Vancouver Island Community Flow Monitoring Network Pilot Project

STATION SUMMARIES

2022-23

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Nanaimo, BC

February 2023

HABITAT CONSERVATION TRUST FOUNDATION
BRITISH COLUMBIA CONSERVATION FOUNDATION
Freshwater Fisheries Society of BC
BRITISH COLUMBIA Community Gaming Grants

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I. BACKGROUND

This document summarizes the seven pilot gauging stations included in the Community Flow Monitoring Network (CFMN) for 2022. The CFMN is a new, community flow monitoring support network for the east coast of Vancouver Island, currently being coordinated by BCCF in partnership with the BC Ministry of Environment (ENV). The seven pilot stations were included as a test of project feasibility, data accuracy, and possible expansion to other regions for this community-supported monitoring model. A map of the seven stations and their locations on Vancouver Island is shown in Figure 1. Funding to support Year 1 of this program was provided by the BC Community Gaming Grant, Habitat Conservation Trust Foundation, Freshwater Fisheries Society of BC, Pacific Salmon Foundation, RBC Foundation Tech for Nature, BC Ministry of Environment, and community volunteers.

Each pilot community station is summarized with a brief history and historical data review, quality control observations, site photos, and the most recent results. Many stations have been in place since the early 2010's; however, issues have been identified with historical record-keeping and results. Several stations received a 2012-2015 data summary report (prepared by J. Craig, BCCF, 2016), after which the stations gradually declined in upkeep due to lack of funding and staff to support monitoring efforts. Some interim monitoring took place between 2015-2021, but this monitoring was not consistent. This historical data is being processed within the Aquarius Time-Series database (aqrt.nrs.gov.bc.ca) as time and funding allows.

Going forward, the focus for the CFMN is to help upload, quality check, and eventually publish streamflow datasets (with a focus on low-flow conditions) for community stations, per RISC guidelines to at least Grade "C", making community data more accessible, defensible, and applicable to a wide variety of uses.

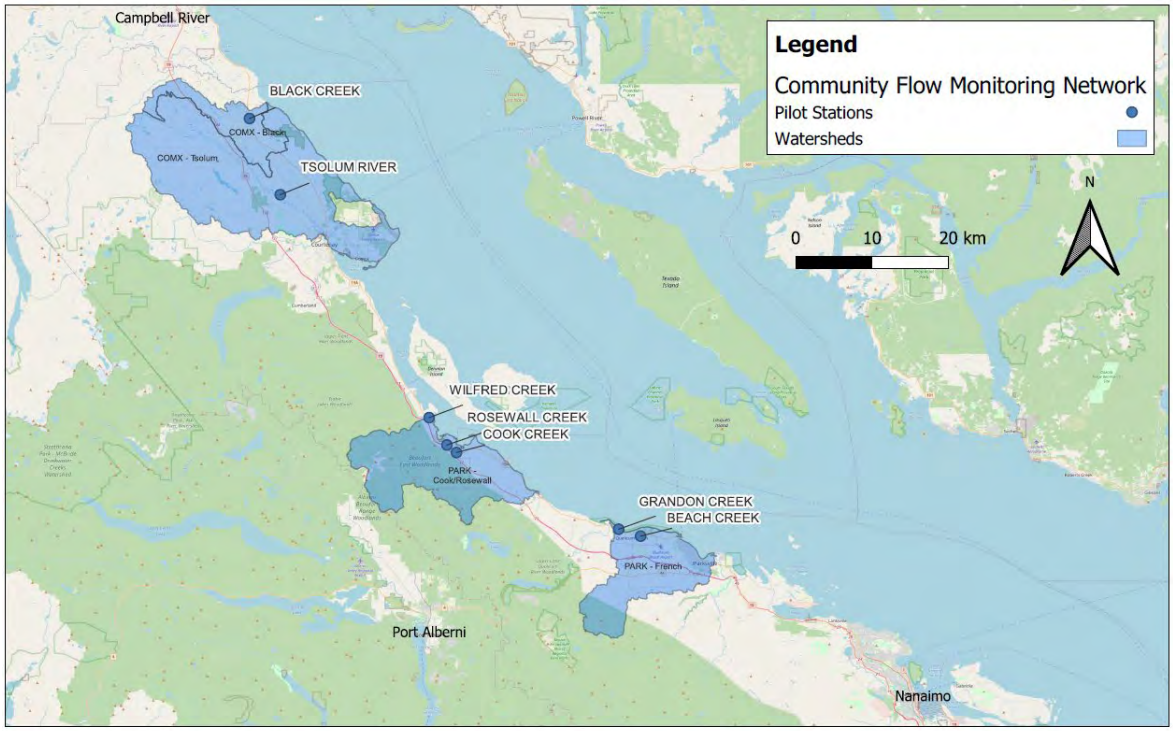


Figure 1. Pilot stations included in the Community Flow Monitoring Network for 2022-23.

RISC Guidelines

All data collected as part of the CFMN will follow the provincial RISC standard for hydrometric data collection to a minimum Grade C quality. RISC grading helps ensure the quality and accuracy of data produced by community members. A provincial standard is used to ensure that government programs, contractors, and partners have uniform guidelines for the collection of hydrometric data, and to facilitate the maintenance of the hydrometric data archive in Aquarius (RISC 2018).

The criteria for RISC Hydrometric standards for stage and discharge data are shown in Figure 2.

Data Quality Indicator	Standard Grade for Discharge Data					
	Grade A/RS	Grade A	Grade B	Grade C	Grade E (Estimated)	Grade U (Unknown data quality)
Instrumentation						
Meter calibration (When applicable)	N/A	Meter calibrated, and the validity of calibration is confirmed	Meter calibrated, and the validity of calibration is confirmed	Meter calibrated, and the validity of calibration is confirmed	Meter previously calibrated but validity of calibration is not confirmed	Undefined
Meter field verification (When applicable)	N/A	At least annually	At least annually	Less often than annually	See Notes below	Undefined
Water level gauge reading/sensor accuracy	Either 3 mm or 0.2% of effective stage, whichever is greater	Either 3 mm or 0.2% of effective stage, whichever is greater	Either 5 mm or 0.2% of effective stage, whichever is greater	1 cm or better	See Notes below	Undefined
Field Procedure						
Minimum number of benchmarks	3	3	3	3	See Notes below	Undefined
Number of verticals in manual flow measurements when current meter is used	N/A	20 or more (if sufficient channel width to meet minimum flow meter panel widths) and not more than 10% of total flow in each panel	20 or more (if sufficient channel width to meet minimum flow meter panel widths) and not more than 10% of total flow in each panel	10 or more (if sufficient channel width to meet minimum flow meter panel widths) and not more than 20% of total flow in each panel	See Notes below	Undefined
Number of manual flow measurements per year	Minimum of one field measurement for rating verification	5 or more over adequate range of streamflows	3 or more over adequate range of streamflows	2 or more over adequate range of streamflows	See Notes below	Undefined
Number of benchmark elevation and ref. gauge elevation level checks per year	2 or more, or at least once when ref. gauge and the benchmarks have been documented to be stable	2 or more, or at least once when ref. gauge and the benchmarks have been documented to be stable	2 or more, or at least once when ref. gauge and the benchmarks have been documented to be stable	1 or more	See Notes below	Undefined
Data Calculation and Assessment						
Discharge rating accuracy /Rating curve shift deviation threshold	<5%	<7%	<15%	<25%	See Notes below	Undefined
Data and calculation reviewed for anomalies	Yes	Yes	Yes	Yes	See Notes below	Undefined
Results are compared with other stations and/or other years for consistency	Yes	Yes	No	No	See Notes below	Undefined

Figure 2. RISC Grade Standards for discharge (flow) data collection.

II. CONSERVATION FOCUS

Streamflow monitoring is critically important as Vancouver Island is observing periods of longer, more intense drought due to climate change (Rodenhuis et al. 2009) as well as continued population growth and development (VIEA 2021). Changes to the timing and seasonality of streamflow may impact the productivity and survival of aquatic species of concern (Fleming et al. 2007). Low flow conditions are a limiting factor for fish habitat suitability, migration, and survival (Levy & Slaney 1993; Aadland 1993; McCabe 2011; Neuman & Newcombe 1977). Many smaller streams on Vancouver Island have not had any long-term monitoring, even though they have historically supported valuable fish stocks and have been subject to intensive water use (Stenhouse 2012).

Streams with high surface- and groundwater-withdrawal pressures are at greater risk of impact on environmental flow needs (EFN). Streams with drainage areas <100 km^2 are often subject to significant flow alterations due to development, agricultural, and domestic water uses (Bradford & Heinonen 2008). Despite their prevalence across the landscape and proximity to urban communities, drainages <100 km^2 comprise only about 15% of the basins actively gauged in Canada (Bradford & Heinonen 2008).

If a stream "is or is likely to become so low that the survival of a population of fish in the stream may be or may become threatened", the EFN regulation under BC's *Water Sustainability Act* provides justification for the enforcement of orders concerning the diversion, rate of diversion, time of diversion, use or storage of water from a stream (or aquifer hydraulically connected to the stream), regardless of FITFIR precedent.

Community flow monitoring tends to be conducted in relatively small, urbanized streams. Several of these streams also support declining stocks of wild and hatchery-raised salmon and trout. Monitoring is important to understand the availability, variation, and timing of streamflow for aquatic habitat, providing a foundation for responsible decision-making, policy development, and ecosystem protection (Government of Canada 2013).

Conservation education and community engagement about EFNs are intended outcomes of this project. We accomplish this by engaging volunteers in hands-on stream stewardship through application of hydrometric monitoring techniques. We also help streamkeeper groups incorporate flow data into their monitoring and habitat restoration projects. Dedicated on-the-ground site visits and checkups by volunteers can alert authorities to potential EFN or low-flow problems more rapidly than if a problem were to be discovered incidentally. By recording defensible data during critical periods, the accessibility, reliability and accuracy of flow records for otherwise ungauged streams is improved.

Aside from collecting and sharing streamflow and water temperature data for under-studied, fish-bearing streams, the broader goals of this project include:

- Providing environmental education and awareness to community members;
- Providing skills training to streamkeeper groups that can be applied to restoration projects;
- Monitoring local impacts of climate change;
- Monitoring impacts of urban and industrial development or land use change; and,
- Helping protect and conserve habitat for aquatic life.

Protection of aquatic habitat is an indirect outcome of this project. This is to be achieved through heightened local awareness of stream conditions, sharing of information about fish habitat requirements through the network, monitoring seasonal changes in habitat condition, and receiving restoration project

support or guidance from the network coordinator and peer mentors. Knowledge transfer happens through hands-on field training, virtual community presentations and workshops, verbal and email communications, and a manual of standard operating procedures that volunteers will be able to reference long past the lifetime of this project. By having access to a collaborative network, volunteers have a forum to voice concerns, generate ideas for action, and access resources to support watershed protection activities.

Because each streamkeeper group involved in the network has unique conservation issues specific to their local stream, a blanket approach to conservation action across all sites is not practical. Instead, groups require individualized priorities be set for their local stream. Through participation in the network, each streamkeeper group has developed a mission statement and conservation objective for their monitoring station, with a direct use in mind for the data. Having an "end-goal" for data is the first step in any monitoring program, as it helps strengthen each monitoring group's activities going forward.

Examples of some of the conservation objectives developed by different streamkeeper groups doing flow monitoring have included:

- Monitoring fish habitat (riffles, pools, woody debris submersion) and the changes over time under different flow conditions, to establish a baseline flow value below which fish habitat and connectivity is severely compromised or threatened;
- Comparing year-to-year flow conditions to better understand extremes (high- and low-flow), how these extreme values impact fish habitat conditions, how climate change may exacerbate these impacts, and what we can do to adapt;
- Quantifying total contributions to mainstem creek flow from smaller tributaries, in order to better advocate for protection of restoration of riparian buffers and conduct landowner outreach;
- Presenting data at local community and council meetings to demonstrate fluctuations in local flow, and emphasize the importance of permeable surfaces to help attenuate storm flows;
- Maintaining a record of the timing and seasonality of stage & discharge conditions to help inform future riparian restoration projects and develop habitat- or species-specific site prescriptions and planting recommendations;
- Correlating flow results with water quality samples to better understand the pollutant load and dilution capacity of the stream, e.g. loading rates and transport or mixing of non-point source pollutants that threaten the survival of aquatic life;
- Quantifying the positive effects of a streambank restoration project by calculating sediment loading before and after a restoration project (corrected for, or correlated with, flow conditions);
- Refining local water balance estimates in the interest of community water conservation, and using local data to help make residents aware of how groundwater pumping, wetland draining and/or deforestation may impact their water resources; and, encouraging residents to take responsibility for promoting, monitoring, conserving, and restoring their watershed.

Recognizing that HCTF does not fund long-term monitoring efforts, this project is a 3-year initiation of the community monitoring network, with a clear start- and end- timeline for HCTF support. HCTF support is intended to provide a robust foundation for network establishment, collaborative stewardship, and support for community action.

III. STATION RESULTS

Beach Creek at Hemsworth Road – 08HB0031

Station Location

The Beach Creek station was first installed on July 23, 2020 by BCCF and the Qualicum Beach Streamkeepers (QBSK) downstream of the Hemsworth/Chester Road – Village Way walking path. The logger is mounted on the downstream face of the walking path culvert, which was replaced by the Town of Qualicum Beach in 2015-16.

Equipment

The logger used to record stage is a submersible pressure sensor (Solinst Edge levelogger M5). The logger (S/N: 2122468) was installed in a steel pipe (approximately 90 cm tall), with a locking cap (Figure 3). Inside the housing, the logger is secured to a piece of aircraft cable looped through the logger's cap. The logger itself rests on the bottom of the housing; due to low water levels in summer it cannot be suspended above the base of the logger housing. The climate dataset used from 2020 – 2022 for barometric compensation was the Qualicum Beach Airport (Station ID 45627), < 5 km away. A Solinst barologger was installed under a nearby streamkeeper's carport on February 10, 2023 to record at 15-minute intervals and match the levelogger record (Figure 4), which will be used for data compensation going forward.

Control

The station's Low Flow section control is a riffle located approximately 1.5-3 m downstream from the station. This riffle is very shallow in late summer and is influenced by growth of in-stream vegetation including reeds and grasses. This shallow riffle is highly mobile and prone to disturbance by walking across the streambed, or accumulation of debris. The High Flow section control is located just downstream of this riffle, at a small riprap cascade before the creek takes a sharp left bend. The High Flow section control appears less prone to movement due to the large boulders (Figure 5-6).

Reference Gauge and Benchmarks

The reference staff gauge is a Water Survey Canada 1 m gauge which was installed next to the levelogger housing on a wooden backing. Three benchmarks were installed with the logger in July 2020 and surveyed on the same day. However, this survey contained errors and was not an accurate record for established survey points. The benchmarks have since been re-surveyed and corrected (in 2022), and an additional two benchmarks were added to the levelogger housing and the staff gauge. The primary benchmark is drilled in to the footpath concrete face, on left bank. Two other benchmarks exist, one at the base of a live tree and one on the woody debris near the High Flow section control.

Site Features

The substrate in the vicinity of the logger is primarily cobbles, small gravel, sand and silty mud, which is prone to deposition near the logger. The reach is straight through the culvert but sinuous upstream and downstream. The creek supports several cutthroat trout, rainbow trout, and coho fry and parr through the summer months (D. James, pers. comm, September 2022). There are some issues with low flows impacting fish passage and habitat quality, which the QBSK are actively seeking to address.

Continued Monitoring

It is recommended to continue monitoring Beach Creek, if the issues noted below can be addressed. Beach Creek benefits from a very dedicated stewardship group with a good grasp of technical concepts and motivated members to monitor in all conditions. The current diversion license for withdrawal of surface

water from Beach Creek is awarded to the Town of Qualicum Beach (Lawn & Garden watering) near the Memorial Golf Club for a total of 32,810 m^3/year. A separate withdrawal license for private irrigation directly downstream of the logger location is status Abandoned, while a separate withdrawal permit on Violetta Creek (tributary to Beach Creek) is status Cancelled. The local aquifer (#217; sand and gravel underneath till) is classified with a Moderate vulnerability and is correlated to 33 groundwater wells, with an additional 284 wells within mapped extent (Figure 7). Aquifer #217 is classified as Less Likely to be hydraulically connected.

Summary

The logger's first accurate stage measurement was recorded on July 23, 2020 at 12:00 PM PST (UTC-8) (Figure 8) and it continues to record. Upon reviewing historical notes and data, the following issues with station equipment and data collection have been noted for Beach Creek:

1) **The station's control is highly mobile.**

   Care must be taken to avoid disturbing the Low Flow section control. Signage could be placed above the logger to inform visitors about the importance of not disturbing the site.

2) **Water level dips very low in late summer.**

   The station could be moved upstream to the deep pool below the Village Way culvert (where bucket measurements are conducted) if low flow conditions continue to impact the logger data quality; however, the pool also has a mobile control. New benchmarks and a new rating curve would need to be established. Moving the station is recommended only if site challenges severely impact data quality and/or drying of the sensor occurs.

3) **The site sees frequent foot traffic but does not have a trail camera.**

   Purchasing and installing a motion-triggered or daily-capture trail camera could help with A) validating stage readings between site visits, B) observing for control changes, and C) capturing interesting flow events. Care should be taken to adjust the time of this camera to match the time measured by the logger, so the time series data can be validated.

4) **Few historical notes were kept about adjustments made during cleaning of debris and sediment around the logger, making Sensor Reset Corrections challenging.**

   More consistent notes should be kept about the clearing of debris before and after logger download. This site is prone to accumulation of silty sand and organic debris in and around the logger pipe, which has caused issues with logger stability in the past. The aircraft cable attachment could also be swapped out for a more stable mounting system (e.g., PVC pipe, aluminum T-post) which would not be as susceptible to movement with sediment deposition.

5) **There are some inconsistencies in site photos.**

   Past site photos did not always capture the staff gauge, station control, or monitoring points. In recent months, however, this has greatly improved. A formal record of monitoring points should be established for the station and site photos should always be captured at these locations.

This summary should be used to guide decisions about historical data interpretation, and to help inform improvements to continued monitoring. The data grade for Beach Creek meets at least "C" and possibly B for 2022, but remains "U" (Unknown) for past years (Table 1; Figure 9-10). Data collection will keep improving in 2023 through involvement in the Community Flow Monitoring Network.

Figure 3. Beach Creek logger in July 2020 (Left) and August 2022 (Right).

Table 1. Beach Creek historical data summary (Grade C RISC Standard in green).

