProDSS – Calibration, Operation and Maintenance (Parameters – Specific Conductance (µS), pH, DO (%, & mg/L), and Temperature (C°))

Revision 1.1

Organization:	Washington State Department of Agriculture
Division:	Natural Resources Assessment Section
Date:	March 2020
Approved by:	

7/8/2020
Monitoring Program Lead, NRAS — Date

6/12/2020
Section Manager — Date

7/9/2020
NRAS Quality Assurance Lead — Date

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Appendix B. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Ambient: Background or away from point sources of contamination. Surrounding environmental condition.

Baseflow: The component of total streamflow that originates from direct groundwater discharges to a stream.

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether or not the uses are currently attained.

Diel: Of, or pertaining to, a 24-hour period.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Dilution factor: The relative proportion of effluent to stream (receiving water) flows occurring at the edge of a mixing zone during critical discharge conditions as authorized in accordance with the state's mixing zone regulations at WAC 173-201A-100.
http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-020

Diurnal: Of, or pertaining to, a day or each day; daily. (1) Occurring during the daytime only, as different from nocturnal or crepuscular, or (2) Daily; related to actions which are completed in the course of a calendar day, and which typically recur every calendar day (e.g., diurnal temperature rises during the day, and falls during the night).

Effective shade: The fraction of incoming solar shortwave radiation that is blocked from reaching the surface of a stream or other defined area.

Existing uses: Those uses actually attained in fresh and marine waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to Washington, and put-and-take fisheries comprised of non-self-replicating introduced native species, do not need to receive full support as an existing use.

Hyporheic: The area beneath and adjacent to a stream where surface water and groundwater intermix.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

Reach: A specific portion or segment of a stream.

Riparian: Relating to the banks along a natural course of water.

Salmonid: Fish that belong to the family *Salmonidae*. Species of salmon, trout, or char.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

Streamflow: Discharge of water in a surface stream (river or creek).

Thalweg: The deepest and fastest moving portion of a stream.

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Total suspended solids (TSS): Portion of solids retained by a filter.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

1-DMax or 1-day maximum temperature: The highest water temperature reached on any given day. This measure can be obtained using calibrated maximum/minimum thermometers or continuous monitoring probes having sampling intervals of thirty minutes or less.

303(d) list: Section 303(d) of the federal Clean Water Act, requiring Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

7-DADMax or 7-day average of the daily maximum temperatures: The arithmetic average of seven consecutive measures of daily maximum temperatures. The 7-DADMax for any individual day is calculated by averaging that day's daily maximum temperature with the daily maximum temperatures of the three days before and the three days after that date.

Acronyms and Abbreviations

BCD	Benton Conservation District
Bureau	U.S. Bureau of Reclamation
BMP	Best management practice
DO	(see Glossary above)
e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
MQO	Measurement quality objective
NIST	National Institute of Science and Technology
NWIS	National Water Information System
PCB	Polychlorinated Biphenyls
QA	Quality assurance
QC	Quality control
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	(See Glossary above)
TSS	(See Glossary above)
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area
YN	Yakama Nation

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony forming units
cms	cubic meters per second, a unit of flow
dw	dry weight
ft	feet
m	meter
mg	milligram
mgd	million gallons per day
mg/L	milligrams per liter (parts per million)
mL	milliliter
mmol	millimole or one-thousandth of a mole
NTU	nephelometric turbidity units

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms *precision* and *bias* be used to convey the information associated with the term *accuracy*. (USGS, 1998)

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella. (Kammin, 2010)

Bias: The difference between the sample mean and the true value. Bias usually describes a systematic difference reproducible over time and is characteristic of both the measurement system and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI). (Kammin, 2010; Ecology, 2004)

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process. (USGS, 1998)

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured. (Ecology, 2004)

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards but should be referred to by their actual designator, e.g., CRM, LCS. (Kammin, 2010; Ecology, 2004)

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator. (USEPA, 1997)

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator. (USEPA, 1997)

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run. (Kammin, 2010)
Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system. (Kammin, 2010; Ecology 2004)

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean. (Kammin, 2010)

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading. (Kammin, 2010)

Data quality indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity. (USEPA, 2006)

Data quality objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. (USEPA, 2006)

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010)

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability, and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).

- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier – data are usable for intended purposes.
- J (or a J variant) – data are estimated, may be usable, may be biased high or low.
- REJ – data are rejected, cannot be used for intended purposes.
  (Kammin, 2010; Ecology, 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set. (Ecology, 2004)

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero. (Ecology, 2004)

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis. (USEPA, 1997)

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport. (Ecology, 2004)

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples. (Kammin, 2010)

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. (USEPA, 1997)

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects. (Ecology, 2004)

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

Measurement result: A value obtained by performing the procedure described in a method. (Ecology, 2004)

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples. (Ecology, 2004; Kammin, 2010)

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:
%RSD = (100 * s)/x
where s is the sample standard deviation and x is the mean of results from more than two replicate samples. (Kammin, 2010)

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all “parameters.” (Kammin, 2010; Ecology, 2004)

Population: The hypothetical set of all possible observations of the type being investigated. (Ecology, 2004)

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:
[Abs(a-b)/((a + b)/2)] * 100
where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled. (USGS, 1998)

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population. (USGS, 1998)

Sample (statistical): A finite part or subset of a statistical population. (USEPA, 1997)

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit. (Ecology, 2004)

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method. (USEPA, 1997)

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency. (USEPA, 1997)

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010)

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis. (Kammin, 2010)

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning. (USEPA, 2006)

References for QA Glossary

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