Year	Overall data grade	Data grade goal	Reference Gauge Present?	Minimum 3 Benchmarks Present?	Benchmarks Surveyed?	Paired Stage-Discharge visits per year	Paired Stage-Discharge visits per year meeting RISC standards	Stage only visits per year	Discharge only visits per year	Field Check with Ministry completed	Highest Rating Deviation (%)	Mean Annual Discharge (m^3/s) (Estimate using Provisional Data)	Notes
2020	U	N/A	Yes	Yes	1/1 (Errors)	3/2	3/2	0	0	No	+14.02	N/A (incomplete year)	
2021	U	N/A	Yes	Yes	0	5/2	2/2	0	0	No	+8.64	~0.043	
2022	C	C	Yes	Yes	1/1	9/2	5/2	4	0	Yes	+11.48	~0.018	Possibly Meets Grade B
												MAD ~ [N/A] m^3/s	

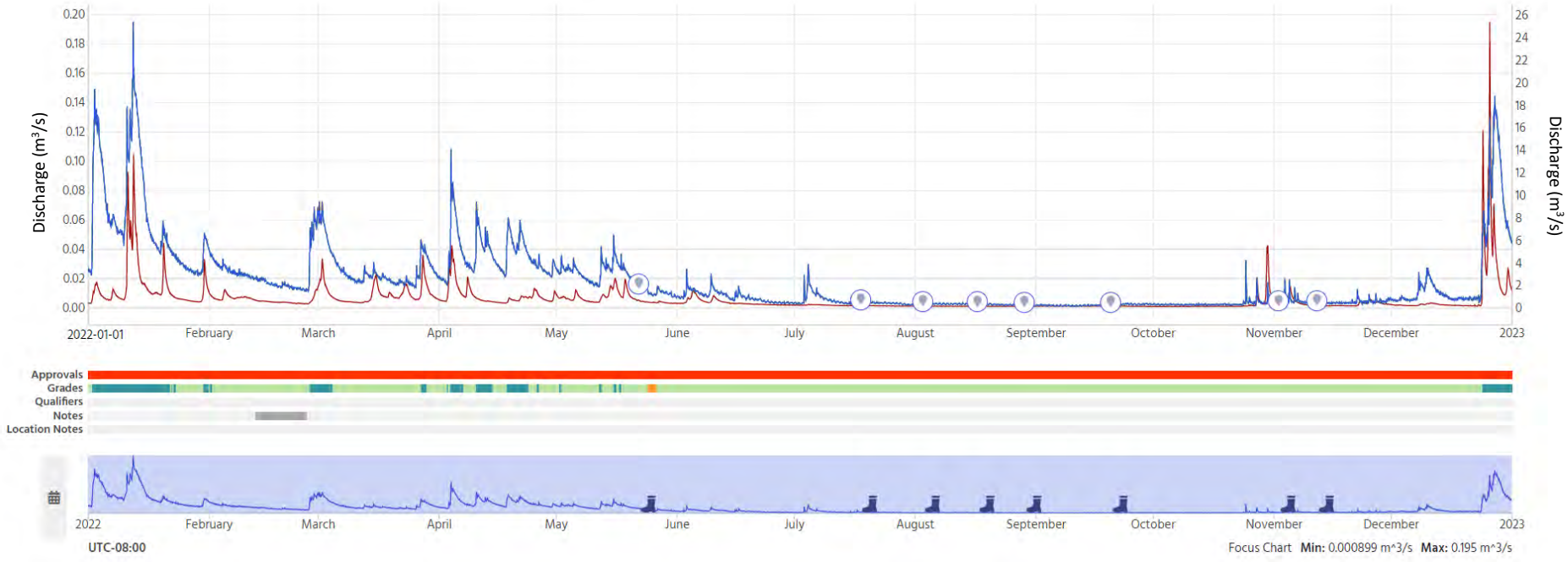


Figure 4. Beach Creek discharge data for 2022 (in blue), calculated using the active rating in Aquarius (PROVISIONAL DATA); results on left-hand Y axis. Nile Creek for comparison (in red), results on right-hand Y axis.

Table 2. Beach Creek 2022 discharge summary.

Date/Time (PST)	Discharge (m^3/s)	Stage (m)	Control Condition	Discharge deviation (%)	Discharge uncertainty (% or Qualitative)	Notes
2022-02-15 15:00	0.029	9.248	Clear	+70.10	16.8	QBSK (training)
2022-05-22 15:00	0.015	9.243	Unspecified	-1.13	19.1	BCCF, QBSK
2022-07-18 12:30	0.004	9.201	Unspecified	+7.65	17.0	QBSK (training)
2022-07-18 12:30	0.005	9.201	Unspecified	+24.29	Good	QBSK (training)
2022-07-18 12:45	0.005	9.201	Unspecified	+34.56	16.5	ENV (training)
2022-08-03 10:30	0.003	9.197	Low Flow Section Control - veg	-2.79	Good	QBSK
2022-08-17 11:00	0.002	9.195	Low Flow Section Control - veg	-7.36	Good	BCCF
2022-08-29 10:30	0.002	9.193	Unspecified	+1.07	Good	QBSK
2022-09-20 14:00	0.003	9.191	Low Flow Section Control - veg	+6.64	Good	BCCF, QBSK
2022-11-02 14:45	0.003	9.196	Unspecified	+11.48	Good	QBSK
2022-11-12 10:30	0.003	9.199	Unspecified	+0.98	Good	QBSK

November 20, 2020 / High Flow Section Control

August 17, 2021 / Low Flow Section Control

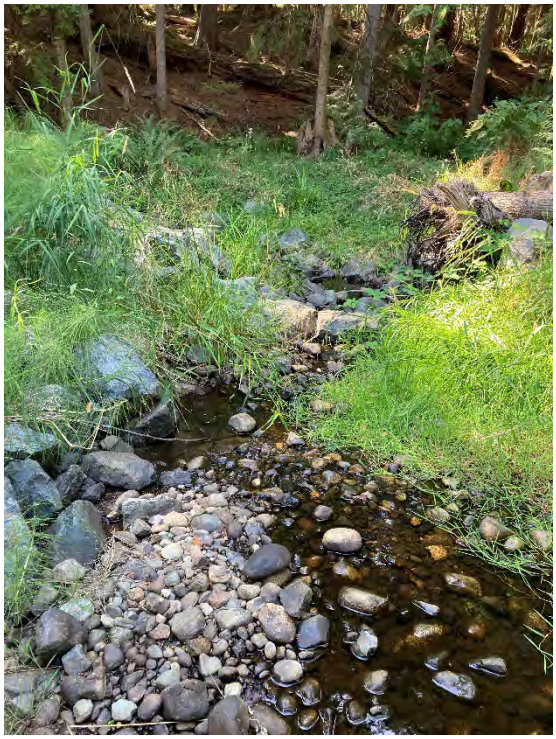
July 28, 2022 / Low Flow Section Control

August 17, 2022 / Low Flow Section Control

September 20, 2022 / Low Flow Section Control

December 26, 2022 / High Flow Section Control

Figure 5. Beach Creek, looking across station from right bank towards Village Way.



August 17, 2021 / Low Flow Section Control

July 28, 2022 / Low Flow Section Control

August 24, 2022 / Low Flow Section Control

December 26, 2022 / High Flow Section Control

Figure 6. Beach Creek, looking downstream at control from walkway above station.

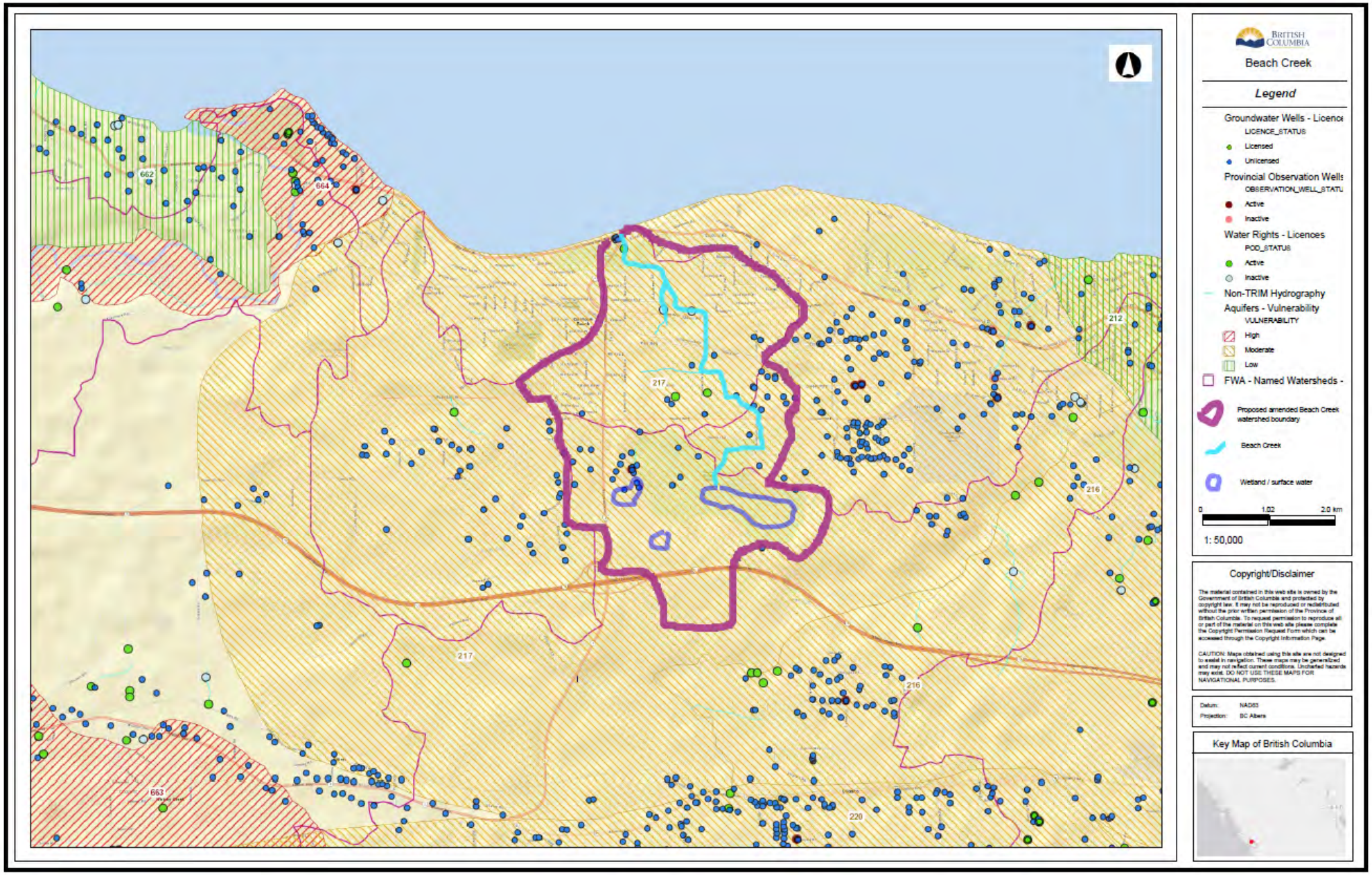


Figure 7. Beach Creek groundwater wells & licensed water demand (current to February 2023) with proposed new watershed boundary based on Town of Qualicum Beach OCP drawings of Beach Creek and digital elevation models (FWA hydrography removes connectivity from Beach Creek to wetlands at Pheasant Glen Golf Course).

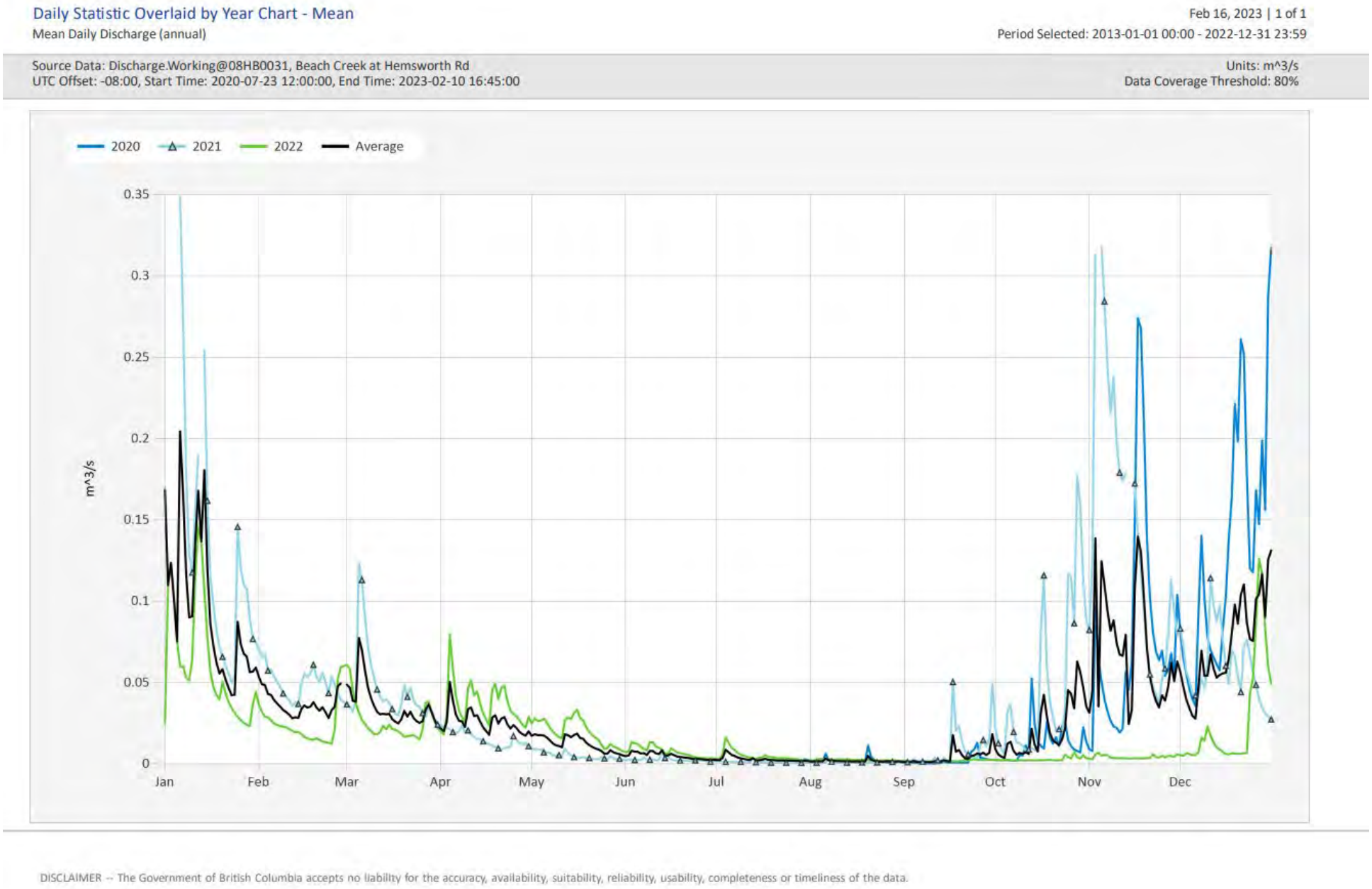


Figure 8. Beach Creek mean daily discharge for July 2020 – December 2022, as calculated using the active rating in Aquarius (PROVISIONAL DATA).

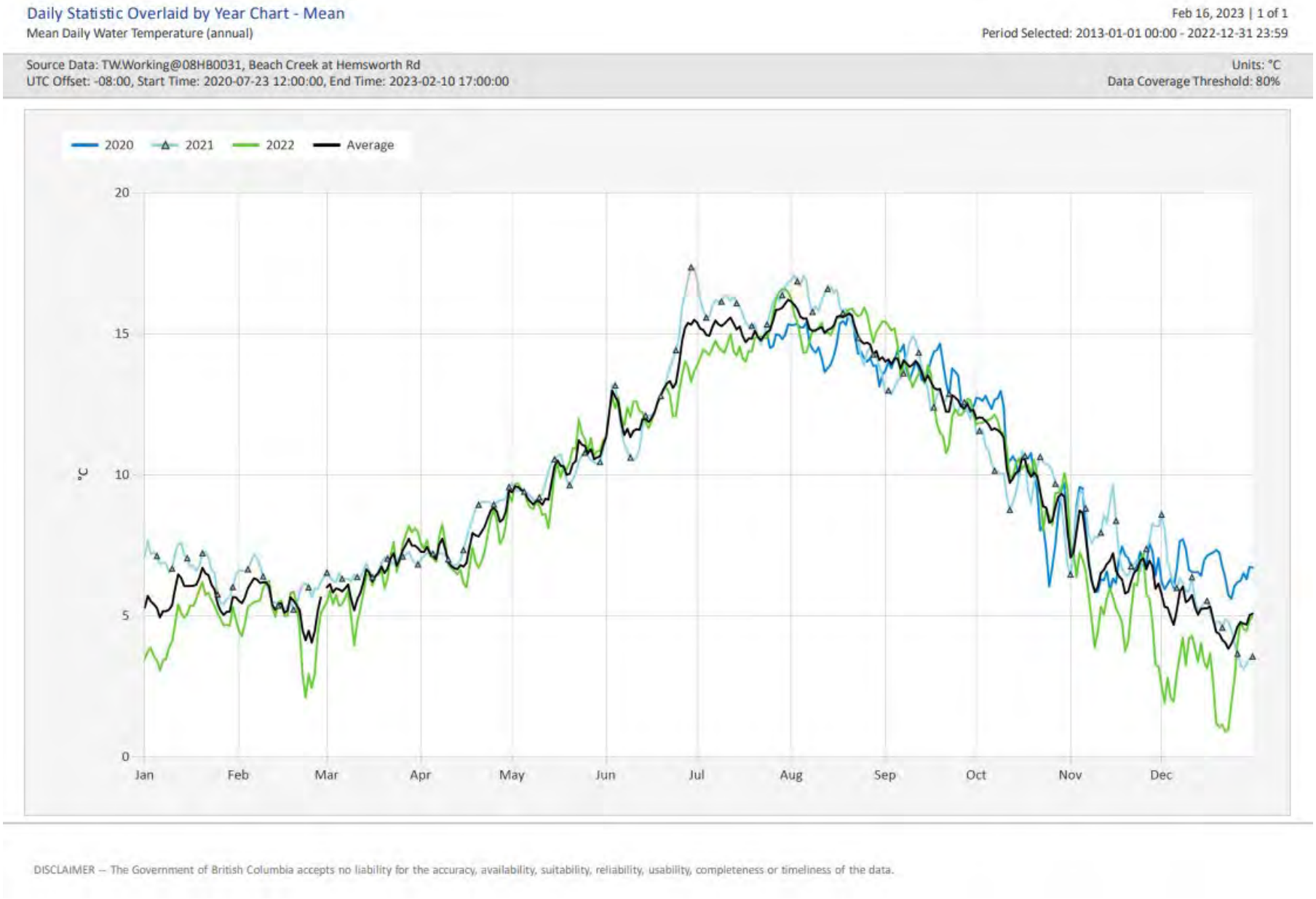


Figure 9. Beach Creek mean daily water temperature for July 2020 – December 2022.

Grandon Creek at Crescent Rd W – 08HB0011

Station Location

The Grandon Creek station was installed on August 17, 2012 by BCCF and the Qualicum Beach Streamkeepers (QBSK) downstream of Crescent Rd W in Qualicum Beach. The logger is located down a steep embankment and attached to a concrete culvert outlet above a series of weirs. The station is bordered by two private properties, and is approximately 75 m upstream of where Grandon Creek drains onto the beach. The station is not tidally influenced. The mouth of Grandon Creek is approximately 95 m southeast of Seaside Nature Park, also bordered by private properties.

Equipment

The logger used to record stage is a submersible pressure sensor (Solinst Edge M5 Levelogger). The logger (S/N: 2010569) was originally installed in a steel pipe (approximately 60 cm tall), with a locking cap (Figure 10). Inside the housing, the logger is secured to a piece of 1" PVC pipe with electrical tape. The climate dataset used from 2012 – 2022 for barometric compensation was the Qualicum Beach Airport (Station ID 45627), < 5 km away. A Solinst barologger was installed under a nearby streamkeeper's carport on February 10, 2023 to record at 15-minute intervals and match the levelogger record going forward (Figure 11).

Control

The station has an engineered control. The station's engineered control is a weir with a center notch and two side wing walls. During low flow, water flows out the weir notch only. At moderate flows, water overtops the notch and flows over the central wall. At high flows, the side wing walls can become covered and flow is incredibly turbulent, overtopping all weir steps below the station. The weir has remained relatively stable since 2012 (Figures 12-13). A stormwater outlet is located directly above the logger, which means this station has additional inputs of water above and beyond that which is coming downstream in the creek; this has never been quantified, but will occur only during rain events where water is washing into the storm drain. The drain is often covered with sand/mud after storms.

Reference Gauge and Benchmarks

The reference staff gauge is a Water Survey Canada 1 m gauge which was installed directly on the concrete face of the culvert structure. The station does not have any benchmarks. The bottom of the levelogger housing pipe has a small plate where the levelogger sits, however this area is prone to deposition and has to be cleaned out due to silt and sand accumulation. A new staff gauge was installed in February 2023 to mimic the placement of the old staff gauge and improve low flow readings.

Site Features

The substrate in the vicinity of the logger is primarily cobbles, small gravel, sand and silty mud, which is prone to deposition near the logger. The reach is straight through the culvert but sinuous upstream and downstream (Figures 12-14). The creek supports cutthroat and coho fry and parr, and some adult spawners have previously been observed in the fall (D. James, pers. comm, 2021). At summer low flows, the weir notch makes upstream fish passage difficult to impossible, but downstream passage is possible. In summer, the weir pools serve as deep shaded habitat.

Continued Monitoring

It is recommended to continue monitoring Grandon Creek, if the issues noted below can be addressed. Grandon Creek benefits from a very dedicated stewardship group with a good grasp of technical concepts and motivated members to monitor in all conditions. The levelogger will likely need to replaced soon due to an aging battery.

A water license (#C024096) for ~13,994 m^3/year is currently issued to a private individual for Domestic water supply and private irrigation. The local aquifer (#217; sand and gravel underneath till) is classified with a Moderate vulnerability and is correlated to 33 groundwater wells, with an additional 284 wells within mapped extent (Figure 15). Aquifer #217 is classified as Less Likely to be hydraulically connected.

Summary

The logger's first accurate stage measurement was recorded on August 17, 2012 at 10:00 AM PST (UTC-8) (Figure 15) and it continues to record. Upon reviewing historical notes and data, the following issues with station equipment and data collection have been noted for Grandon Creek:

1) **The site is lacking benchmarks.**

   No benchmarks have been installed, however the station is naturally quite stable due to the presence of the weir structure. Some small shifts in the rating have been observed over time, but the site is overall quite consistent. Benchmarks could be installed to help with quality control at the site, especially since the area around the logger is prone to deposition.

2) **No records were kept about station control condition prior to 2022.**

   Written descriptions of the control condition and photographs from the same upstream and downstream views of the weir should be collected at every site visit. Specific photo points should be established, e.g. from the pool below the station looking directly upstream at the weir notch (cannot be accessed during high flow), or from left- or right-bank wing wall looking downstream (could be accessed even at high flow). Review historical photos for reference.

3) **Few consistent notes were kept about adjustments made during cleaning of debris and sediment around the logger, making Sensor Reset Corrections challenging.**

   More consistent notes must be kept about the clearing of debris before and after logger download. This site is prone to accumulation of small gravel in and around the logger pipe, which has caused issues with logger stability in the past. Deposition will always occur at this site.

4) **Field note-taking has been inconsistent (or nonexistent). There were many inconsistencies in Staff Gauge records, Site Visit and Measurement times and time zones.**

   Every site visit must include: time zone, site arrival time, stage reading, control condition, measurement start time, measurement end time, logger download details, site leave time. On occasions with high flow, discharge measurements were conducted but no staff gauge reading was collected; this should be avoided in future.

This summary can be used to help guide decisions about historical data interpretation and to help inform continued monitoring. Overall, the data grade for Grandon Creek is "U" (Unknown) (Table 3; Figures 16-17) but quickly improving towards "C". Data collection will keep improving in 2023 through involvement in the Community Flow Monitoring Network.

Figure 10. Grandon Creek logger in February 2014 (Left) and November 2022 (Right).

Table 3. Grandon Creek historical data summary (Grade C RISC Standard in green).

Year	Overall data grade	Data grade goal	Reference Gauge Present?	Minimum 3 Benchmarks Present?	Benchmarks Surveyed?	Paired Stage-Discharge visits per year	Paired Stage-Discharge visits per year meeting RISC standards	Stage only visits per year	Discharge only visits per year	Field Check with Ministry completed	Highest Rating Deviation (%)	Mean Annual Discharge (m^3/s) (Estimate using Provisional Data)	Notes
2012	U	N/A	Yes	No	0	4/2	2/2	0	2	No	+35.75	N/A (incomplete year)	
2013	U	N/A	Yes	No	0	2/2	2/2	0	0	No	+26.4	0.057	
2014	U	N/A	Yes	No	0	2/2	2/2	0	0	No	+9.72	0.149	
2015	U	N/A	Yes	No	0	0	0	1	0	No	N/A	0.122	
2016	U	N/A	Yes	No	0	0	0	0	0	No	N/A	0.158	
2017	U	N/A	Yes	No	0	4/2	3/2	0	1	No	+16.45	0.133	
2018	U	N/A	Yes	No	0	2/2	1/2	0	1	No	+13.13	0.146	
2019	U	N/A	Yes	No	0	3/2	0	0	0	No	+24.82	0.064	
2020	U	N/A	Yes	No	0	0	0	2	0	No	N/A	0.151	
2021	U	N/A	Yes	No	0	1/2	0	0	0	No	+91.8	0.134	Control issue at weir, requires shift correction
2022	U but improving	Grade C	Yes	No	0	3/2	2/2	4	0	No	+11.32	0.081	
												MAD ~ 0.120 m^3/s	

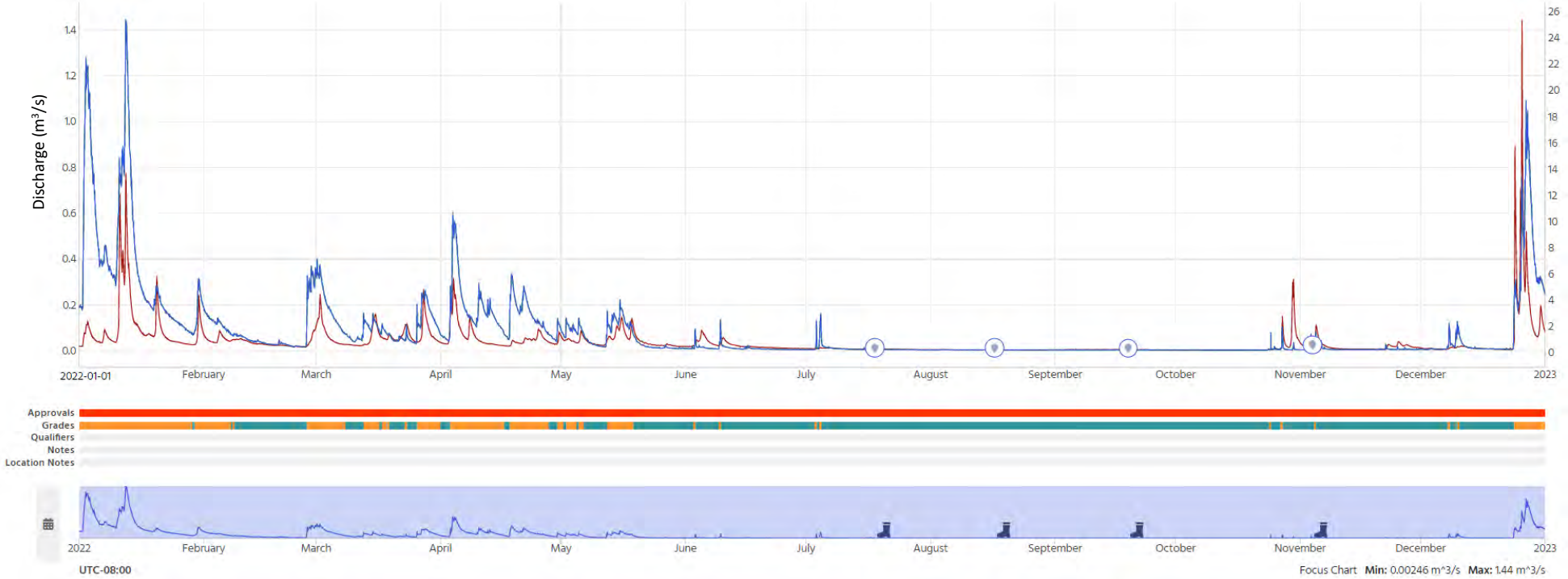


Figure 11. Grandon Creek discharge data for 2022 (in blue), calculated using the active rating in Aquarius (PROVISIONAL DATA); results on left-hand Y axis. Nile Creek for comparison (in red); results on right-hand Y axis.

Table 4. Grandon Creek 2022 discharge summary.

Date/Time (PST)	Discharge (m^3/s)	Stage (m)	Control Condition	Discharge deviation (%)	Discharge uncertainty (%)	Notes
2022-07-18 15:00	0.004 (Estimated)	0.210	Clear	-30.33	Estimate	Ministry estimate
2022-08-17 10:00	0.003	0.190	Clear	-4.77	Good	BCCF
2022-09-19 16:00	0.003	0.188	Clear	-11.32	Fair	BCCF, QBSK
2022-11-04 13:00	0.017 (Estimated)	0.240	Clear	+50.18	Fair	QBSK (practice)

a)

October 3, 2013 / Low Flow

February 17, 2014 / High Flow

b)

June 25, 2013 / Low Flow

December 19, 2014 / Moderate Flow

Figure 12. Grandon Creek, looking a) downstream at control from culvert mouth next to station (top); b) at control notch from left bank wing wall (bottom) (side-by-side views from similar angles).

June 13, 2017

July 29, 2019

August 17, 2021 / Note blockage in control

November 25, 2022

Figure 13. Grandon Creek, looking upstream at control from second weir step-pool.

a)

February 17, 2014 / High Flow

July 29, 2019 / Low Flow

b)

February 17, 2014 / High Flow

February 12, 2023 / Low Flow

Figure 14. Grandon Creek, upstream of Crescent Rd W and gauging station, looking a) upstream from park walking trail entrance before culverts (top); b) downstream at secondary culvert under walking trail entrance (side-by-side views from similar angles).

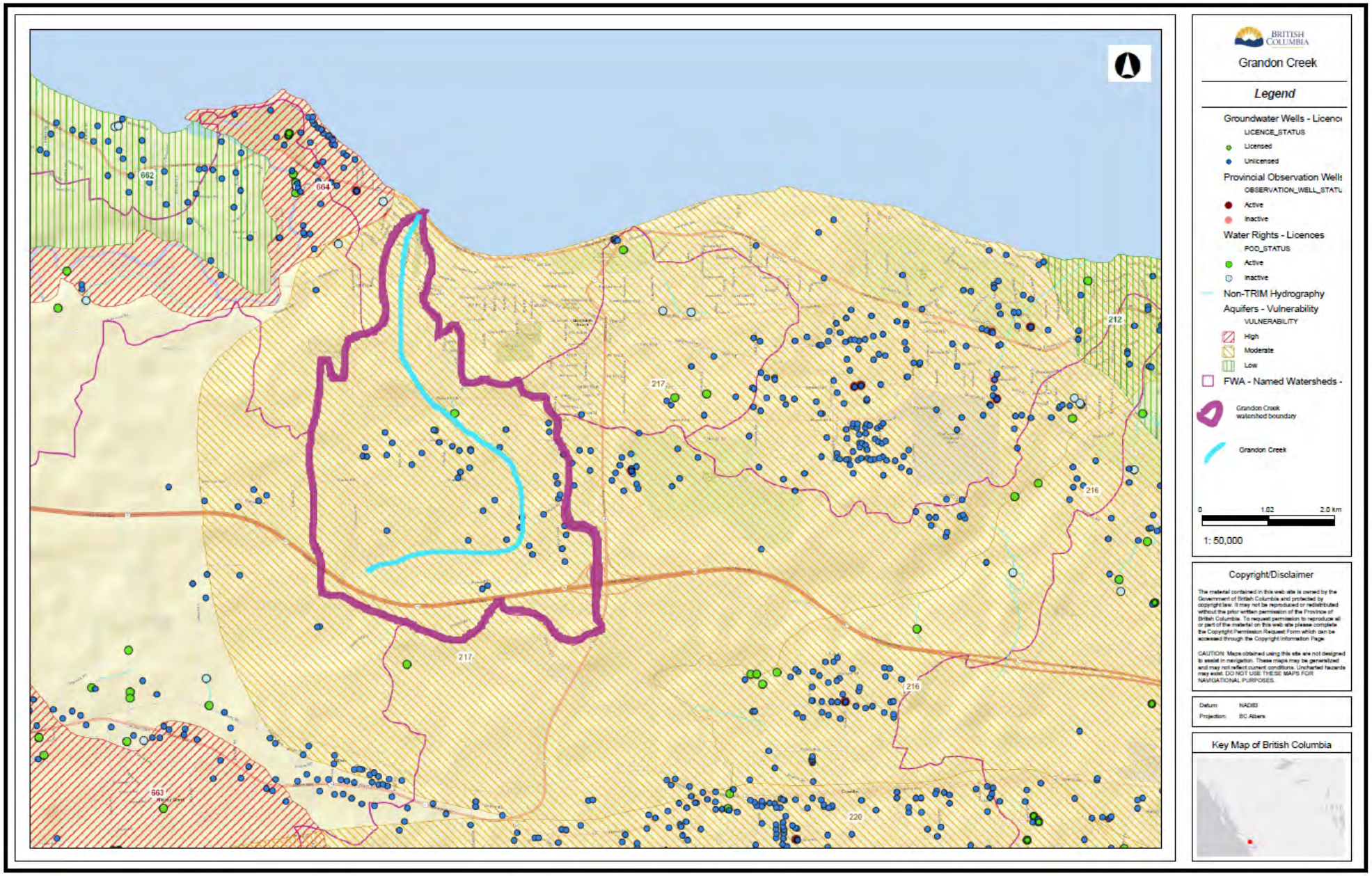


Figure 15. Grandon Creek groundwater wells & licensed water demand (current to February 2023).

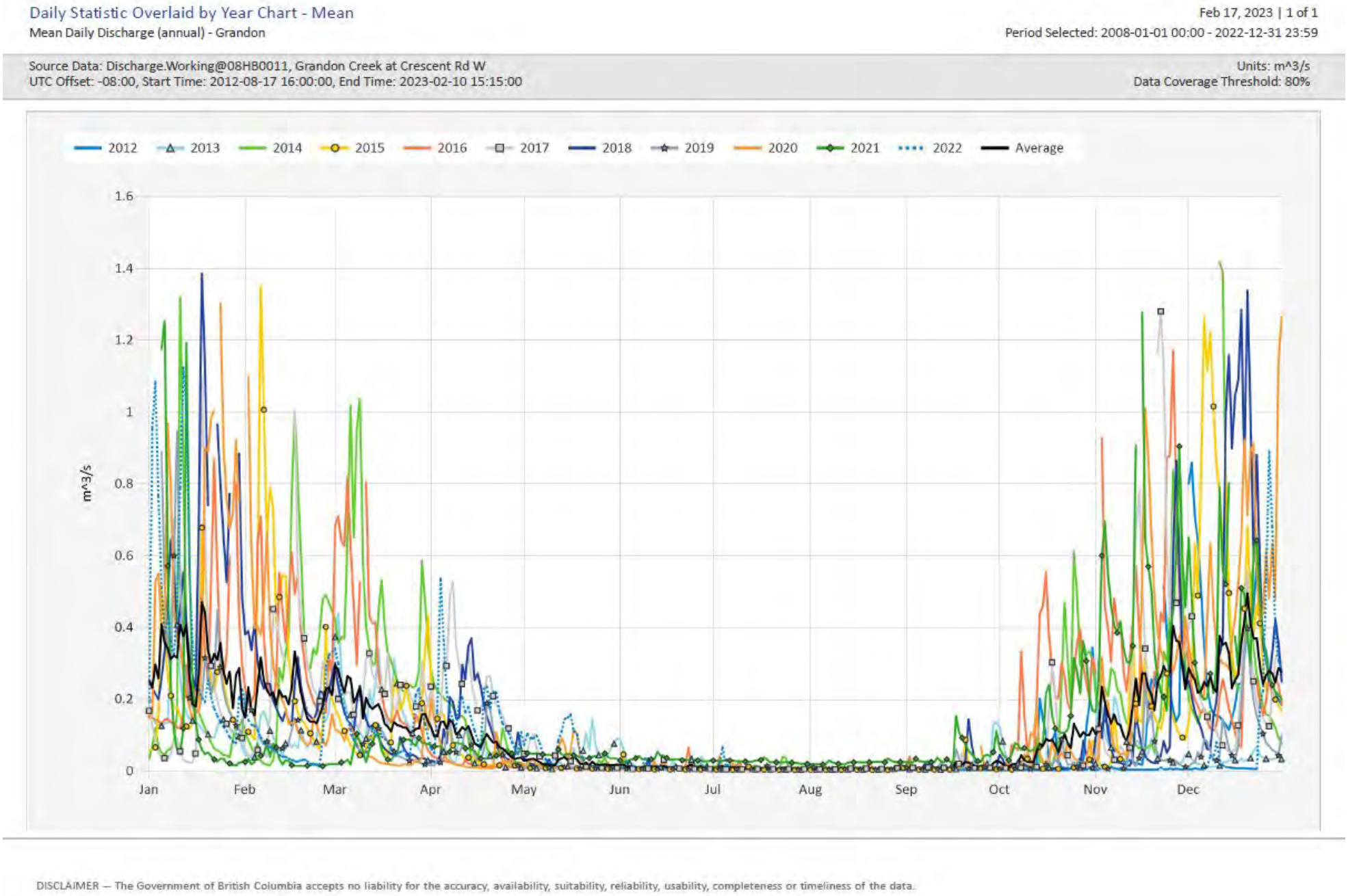


Figure 16. Grandon Creek mean daily discharge for August 2012 – December 2022, calculated using the active rating in Aquarius (PROVISIONAL DATA).

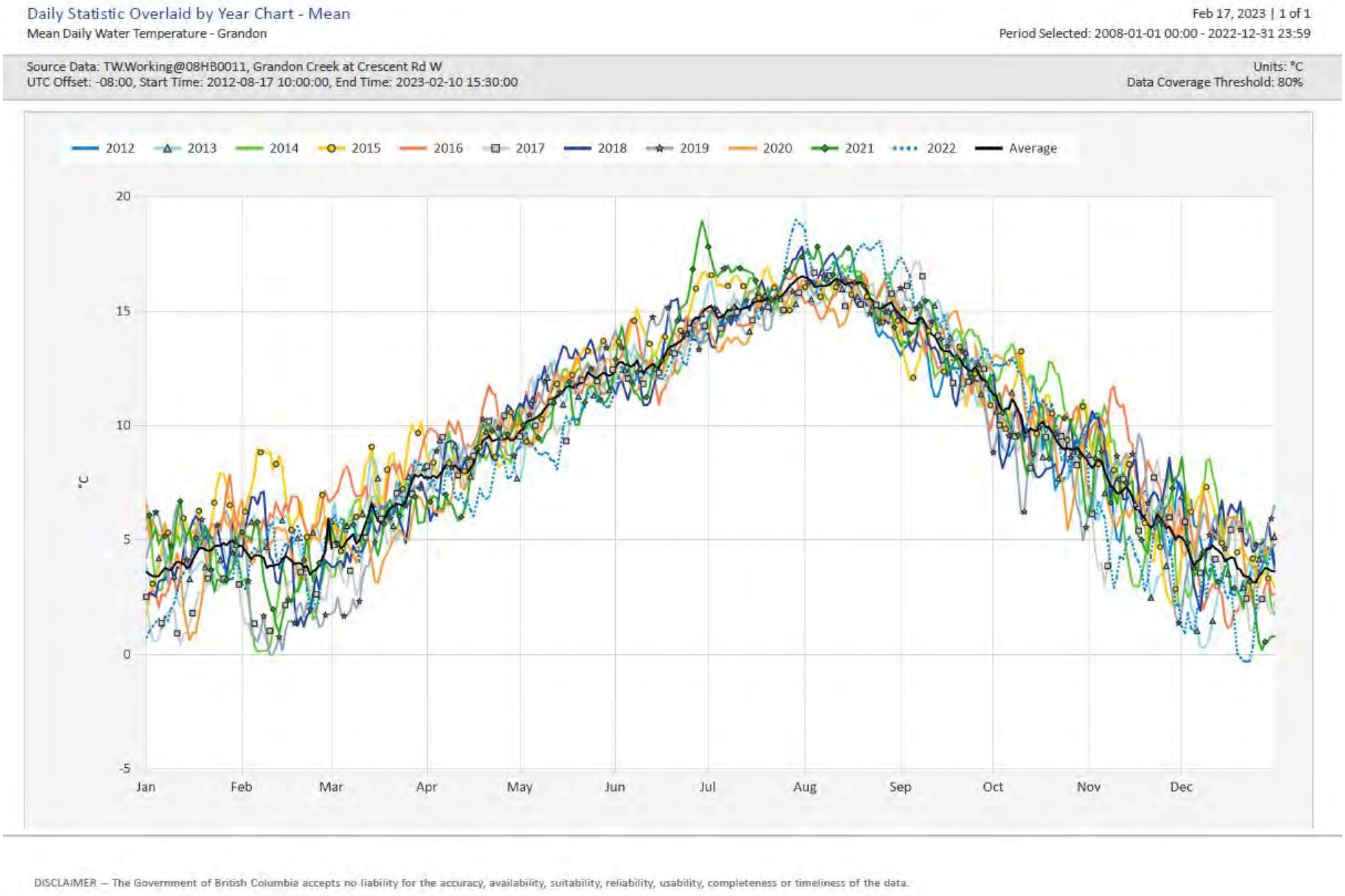


Figure 17. Grandon Creek mean daily water temperature for August 2012 – December 2022.

Cook Creek at HWY 19A – 08HB0032

Station Location

The historical Cook Creek station was installed on November 25, 2013 by BCCF and the Fanny Bay Salmonid Enhancement Society (FBSES) upstream of Hwy 19 next to the Cook Creek Forest Service Road. The historical logger was located down a steep embankment and attached to a large boulder. This station was operated from roughly 2014-2018, but difficulties with safety and site access prompted relocating the logger to a new location in 2018. The current logger is located near the junction of Hwy 19A and Cook Creek Road, upstream of the confluence with Chef Creek. The logger is located on left bank, upstream of the Hwy 19A bridge and just upstream from a beaver pond outlet which is the site of a historical MOTI restoration project. There was an existing staff gauge in this location related to the MOTI project (S. Wong, MOTI, pers. comm., 2020).

Equipment

The historical logger used to record stage was a submersible pressure sensor (Solinst levelogger Gold). The logger was installed in an aluminum pipe (approximately 70 cm tall), with a locking cap (Figure 18). Inside the housing, the logger was secured to a piece of aircraft cable looped through the logger's cap. Due to the logger make and model, an offset of 9.5 m needed to be applied to the logger data. A new Edge M5 levelogger (S/N: 2103798) was installed on July 19, 2022 due to a dead battery in the original logger, and the offset no longer applies. The logger pipe was also adjusted on this date to account for deposition in the area of the logger. The dataset used for compensation was the Bowser Elementary School barometric pressure (< 5 km away) until October 6, 2022, when a local barologger was moved to the Cook Creek location (Figure 19).

Control

The station's section control is a riffle located approximately 10-15 m downstream from the station. This riffle is quite shallow in late summer and is influenced by a large overhanging cedar tree on right bank. The Low Flow Section Control is characterized by a dry gravel bar along left bank, and a very shallow riffle on right bank where the point of zero flow (PZF) is located. The Low Flow Section Control accumulates leaf litter in late fall while water levels are low, which can influence the control condition and causes variable rating shifts. The Moderate Flow Section Control is characterized by a fully submerged riffle, which still influences the gauging equipment but is less prone to influences of the cedar tree on right bank or low-flow conditions. Channel control occurs at stages > 9.5 m, where the section control is completely submerged; channel control extends to roughly the highway bridge.

Reference Gauge and Benchmarks

The ~1.2 m reference staff gauge was pre-existing (installed by MOTI). The gauge was buckling due to wear and was re-mounted flush with the back panel in July 2022. Four benchmarks were installed with the logger in July 2022 and surveyed on the same day. They were re-surveyed within +/- 3 mm of the original established elevations in October 2022. Most of the benchmarks are located near the logger, although the primary benchmark is located downstream of the logger on the left bank bridge footing. The staff gauge was lost during a storm in winter 2022 (and BM4 with it). The staff gauge requires replacement during low water. Until it can be replaced, BM2 can be used as a submerged reference point.

Site Features

The substrate in the vicinity of the logger is primarily cobbles, gravel and sand, which is prone to deposition near the logger. The reach is generally quite straight with some cut banks (Figures 20-21). The

beaver pond outlet may cause some backwatering effect in the vicinity of the logger; thus, this threshold should be checked at various flow conditions. Cook Creek undergoes strong temperature fluctuations, reaching a maximum of ~ 22°C with diurnal fluctuations of +5°C not uncommon in summer. Because this location is a glide rather than a pool, the site warms quickly due to solar radiation.

Continued Monitoring

It is recommended to continue monitoring Cook Creek. The FBSES is undertaking some restoration works downstream of the gauging location. Beaufort Watershed Stewards have been involved in monitoring. This creek supports hundreds of coho fry and parr through the summer, which are frequently seen swimming near the transect reach. The FBSES installs a smolt trap immediately downstream from the logger in the spring, which impacts the stage-discharge relationship and needs to be accounted for in the Stage.Working dataset (not yet done). It is recommended the users of the smolt trap at Cook Creek be made aware of the logger requirements, and make note of the dates & times installed so the raw data can be shifted and corrected. There are two water licenses (#C047879, # C113533) near the mouth of Chef Creek, one for private domestic use and one for Ministry of Forests (Conservation Use). There is no local aquifer listed (Figure 22).

Summary

The station's first accurate stage measurement was recorded on August 2, 2018 at 8:00 PM PST (UTC-8) (Figure 22) and continues to record. Upon reviewing historical notes and data, the following issues with station equipment and data collection have been noted for Cook Creek:

1) **No records were kept about station control condition prior to 2022.**

   Written descriptions of the control condition, and photographs from upstream and downstream of the station control, should be collected at every site visit. Specific photo points should be established, e.g. from Hwy 19A bridge looking upstream, or directly across from logger looking downstream.

2) **Few consistent notes were kept about adjustments made during cleaning of debris and sediment around the logger, making Sensor Reset Corrections challenging.**

   More consistent notes must be kept about the clearing of debris before and after logger download. This site is very prone to accumulation of small gravel in and around the logger pipe, which has caused issues with logger stability in the past. The aircraft cable attachment could also be swapped out for a more stable mounting system (e.g., aluminum T-post) that wouldn't be as susceptible to moving upwards with sediment deposition. Deposition will always occur at this site.

3) **Field note-taking has been inconsistent (or nonexistent). There were many inconsistencies in Staff Gauge records, Site Visit and Measurement times and time zones.**

   Every site visit must include: time zone, site arrival time, stage reading, control condition, measurement start time, measurement end time, logger download details, site leave time.

This summary should be used to help guide decisions about historical data interpretation and to help inform continued monitoring. The data grade for Cook Creek is "C" for 2022, but "U" (Unknown) for past years (Table 5; Figures 22-23). Data collection will keep improving in 2023 through involvement in the Community Flow Monitoring Network. The staff gauge will need to be replaced as soon as water levels drop low enough for installation.

Figure 18. Cook Creek logger housing in May 2019 (Left), July 2022 (Center), and February 2023 after loss of staff gauge (Right).

Table 5. Cook Creek historical data summary (Grade C RISC Standard in green).

Year	Overall data grade	Data grade goal	Reference Gauge Present?	Minimum 3 Benchmarks Present?	Benchmarks Surveyed?	Paired Stage-Discharge visits per year	Paired Stage-Discharge visits per year meeting RISC standards	Stage only visits per year	Discharge only visits per year	Field Check with Ministry completed	Highest Rating Deviation (%)	Mean Annual Discharge (m^3/s)	Notes
2017	U	N/A	Yes	No	No	1/2	1/2	0	0	No	0.33	N/A (incomplete year)	Require improved shift corrections (low flow)
2018	U	N/A	Yes	No	No	3/2	3/2	0	0	No	-69.96 (-78.50 w/o shift)	N/A (incomplete year)	
2019	U	N/A	Yes	No	No	6/2	3/2	0	0	No	-46.2	~0.521	
2020	U	N/A	Yes	No	No	2/2	1/2	0	0	No	-22.2	~0.606	
2021	U but improving	N/A	Yes	No	No	6/2	5/2	0	0	No	+36.87 (+84.19 w/o shift)	~0.723	
2022	C	C	Yes	Yes	2/1	5/2	4/2	1	1	Yes	+17.28	~0.626	Nearly meets Grade B
												MAD ~ [N/A] m^3/s	

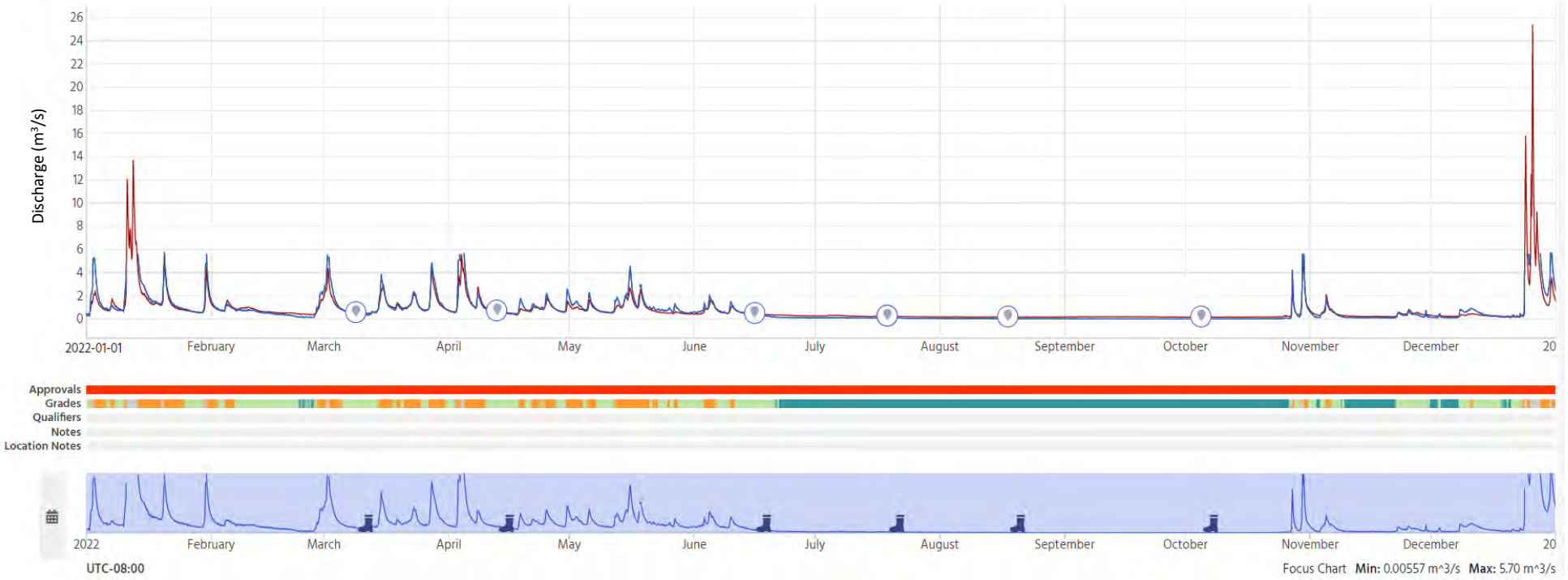


Figure 19. Cook Creek discharge data for 2022 (in blue), calculated using the active rating in Aquarius (PROVISIONAL DATA). Nile Creek for comparison (in red).

Table 6. Cook Creek 2022 discharge summary.

Date/Time (PST)2	Discharge (m^3/s)	Stage (m)	Control Condition	Discharge deviation (%)	Discharge uncertainty (%)	Notes
2022-03-09 11:00	0.407	9.160	Unspecified	-11.97	3.0	BWS solo
2022-04-13 13:00	0.557	9.177	Unspecified	-4.68	3.0	BWS solo
2022-06-16 11:15	0.310	Not provided	Unspecified	N/A	3.0	BWS solo
2022-07-19 10:15	0.0938	9.065	Low Flow Section Control - clear	+17.28	3.0	ENV (training)
2022-07-19 10:45	0.088	9.065	Low Flow Section Control - clear	+9.98	3.3	BWS (training)
2022-08-18 10:15	0.028	9.037	Low Flow Section Control - veg	-3.44 (-44.72 w/o shift)	4.9	BCCF
2022-10-05 10:30	0.010	9.045	Low Flow Section Control - debris	-16.81 (-82.88 w/o shift)	34.0 (Velocity = greatest source of uncertainty; flow nearly stagnant)	BCCF & BWS

November 30, 2017 / Channel Control

May 30, 2019 / Low Flow Section Control

September 19, 2019 / Moderate flow section control

September 22, 2020 / Low Flow Section Control

May 24, 2022 / Moderate flow section control & smolt trap (left)

August 19, 2022 / Low Flow Section Control

Figure 20. Cook Creek, looking downstream from near gauging station towards Hwy 19A bridge.

December 4, 2018 / Moderate Flow

July 22, 2019 / Low Flow

September 9, 2019 / Moderate Flow

September 22, 2020 / Low Flow

May 24, 2022 / Moderate Flow

February 6, 2023 / Moderate Flow

Figure 21. Cook Creek, looking upstream from near station.

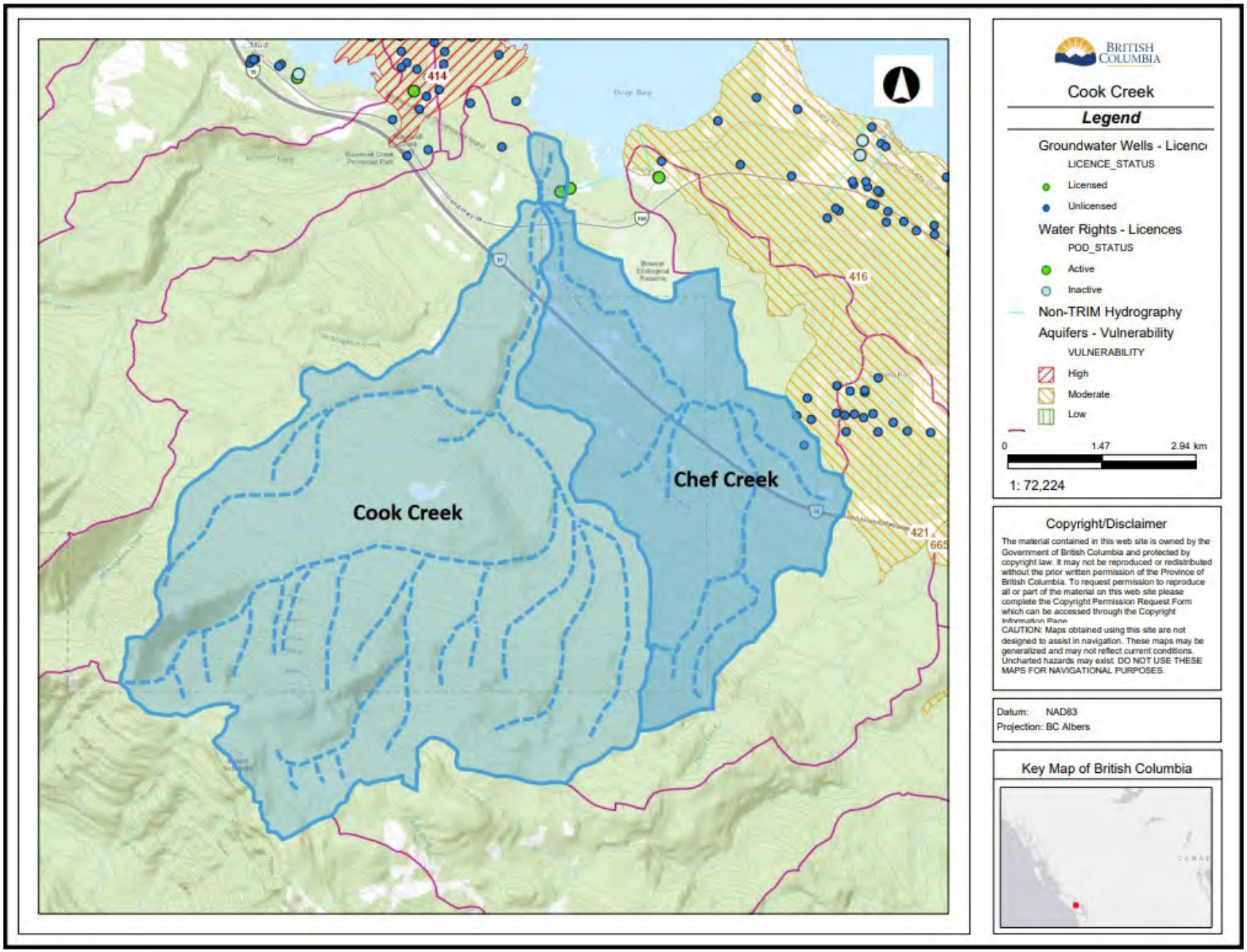


Figure 22. Cook Creek water license data (current to February 2023).

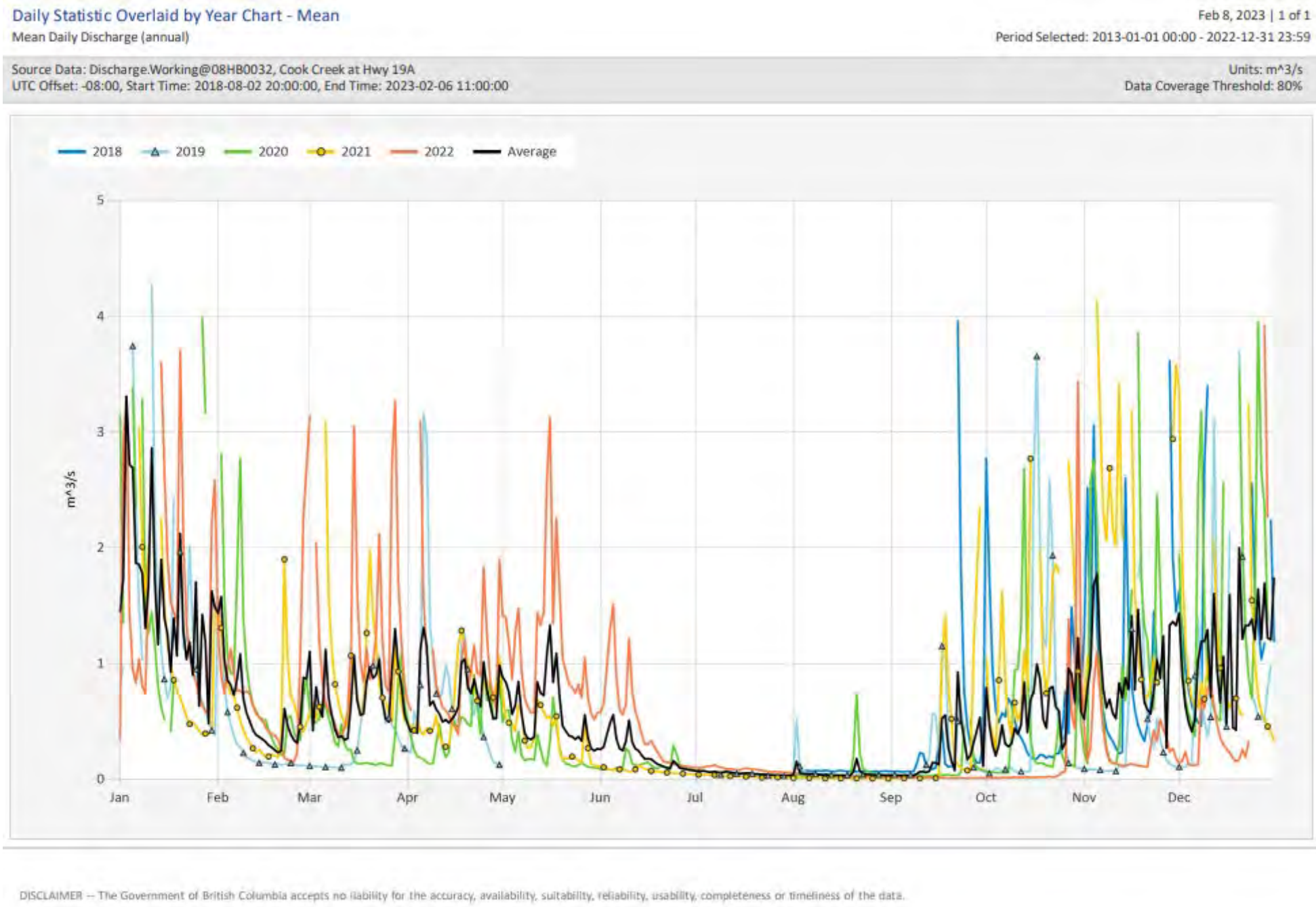


Figure 23. Cook Creek mean daily discharge for August 2018 – December 2022, as calculated using the active rating in Aquarius (PROVISIONAL DATA).

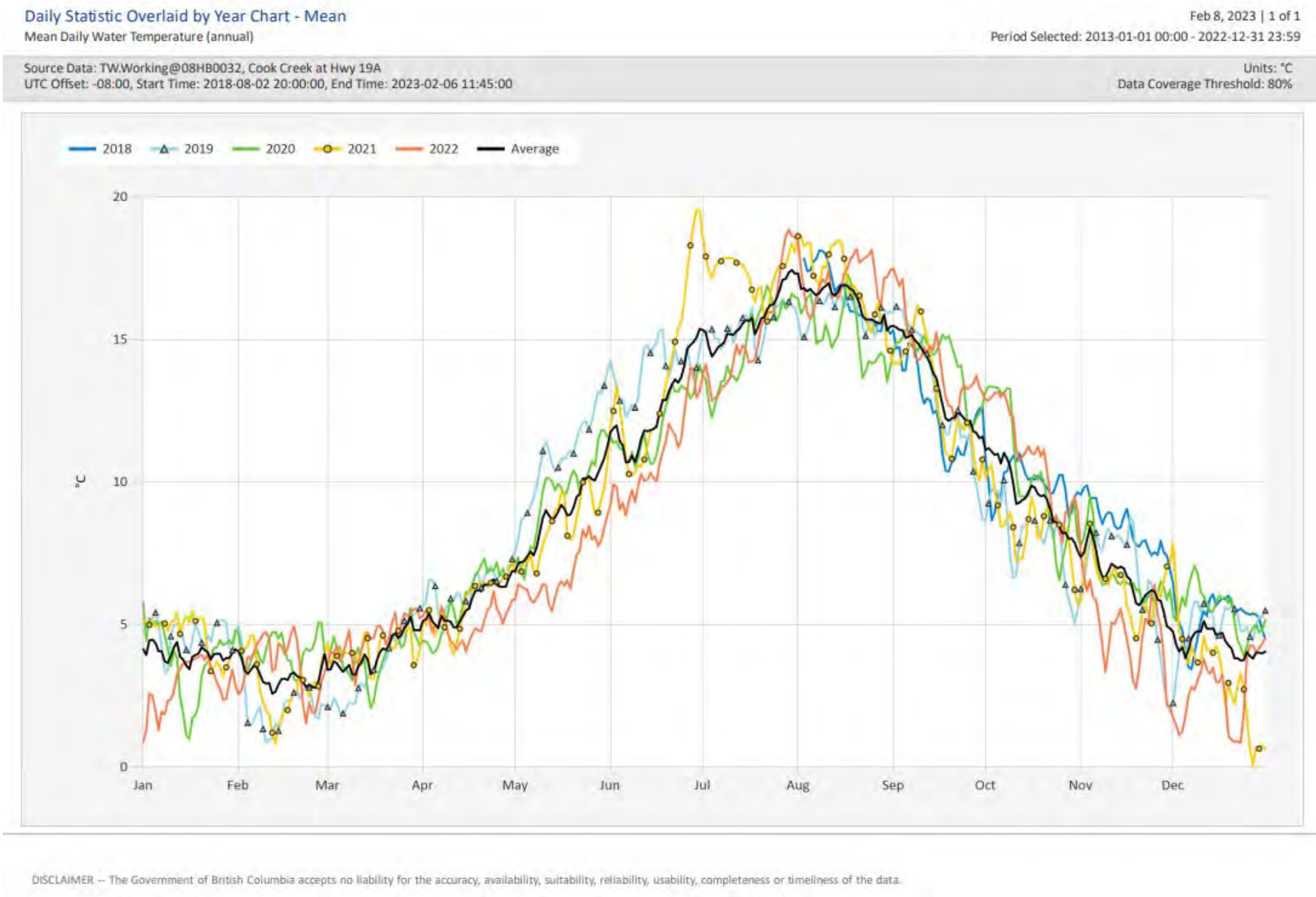


Figure 24. Cook Creek mean daily water temperature for August 2018 – December 2022.

Rosewall Creek near HWY 19A Bridge – 08HB0008

Station Location

The Rosewall Creek station was installed on October 12, 2012 by BCCF and the Fanny Bay Salmonid Enhancement Society (FBSES). The station was installed approximately 200 m upstream from the Rosewall Creek Provincial Park parking lot, in a relatively good gauge pool attached to a mature maple tree located on right bank. The logger location was in a deep, shaded pool. A Scientific Park Use Permit was required for the operation of this site, which was valid for ten years from the date of install.

Equipment

The logger used to record stage was a submersible pressure sensor (Solinst Edge M5 levelogger). The logger (S/N: 2040042) was installed in a painted steel pipe (approximately 1.68 m tall), with locking cap (Figure 21). Inside the housing, the logger was secured to a piece of 1" PVC pipe using electrical tape. A barologger was installed nearby, hung by a nail under a covered outdoor area at the Rosewall Creek Hatchery (<5 km away). The barologger remained there until October 6, 2022 when the logger was moved to Cook Creek. The Rosewall levelogger stopped recording (presumed battery failure) on October 22, 2022 (Figure 23).

Control

The station's section control is a riffle located along right bank approximately 15-20 m downstream from the station. This riffle appears to be quite dynamic, and large woody debris is observed to have piled up in the vicinity downstream of the control in recent years. The thalweg of the river undercuts the right bank just downstream of the control, before the river makes a strong left bend. This section of the bank was live staked in an attempt to stabilize the bank from eroding. The few historical photos that exist of the general area of the station control show how the downstream bank has eroded and changed since 2012 (Figures 24-25).

Reference Gauge and Benchmarks

No reference staff gauge or benchmarks were installed with the logger and its housing, and this site was never surveyed. However, some field notes were recorded during install and a few subsequent site visits indicated the relative height of the water surface above the bottom of the pipe. The tree on which the logger was mounted is suspected to have been shifting over time, perhaps due to bank undercutting by the river. Woody debris became caught in the tree in winter 2022, affecting its stability. No rating curve exists for the station due to a lack of stage reference points uploaded to Aquarius.

Site Features

The substrate near the logger is sand, medium- to large- cobbles, and small boulders with low- to moderate- embeddedness. Rosewall Creek undergoes strong temperature fluctuations, reaching a maximum of ~ 20.5°C with diurnal fluctuations of 4°C not uncommon in summer. Due to issues with bank stability where the gauging station is currently mounted, it is recommended the station at Rosewall Creek be relocated; the existing logger was removed in February 2023; therefore, it is a good opportunity to move the station before a new logger is installed. A number of suitable sites are located upstream, beneath the HWY 19A bridge where some large riprap is placed along right bank. The water along right bank in this location is relatively deep, and does not appear to go dry in late summer. However, this location is not a pool (more of a glide), and the section control there is relatively poorly defined. Further site selection and station relocation could be undertaken with support from ENV in summer 2023, pending a Memorandum of Understanding between BC ENV and BC Parks.

Continued Monitoring

While the equipment at this station was recently removed, it is recommended to continue monitoring Rosewall Creek if the issues noted below can be addressed. Data collection could keep improving in 2023 through involvement in the Community Flow Monitoring Network, or through adoption by the provincial hydrometric network for a telemetry station (N. Goeller, pers. comm., February 2023). The creek has a high fisheries value and BCCF has received a number of requests for Rosewall Creek data. A water license (#C128764) for withdrawal of 0.2832 m^3/s (roughly 10% of estimated MAD – see data below) is currently issued to DFO for water diversion to the Rosewall Creek hatchery, located downstream of the monitoring location. The local aquifer (#414; alluvial fan at the mouth of Rosewall Creek) is classified with a High vulnerability and is correlated to 11 groundwater wells, with an additional 24 wells within mapped extent (8 Commercial/Industrial, 7 Irrigation, 14 Private Domestic, 6 Unknown) (Figure 25). Aquifer #414 is classified as More Likely to be hydraulically connected.

Summary

The logger's first accurate stage measurement was recorded on October 12, 2012 at 10:00 AM PST (UTC-8) and the last valid measurement was on October 22, 2022 at 03:15 AM PST (UTC-8) (Figure 27). Upon reviewing historical notes and data, the following issues with station equipment and data collection have been noted for Rosewall Creek:

1) **The levelogger is removed.**

   There is interest by the province in monitoring this site, and it could potentially be handed to provincial staff with continued intermittent support by volunteers (FBSES and Beaufort Watershed Stewards) for low-flow data collection support.

2) **No records were kept about control condition prior to 2022 and site photographs were taken inconsistently, making interpretation of control and site conditions challenging in the absence of written notes.**

   Written descriptions of the control condition, and photographs from upstream and downstream of the station control should be collected at every site visit. Photo survey points should be established for keeping better records to document site changes.

3) **Few (or no) notes were kept about adjustments made to the logger location within the steel housing before or after download, making Sensor Reset Corrections challenging.**

   The location of the logger on the PVC pipe both before and after logger download wasn't consistently tracked. An attachment or marking could be drilled in the mounting system to denote where the logger should always rest in future

4) **Field note-taking was inconsistent (or nonexistent). There were many inconsistencies in Site Visit and Measurement times and time zones.**

   Every site visit must include: time zone, site arrival time, stage reading, control condition, measurement start time, measurement end time, logger download details, site leave time.

5) **No stage reference points existed.**

   A submerged reference point was installed in October 2022, but the point was submerged in gravel and cobbles after a high flow event in winter 2022 and could not be relocated as of February 2023.

This summary should be used to guide decisions about historical data interpretation, and to help inform continued monitoring. Overall, the data grade for the ten-year historical record of Rosewall Creek streamflow data is "U" (Unknown) (Table 7; Figures 27-28).

Figure 25. Rosewall Creek logger housing in October 2012 (Left) and September 2020 (Right).

Table 7. Rosewall Creek historical data summary (Grade C RISC Standard in green).

Year	Overall data grade	Data grade goal	Reference Gauge Present?	Minimum 3 Benchmarks Present?	Benchmarks Surveyed?	Paired Stage-Discharge visits per year	Paired Stage-Discharge visits per year meeting RISC standards	Stage only visits per year	Discharge only visits per year	Field Check with Ministry completed	Highest Rating Deviation (%)	Mean Annual Discharge (m^3/s) (Estimate using Provisional Data)	Notes
2012	U	N/A	No	No	0	0	0	0	3	No	N/A	N/A (incomplete year)	All site visits could use subm. press. tran. raw value as stage confirmation (requires assumption of steady logger placement)
2013	U	N/A	No	No	0	0	0	0	6	No	N/A	~2.05	
2014	U	N/A	No	No	0	0	0	0	6	No	N/A	~2.41	
2015	U	N/A	No	No	0	0	0	0	4	No	N/A	~2.04	
2016	U	N/A	No	No	0	0	0	0	6	No	N/A	~3.18	
2017	U	N/A	No	No	0	0	0	0	5	No	N/A	N/A (incomplete year)	
2018	U	N/A	No	No	0	0	0	0	8	No	N/A	~3.49	
2019	U	N/A	No	No	0	0	0	0	7	No	N/A	~2.44	
2020	U	N/A	No	No	0	0	0	0	3	No	N/A	~2.71	
2021	U	N/A	No	No	0	0	0	0	2	No	N/A	~2.85	
2022	U	N/A	Yes	No	1/1	1/2	1/2	0	2	No	N/A	N/A (incomplete year)	
												MAD ~ [N/A] m^3/s	

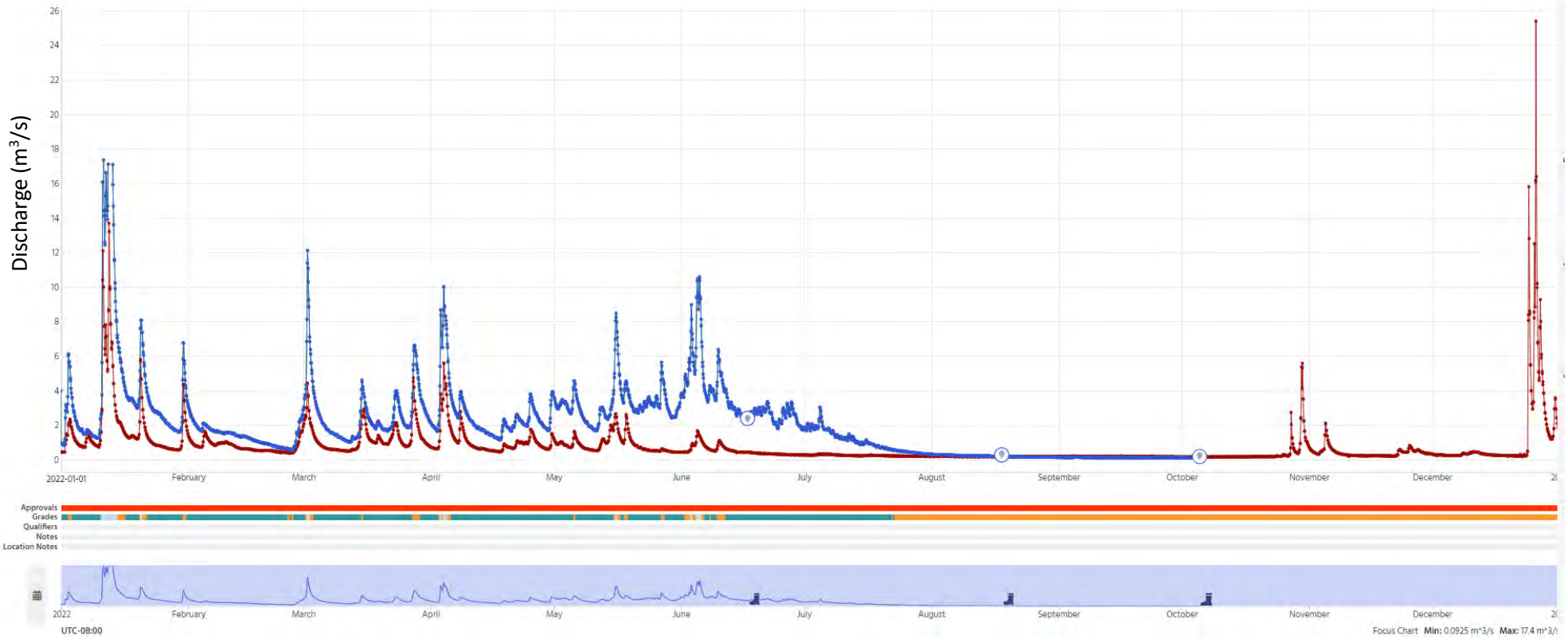
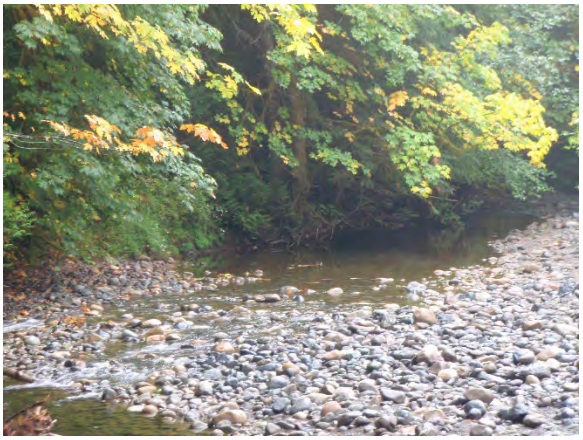


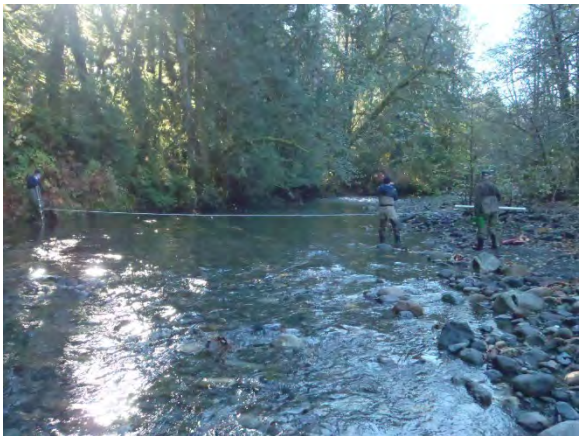
Figure 26. Rosewall Creek estimated discharge for 2022 (in blue), calculated using the active rating in Aquarius (PROVISIONAL DATA). Nile Creek shown for comparison (in red).

Table 8. Rosewall Creek 2022 discharge summary.

Date/Time (PST)	Discharge (m^3/s)	Stage (m)	Control Condition	Discharge deviation (%)	Discharge uncertainty (%)	Notes
2022-06-17 @ 13:55	2.290	N/A	Unspecified	N/A	3.05	BWS
2022-08-18 @ 12:30	0.199	N/A	Clear	N/A	3.3	BCCF
2022-10-05 @ 15:45	0.089	N/A	Debris – light (leaf litter)	N/A	5.0	BCCF, FBSES



October 12, 2012



November 9, 2012

February 27, 2013

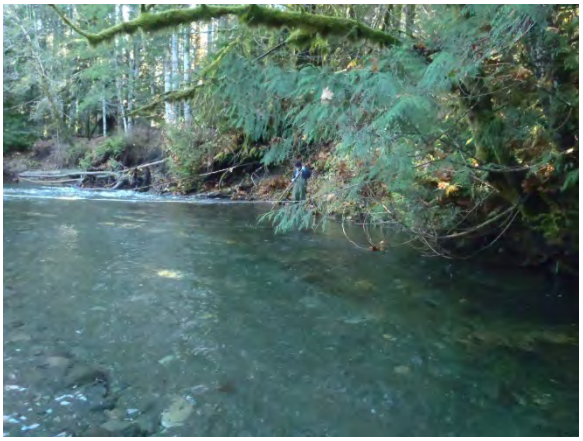
November 27, 2017

March 3, 2020

February 6, 2023

Figure 27. Rosewall Creek, looking upstream from below/near control riffle toward station.

a)



November 9, 2012

August 18, 2022

b)

June 4, 2018

October 5, 2022

February 6, 2023

c)

February 27, 2013

August 18, 2022

February 6, 2023

Figure 28. Rosewall Creek, looking downstream from near/upstream station toward control riffle (side-by-side views from similar angles).

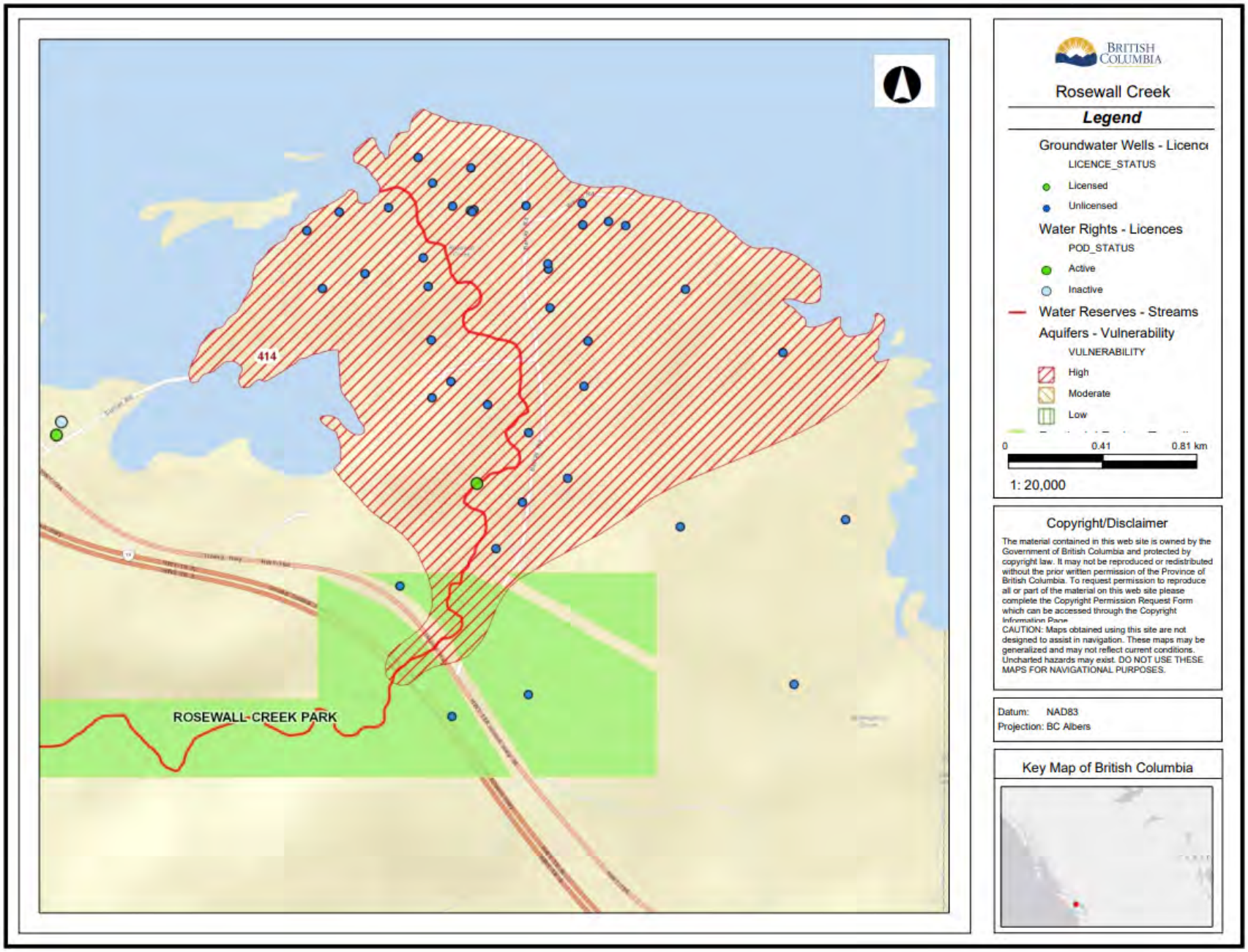


Figure 29. Rosewall Creek groundwater wells & licensed water demand (current to February 2023).

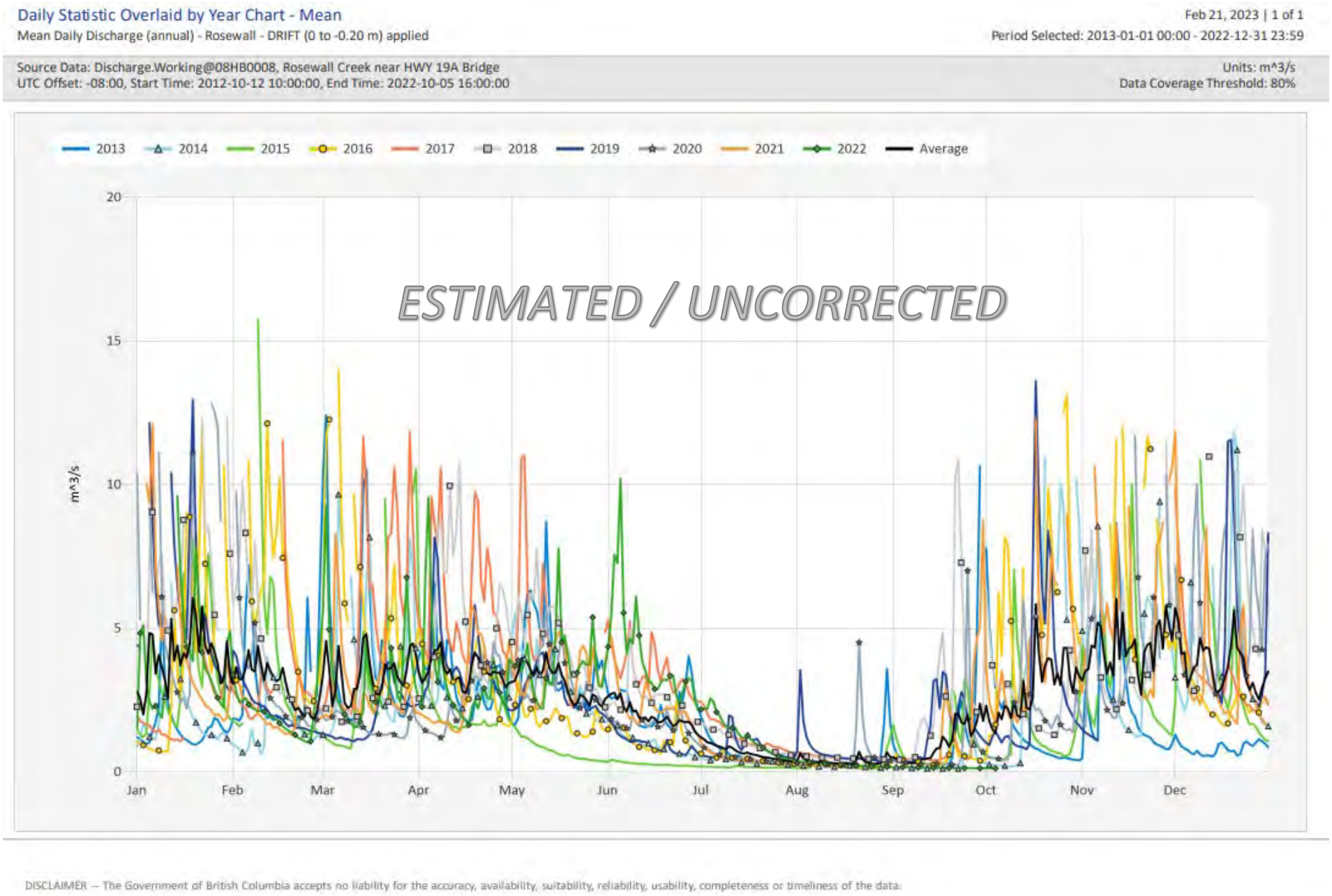


Figure 30. Rosewall Creek estimated and uncorrected mean daily discharge for October 2012 – December 2022 (PROVISIONAL DATA).

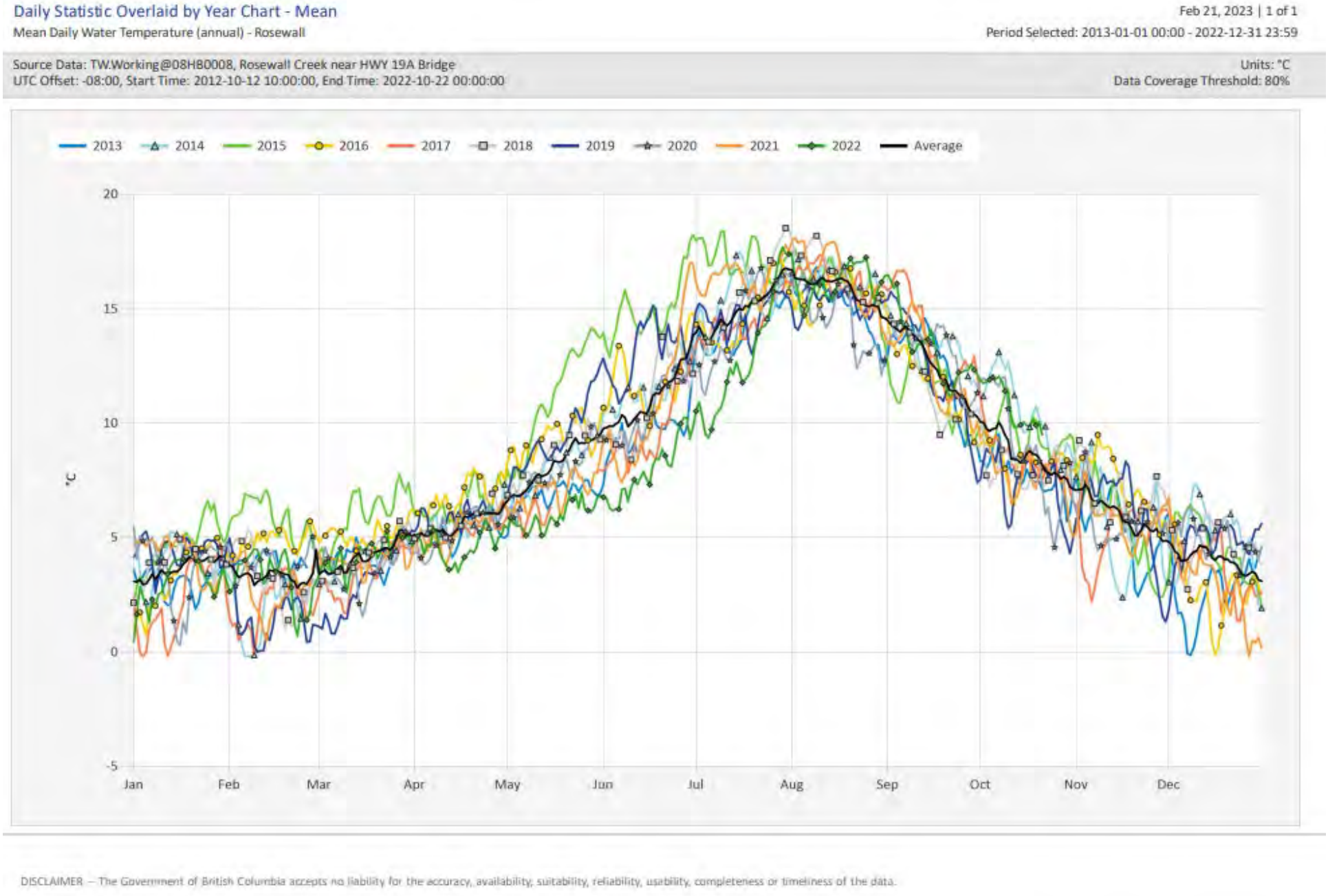


Figure 31. Rosewall Creek mean daily water temperature for October 2012 – December 2022.

Wilfred Creek at HWY 19A – 08HB0024

Station Location

The Wilfred Creek station was installed on August 2, 2018 by BCCF and the Fanny Bay Salmonid Enhancement Society (FBSES) downstream of Hwy 19A along left bank. The logger is located next to private property but can be accessed by walking downstream directly from the Hwy 19A bridge, with parking access available at the end of Coal Creek Rd.

Equipment

The logger used to record stage is a submersible pressure sensor (Solinst Edge M5 Levelogger). The logger (S/N: 2039637) is installed in a steel pipe (approximately 60 cm tall), with a locking cap (Figure 32). Inside the housing, the logger is secured to a piece of aircraft cable looped through the logger's cap. The housing is mounted at an angle to better attach to the riprap and avoid impact from woody debris. The barologger in use is the Rosewall hatchery barologger (moved to Cook Creek location on October 5, 2022) (Figure 33).

Control

The station's control is defined by a riprap cascade located approximately 25 m downstream from the station (Figures 34-38). At low flows, the control is characterized by a shallower riffle further upstream from the riprap cascade. This reach rarely accumulates debris and appears to maintain an even flow depth year-round.

Reference Gauge and Benchmarks

The site has not been able to support a staff gauge (despite three attempts at install) due to high discharge and woody debris transport in winter. Four benchmarks were installed in July 2022 and surveyed on the same day. They were re-surveyed within +/- 3 mm of the original established elevations in October 2022. Most of the benchmarks are located near the logger, although the primary benchmark is located upstream of the logger on the right bank bridge footing (Figures 34-35). BM4 is used as a submerged reference point for stage at higher water and is valid since July 19, 2022.

Site Features

The substrate in the vicinity of the logger is primarily cobbles and boulders, with some smaller gravel. The reach is relatively straight downstream of Hwy 19A (Figures 37-39). Adult pink, chum and coho salmon have been observed in Wilfred Creek. Juvenile coho and rainbow trout have been observed in pools upstream from the gauging site. Diurnal water temperature fluctuations are, on average, about +3°C in the summer months, which is a lower fluctuation than some of the other, smaller streams in the Fanny Bay region (e.g. Cook, Rosewall). The maximum recorded water temperature is ~ 19°C.

Continued Monitoring

It is recommended to continue monitoring Wilfred Creek. The creek has a high fisheries value, supporting multiple species of adult and juvenile fish. Nearby property owners on Stelling Road are supportive and engaged in monitoring outcomes. This site is of interest to water balance studies being undertaken by the Beaufort Watershed Stewards. There are 8 active water licenses on Wilfred Creek, licensed to the Ships Point Improvement District and several private owners amounting to ~173,377 m^3/year. There are an additional 5 licenses status Cancelled or Abandoned. The local aquifer (#419; unconfined sand and gravel) is classified with a Moderate vulnerability and is correlated to 26 groundwater wells, with an additional 64 wells within mapped extent. Aquifer #419 is classified as More Likely to be hydraulically connected (Figure 40).

Summary

The logger's first accurate stage measurement was recorded on August 2, 2018 at 9:00 PM PST (UTC-8) (Figure 41) and it continues to record. Upon reviewing historical notes and data, the following issues with station equipment and data collection have been noted for Wilfred Creek:

1) **No records were kept about station control condition or stage reference prior to 2022.** Written descriptions of the control condition, and photographs from upstream and downstream of the station control, should be collected at every site visit. Specific photo points should be established, e.g. looking upstream from below riprap cascade, or directly across from logger looking downstream. A measurement of stage relative to BM4 should be collected during every site visit.

2) **Few consistent notes were kept about adjustments made during cleaning of debris and sediment around the logger, making Sensor Reset Corrections challenging.**

   The logger is installed at an angle, which makes validating sensor location challenging. More consistent notes must be kept about the clearing of debris and supposed sensor location before and after logger download. The aircraft cable attachment should also be swapped out for a more stable mounting system (e.g., aluminum T-post) that wouldn't be as susceptible to moving upwards with sediment deposition. Minor deposition will likely always occur at this site.

3) **Field note-taking has been inconsistent (or nonexistent). There were inconsistencies in stage records, Site Visit and Measurement times and time zones.**

   Every site visit must include: time zone, site arrival time, stage reading, control condition, measurement start time, measurement end time, logger download details, site leave time.

This summary should be used to guide decisions about historical data interpretation, and to help inform continued monitoring. Overall, the data grade for Wilfred Creek is "C" for 2022, but "U" (Unknown) for past years (Table 9; Figures 41-42). Data collection will keep improving in 2023 through involvement in the Community Flow Monitoring Network.

Figure 32. Wilfred Creek logger housing in August 2018 (Left), September 2019 (Center) and February 2023 (Right).

Table 9. Wilfred Creek historical data summary (Grade C RISC Standard in green).

Year	Overall data grade	Data grade goal	Reference Gauge Present?	Minimum 3 Benchmarks Present?	Benchmarks Surveyed?	Paired Stage-Discharge visits per year	Paired Stage-Discharge visits per year meeting RISC standards	Stage only visits per year	Discharge only visits per year	Field Check with Ministry completed	Highest Rating Deviation (%)	Mean Annual Discharge (m^3/s) (Estimate using Provisional Data)	Notes
2018	U	N/A	No	No	No	0	0	0	3	No	N/A	N/A (incomplete year)	
2019	U	N/A	No	No	No	0	0	0	4	No	N/A	~1.13	
2020	U	N/A	No	No	No	0	0	0	1	No	N/A	~1.03	
2021	U	N/A	No	No	No	0	0	0	5	No	N/A	N/A (incomplete year)	Missing data Jan – Aug
2022	C	C	Yes	Yes	2/1	3/2	3/2	1	3	Yes	+19.56	~1.04	Nearly meets Grade B
												MAD ~ [N/A] m^3/s	

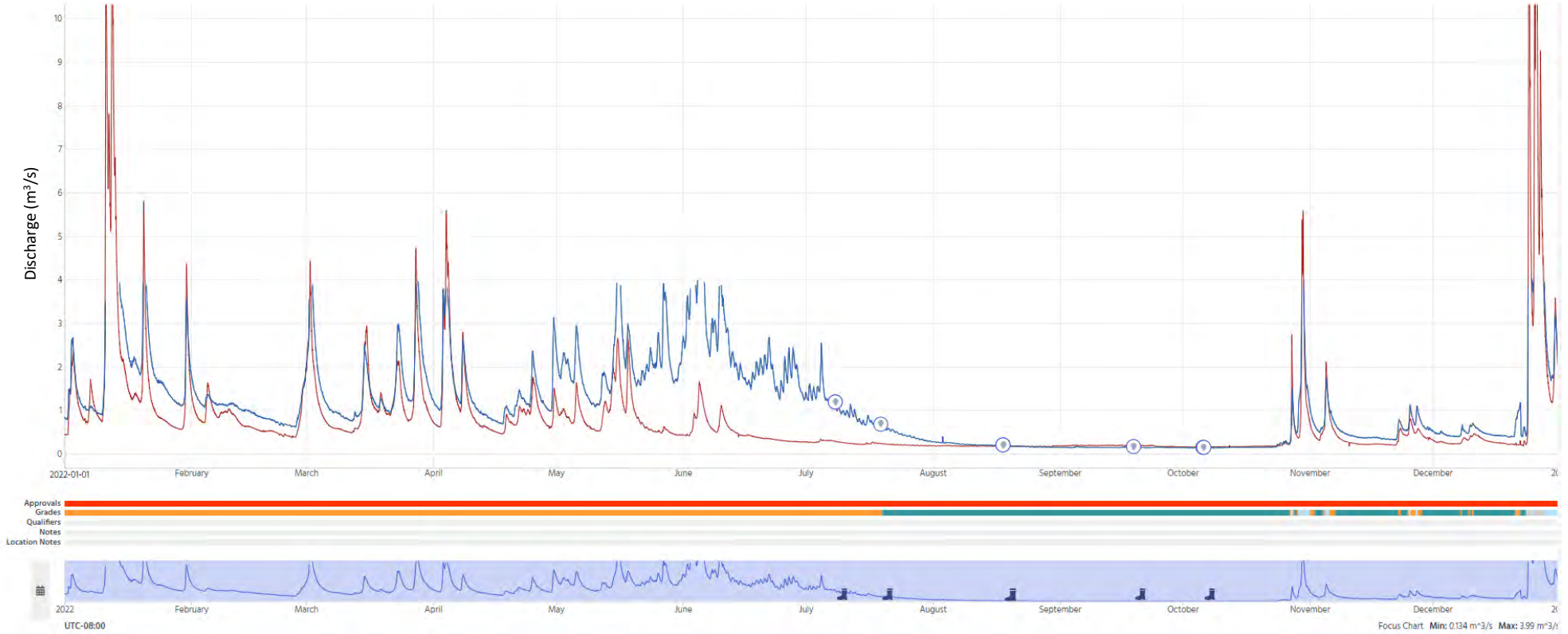


Figure 33. Wilfred Creek discharge data for 2022 (in blue), calculated using the active rating in Aquarius (PROVISIONAL DATA). Nile Creek for comparison (in red).

Table 10. Wilfred Creek 2022 discharge summary.

Date/Time (PST)	Discharge (m^3/s)	Stage (m)	Control Condition	Discharge deviation (%)	Discharge uncertainty (%)	Notes
2022-07-08 14:30	1.150	Unspecified	Unspecified	N/A	6.2	BWS solo
2022-07-19 15:45	0.649	9.439	Clear	+19.56	5.2	Ministry (training), BWS, BCCF
2022-08-18 14:00	0.167	9.327	Clear	-6.79	5.6	BCCF
2022-09-19 9:30	0.128	Unspecified	Unspecified	N/A	6.9	BWS solo
2022-10-06 9:30	0.113	9.308	Clear – low flow	-18.46	3.3	BCCF, BWS

August 17, 2021 October 5, 2022

Figure 34. Wilfred Creek, looking upstream from the tip of the riprap cascade towards the Hwy 19A bridge (same rock is circled).

August 17, 2021 August 18, 2022

Figure 35. Wilfred Creek, looking upstream from below the riprap cascade towards the Hwy 19A bridge (same rock is circled).

July 23, 2020 September 22, 2020

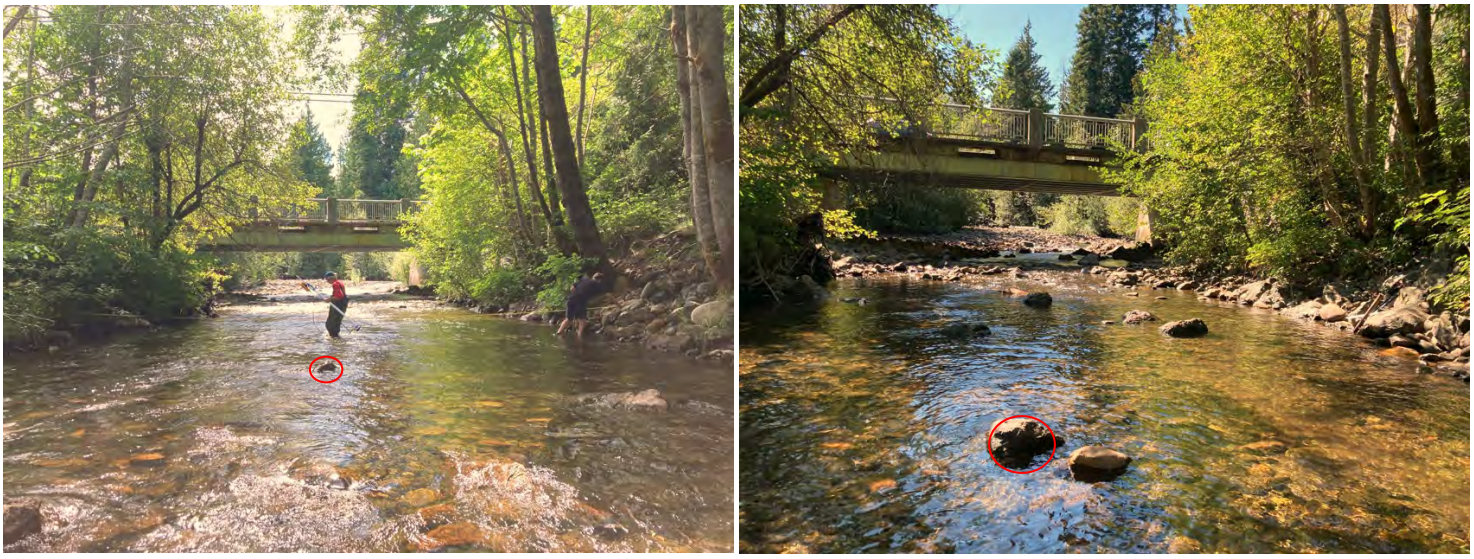
Figure 36. Wilfred Creek, looking from left bank across to right bank at the riprap cascade (same rock is circled).

September 19, 2019 June 23, 2021

Figure 37. Wilfred Creek, looking downstream from near station towards control (same rock is circled).

July 23, 2020 October 5, 2022

Figure 38. Wilfred Creek, looking downstream from below station towards control (same rock is circled).



June 23, 2021 August 8, 2022

Figure 39. Wilfred Creek, looking upstream from below station towards Hwy 19A bridge (same rock is circled).

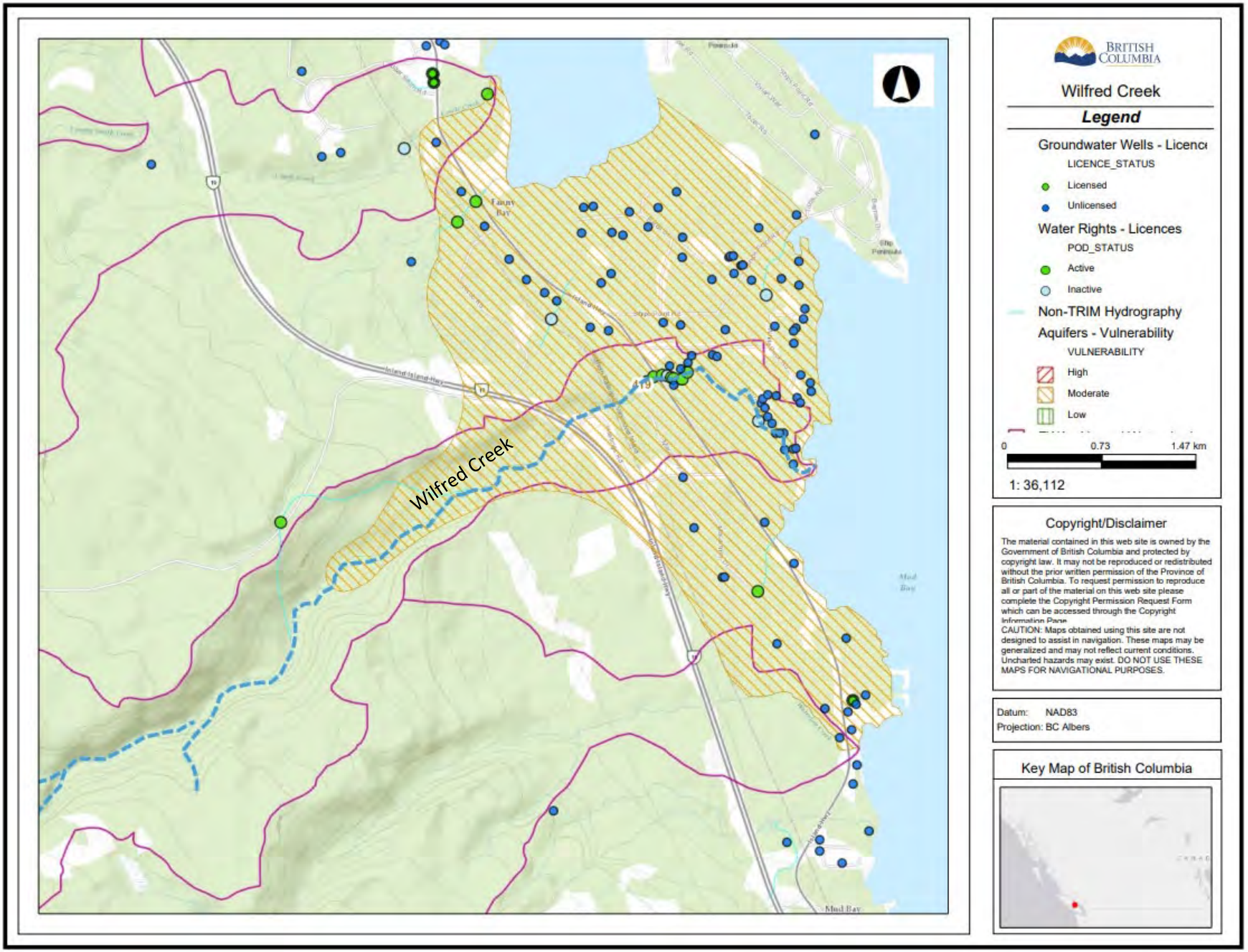


Figure 40. Wilfred Creek groundwater wells & licensed water demand (current to February 2023).

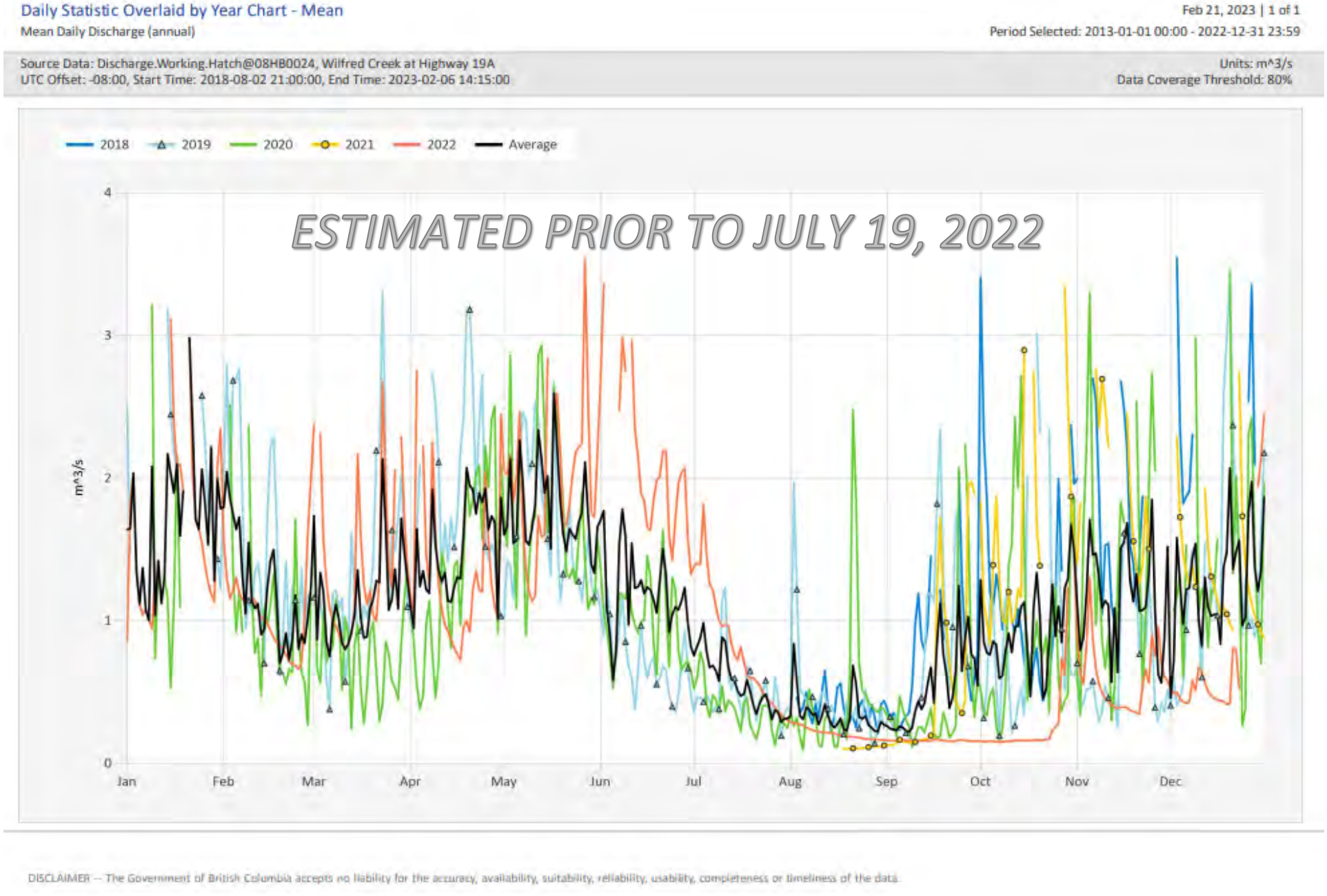


Figure 41. Wilfred Creek estimated mean daily discharge for August 2018 – December 2022, calculated using the active rating in Aquarius (PROVISIONAL DATA).

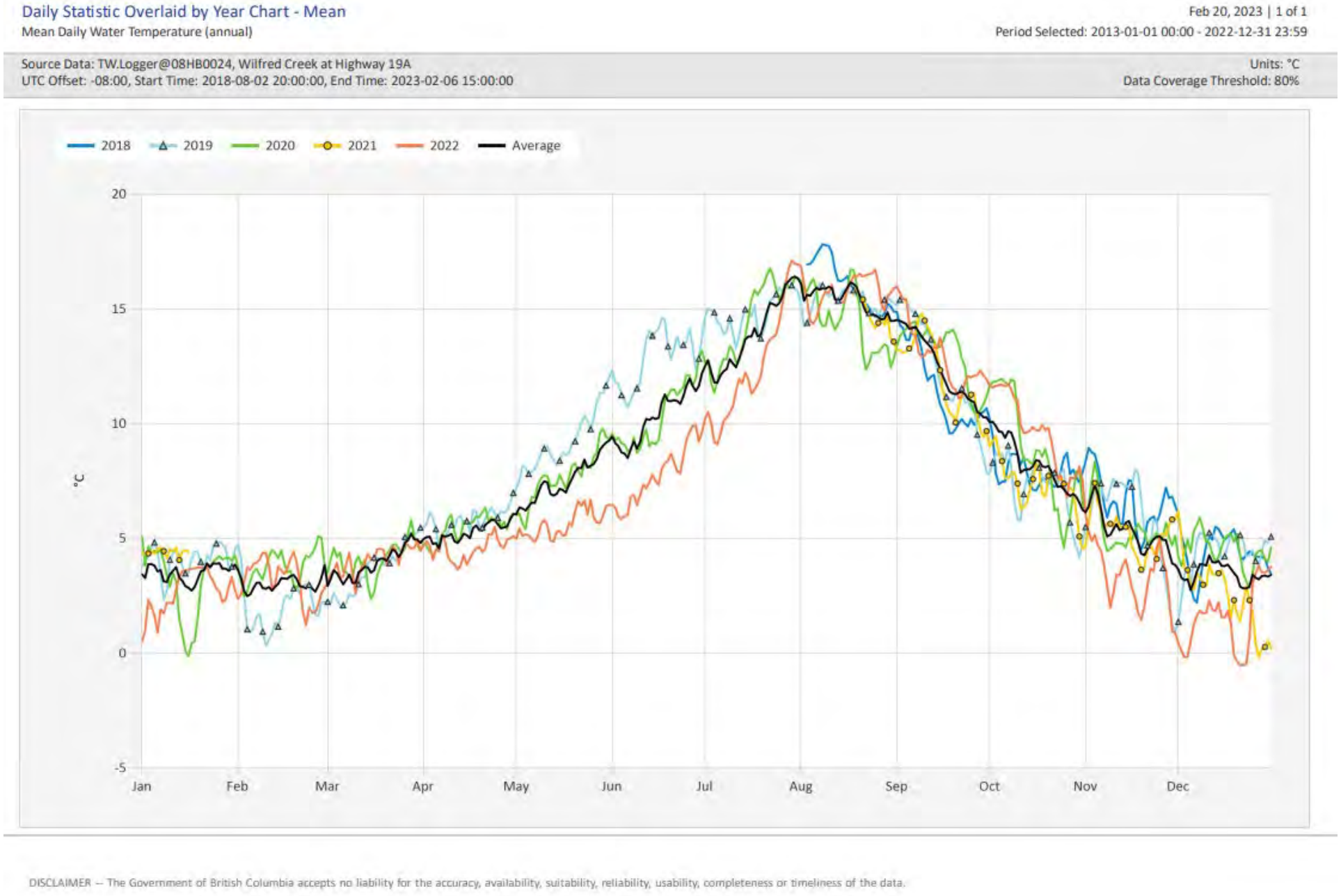


Figure 42. Wilfred Creek mean daily water temperature for August 2018 – December 2022 * (Note: logger data missing for January – August 2021).

Black Creek near HWY 19A and Enns Rd Intersection – 08HD0001

Station Location

The Black Creek station was installed on August 4, 2012 by BCCF and the Black Creek Stewards on private property near Hwy 19A in Black Creek, BC. The logger is mounted to a large tree on right bank in a small eddy pool, within a stretch of stream that is well shaded by riparian vegetation. Access is via private property and permission is required.

Equipment

The logger used to record stage is a submersible pressure sensor (Solinst Edge levelogger M5). The logger (S/N: 2010854) was installed in a steel pipe (approximately 1 m tall), with a locking cap (Figure 43). Inside the housing, the logger is secured to a piece of aircraft cable looped through the logger's cap. The climate dataset used for barometric compensation is the Comox Airport (Station ID 71893), ~22 km away.

Control

The station's section control is a riffle located downstream from the logger, past the small walking bridge (Figures 45-46). This riffle is quite shallow in late summer. This site is not visited outside of the low flow season.

Reference Gauge and Benchmarks

The reference staff gauge is a Water Survey Canada 1 m gauge which was installed next to the levelogger housing in October 2012. The logger has become tarnished and is difficult to read. The site has never had any benchmarks although historical measurements of the water level relative to the length of the mounting cable were made, but inconsistently.

Site Features

The substrate in the station's reach is primarily large gravel to cobbles. This section of Black Creek frequently becomes stagnant in late summer; presence of didymo and dark, tannic water is common. The DFO-Pacfish monitoring station on Black Creek is located just a few kilometers downstream, which records real-time stage and water temperature (Figure 44). There are 23 active water licenses within the Black Creek watershed, with another 4 Abandoned. License uses include private domestic, private irrigation, livestock & animal watering, stream storage (non-power), conservation storage, land improvement, and crop suppression. The cumulative licensed withdrawal across the entire watershed is 954,166 m^3/year; 192,959 m^3/year (20%) is licensed directly from Black Creek. The local aquifers are #411 (fractured bedrock) and #408 (unconfined sand and gravel). #411 is classified with a Low vulnerability and is correlated to 172 groundwater wells, with an additional 156 wells within mapped extent. Aquifer #411 is classified as More Likely to be hydraulically connected. #408 is classified with a Moderate vulnerability and is correlated to 1510 groundwater wells, with an additional 92 wells within mapped extent. Aquifer #408 is classified as More Likely to be hydraulically connected (Figure 47).

Continued Monitoring

Continued monitoring at this site on Black Creek is not recommended due to the lack of stewardship support. The property owner is interested in keeping the equipment at his property, thus the station may be converted to a stage-only station which only requires periodic checks and validations of the staff gauge.

Summary

The station's first stage measurement was recorded on August 3, 2018 at 10:00 AM PST (UTC-8) (Figure 47) and continues to record. first Some issues with the station and data collection have been noted for Black Creek:

1) **The site does not have a barometric logger.**
   The Comox Airport barometric pressure record is a usable dataset, but the site is nearly 30 km away from the station. A local barologger would have been more accurate; a local barologger was in place from 2012-2015 but had since been removed.

2) **Few notes were kept about adjustments made during sensor downloads, making Sensor Reset Corrections challenging.**

   The logger was relatively stable within its housing, so little SRC likely need to be applied.

3) **There are inconsistencies in site photos.**

   Past site photos did not always capture the staff gauge, station control, or transect locations.

4) **The minimum number of site visits was never met.**

   If any monitoring continues at this site, a minimum of 4 site visits per year, at a range of different stage heights, should be conducted.

This summary should be used to guide decisions about historical data interpretation. Overall, the data grade for Black Creek is "U" (Unknown) (Table 11; Figures 48-49). It is recommended that data collection be ceased for this station, removing Black Creek from the monitoring network and making space for an alternate group with more capacity to conduct annual monitoring.

Figure 43. Black Creek logger housing in August 2012 (Left) and July 2017 (Right).

Table 11. Black Creek historical data summary.

Year	Overall data grade	Data grade goal	Reference Gauge Present?	Minimum 3 Benchmarks Present?	Benchmarks Surveyed?	Paired Stage-Discharge visits per year	Paired Stage-Discharge visits per year meeting RISC standards	Stage only visits per year	Discharge only visits per year	Field Check with Ministry completed	Highest Rating Deviation (%)	Mean Annual Discharge (m^3/s) (Estimate using Provisional Data)	Notes
2012	U	N/A	Yes	No	No	0	0	0	1	No	+9.34	N/A (incomplete year)	
2013	U	N/A	Yes	No	No	1/2	0	0	1	No	+87.94	N/A (incomplete year)	
2014	U	N/A	Yes	No	No	1/2	0	0	0	No	+9.16	N/A (incomplete year)	
2015	U	N/A	Yes	No	No	1/2	0	0	0	No	-10.63	N/A (incomplete year)	
2016	U	N/A	Yes	No	No	0	0	0	0	No	N/A	N/A (incomplete year)	
2017	U	N/A	Yes	No	No	0	0	0	0	No	N/A	N/A (incomplete year)	
2018	U	N/A	Yes	No	No	1/2	0	0	0	No	+67.32	N/A (incomplete year)	
2019	U	N/A	Yes	No	No	2/2	0	0	0	No	+18.55	N/A (incomplete year)	
2020	U	N/A	Yes	No	No	1/2	0	0	0	No	+8.16	N/A (incomplete year)	
2021	U	N/A	Yes	No	No	1/2	0	0	0	No	-8.99	N/A (incomplete year)	
2022	U	N/A	Yes	No	No	0	0	0	0	No	N/A	N/A (incomplete year)	
												MAD ~ [N/A] m^3/s	

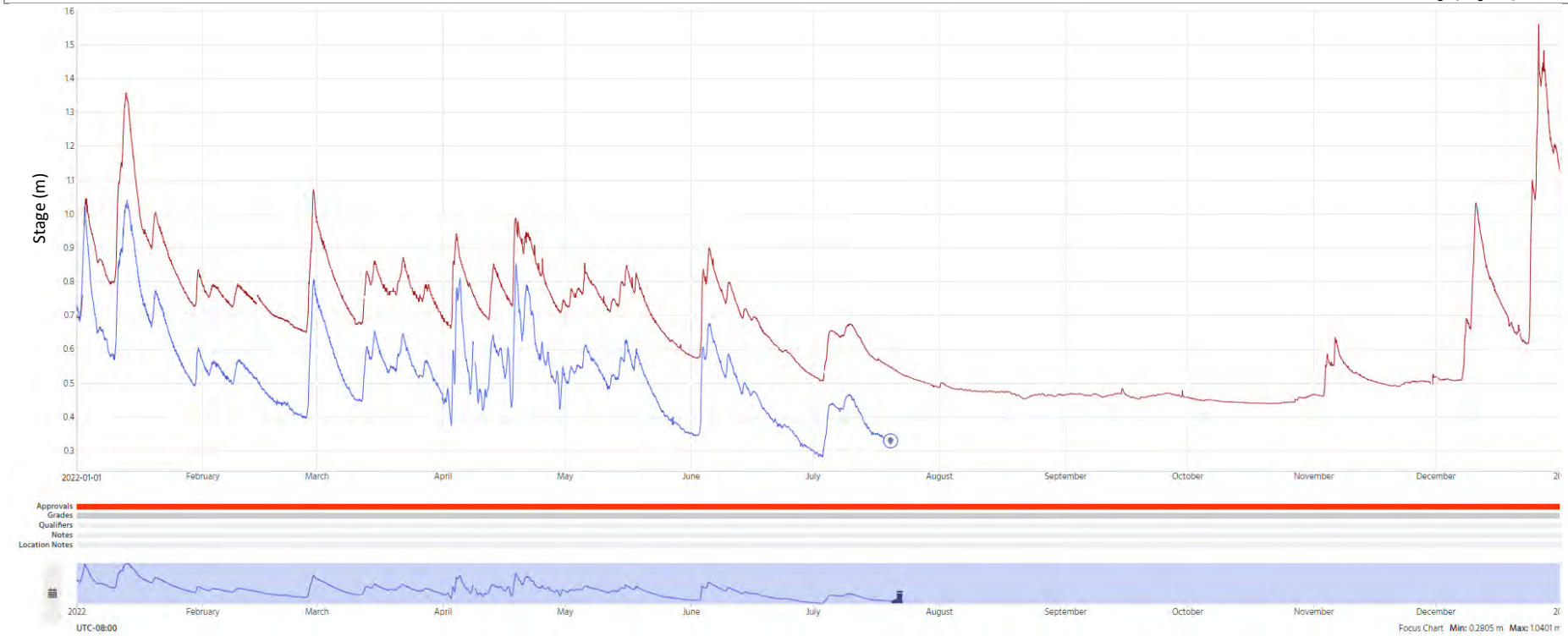


Figure 44. Black Creek corrected stage data for 2022 (in blue); DFO Black Creek Pacfish station sensor depth (stage) (m) for comparison (in red) (AS PROVIDED).

Undated homeowner file photo (pre-2012)

August 7, 2012

October 4, 2013

Figure 45. Black Creek, looking from access path at left bank across to station (right bank at base of maple tree).

Undated file photo (pre-2012)

October 4, 2013

Figure 46. Black Creek, looking downstream from wooden bridge.

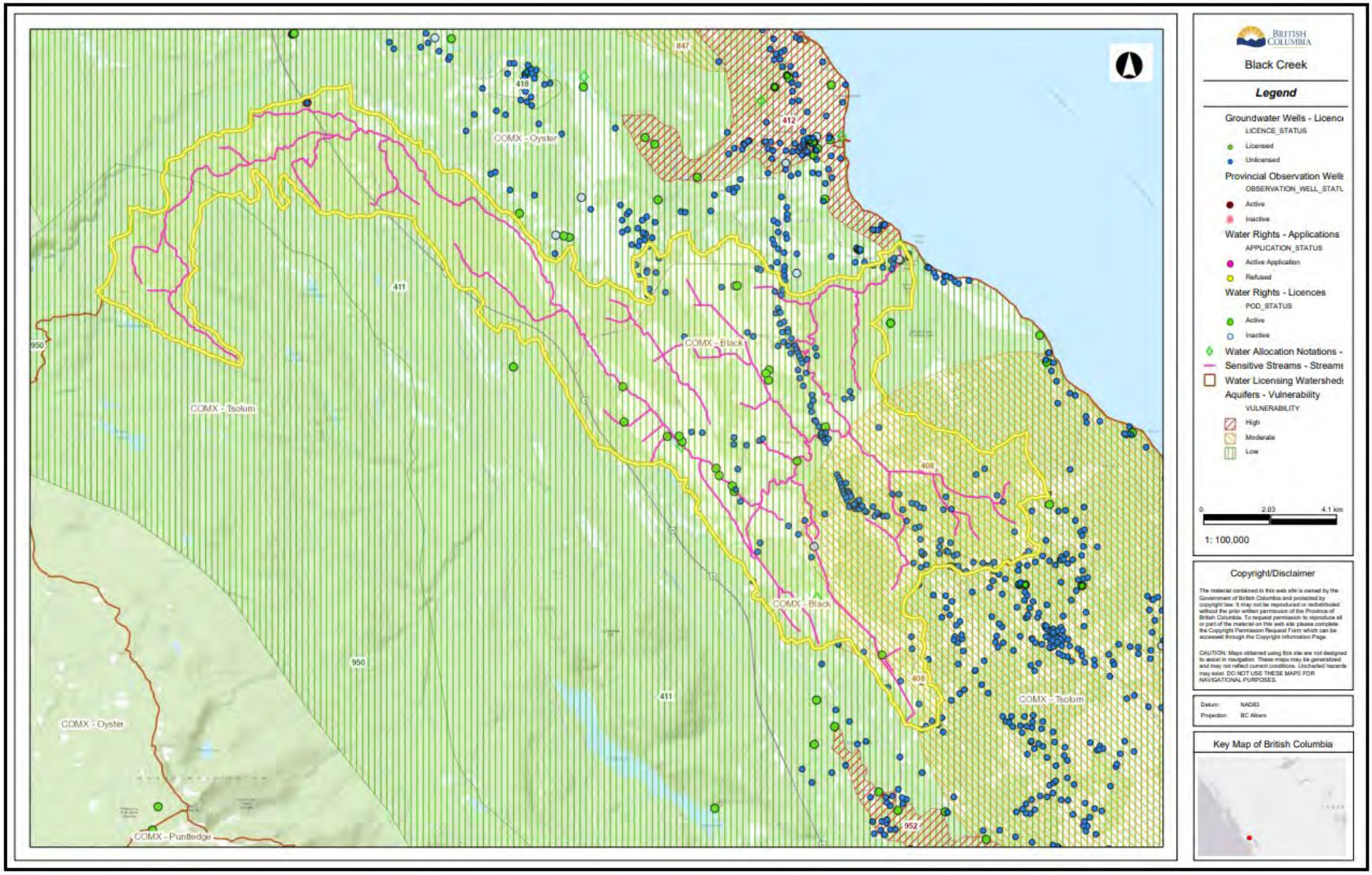


Figure 47. Black Creek groundwater wells and water license demand (current to February 2023).

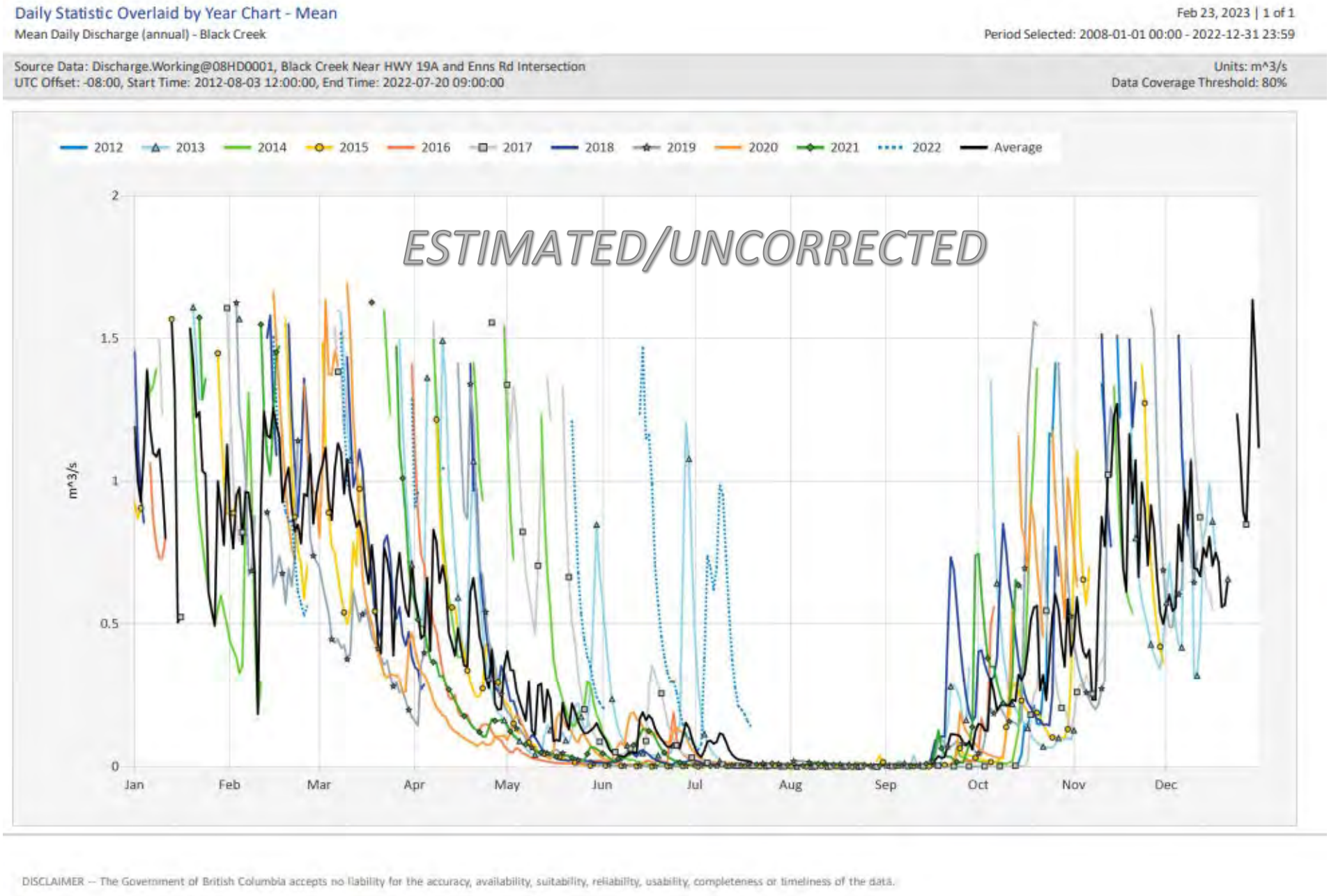


Figure 48. Black Creek at Hwy 19A estimated discharge from August 2012 - July 2022 (PROVISIONAL DATA).

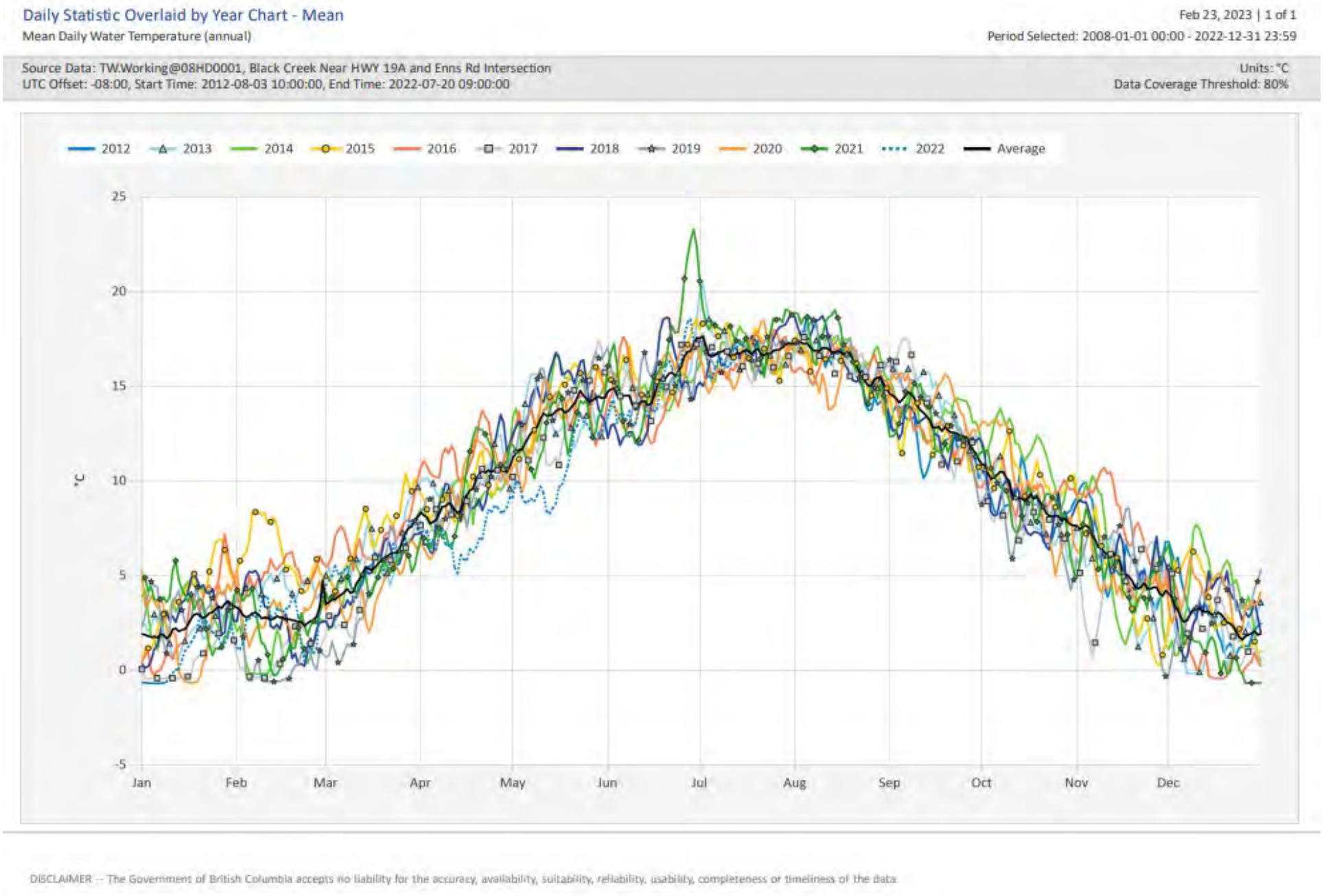


Figure 49. Black Creek at Hwy 19A water temperature data from August 2012 - July 2022.

Tsolum River near End of Michaels Drive – 08HB0012

Station Location

The Tsolum River near End of Michaels Drive station (usually called Tsolum at McNaughton) was installed on September 13, 2012 by BCCF and the Tsolum River Restoration Society (TRRS). The site is accessed via private property near Todd Road/Michaels Drive north of Courtenay. The station is located a short walk from the driveway to the right bank of the river, where the logger is mounted to a large boulder at a relatively straight reach near left bank.

Equipment

The logger used to record stage is a submersible pressure sensor (Solinst Edge M5 Levelogger). The logger (S/N: 2010571) was installed in a steel pipe (approximately 120 cm tall), with a locking cap (Figure 50). Inside the housing, the logger was secured to a piece of PVC pipe for 2012-2022, until the mounting system was switched to a piece of aircraft cable looped through the logger's cap in late 2022. The pipe is installed vertically on a large boulder. The climate dataset used from 2012 – 2022 for barometric compensation was the Comox Airport (Station ID 71893), ~18 km away. A Solinst barologger was installed under a nearby tree on in early 2023 to record at 1-hour intervals and match the levelogger record (Figure 51).

Control

The station's low flow section control is defined by a riffle located approximately 30 m downstream from the station along right bank (Figures 52-55). The PZF was estimated at 8.290 m during a level survey in November 2022. At high flows, the station is under channel control which extends far downstream from the station.

Reference Gauge and Benchmarks

The site had a staff gauge installed beside the logger in July 2020. Prior to this, there was no stage validation for the site. Four benchmarks were installed in July 2022 and surveyed on the same day. They were re-surveyed within +/- 3 mm of the original established elevations in November 2022. Two of the benchmarks are located upstream of the logger mounted to boulders and can only be accessed under low flow conditions. The primary benchmark is located on top of the boulder where the logger is mounted (Figure 56).

Site Features

The substrate in the vicinity of the logger is primarily cobbles and boulders, with some smaller gravel. The reach is relatively straight but not even; a deeper pool located on right bank shallows out to a small gravel bar on left bank. Diurnal water temperature fluctuations of 5-6°C are not uncommon in the summer months at this site. The maximum recorded water temperature was 27.3 °C in June 2021.

Continued Monitoring

The Province of BC has interest in further monitoring this river and recently installed a telemetry station at Fitzgerald Road (08HA0038). It is recommended for the TRRS to continue monitoring Tsolum River at McNaughton, and to address the notes below. This site benefits from a very dedicated stewardship group with a good grasp of technical concepts and motivated members to monitor in all conditions. The creek supports a diversity of fish species while also providing critical water for agricultural irrigation. The TRRS has specific conservation goals related to the long-term monitoring at this site, including comparison with the Water Survey of Canada gauge (Tsolum River near Courtenay) and releases from Wolf Lake.

There are 107 active water licenses within the Tsolum River watershed, with another 9 Abandoned. License uses include private domestic, private irrigation, livestock & animal watering, stream storage (non-power), conservation storage and use, camps and public facilities, commercial, greenhouse and nurseries, lawn and garden watering, and land improvement. The cumulative licensed use across the entire watershed is ~41,235,356 m^3/year; ~699,408 m^3/year (1.7%) is licensed directly from Tsolum River. The local aquifers include #411 (fractured bedrock) and #408 (unconfined sand and gravel), mentioned above in the Black Creek summary, as well as #952. Aquifer #952 is classified with a High vulnerability and is correlated to 64 groundwater wells, with an additional 2 wells within mapped extent. Aquifer #952 is classified as More Likely to be hydraulically connected. (Figure 57).

Summary

The logger's first accurate stage measurement was recorded on September 13, 2012 at 3:00 PM PST (UTC-8) and it continues to record (Figure 58). The logger may need to be replaced soon due to the ~ 10-year lifespan. Few issues with the station and data collection have been noted for this site:

1) **There was no staff gauge prior to 2020.**

   Data prior to July 2020 is estimated due to a lack of stage validation. Going forward, stage readings use the staff gauge and correct to local datum.

2) **There are some inconsistencies in site photos.**

   Past site photos did not always capture the staff gauge, station control, or monitoring points. In recent months this has greatly improved. A formal record of monitoring points should be established for the station, perhaps based on the similar photos included in this report for comparison with historical records.

The data grade for Tsolum River at McNaughton reached grade A/B in 2022. Historical data is all grade "U" (Unknown) (Table 12, Figures 58-59). Data collection will keep improving in 2023 through involvement in the Community Flow Monitoring Network.

Figure 50. Tsolum River at McNaughton logger location in October 2012, (left), July 2020 (center), and August 2022 (right).

Table 12. Tsolum River at McNaughton 2022 discharge summary.

Year	Overall data grade	Data grade goal	Reference Gauge Present?	Minimum 3 Benchmarks Present?	Benchmarks Surveyed?	Paired Stage-Discharge visits per year	Paired Stage-Discharge visits per year meeting RISC standards	Stage only visits per year	Discharge only visits per year	Field Check with Ministry completed	Highest Rating Deviation (%)	Mean Annual Discharge (m^3/s) (Estimate using Provisional Data)	Notes
2012	U	N/A	No	No	0	0	0	0	3	No	N/A	N/A (incomplete year)	
2013	U	N/A	No	No	0	0	0	0	2	No	N/A	~4.19	
2014	U	N/A	No	No	0	0	0	0	1	No	N/A	N/A (incomplete year)	
2015	U	N/A	No	No	0	0	0	0	3	No	N/A	~2.86	
2016	U	N/A	No	No	0	0	0	0	1	No	N/A	N/A (incomplete year)	
2017	U	N/A	No	No	0	0	0	0	1	No	N/A	~3.37	
2018	U	N/A	No	No	0	0	0	0	1	No	N/A	~3.27	
2019	U	N/A	No	No	0	0	0	0	3	No	N/A	~2.75	
2020	U	N/A	Yes	No	0	0	0	1	1	No	-11.95	~3.37	
2021	U but improving	N/A	Yes	No	0	2/2	1/2	0	1	No	+4.29	N/A (incomplete year)	
2022	A-B	C	Yes	Yes	2/1	6/2	5/2	0	0	Yes	-5.69	N/A (incomplete year)	
												MAD ~ [N/A] m^3/s	

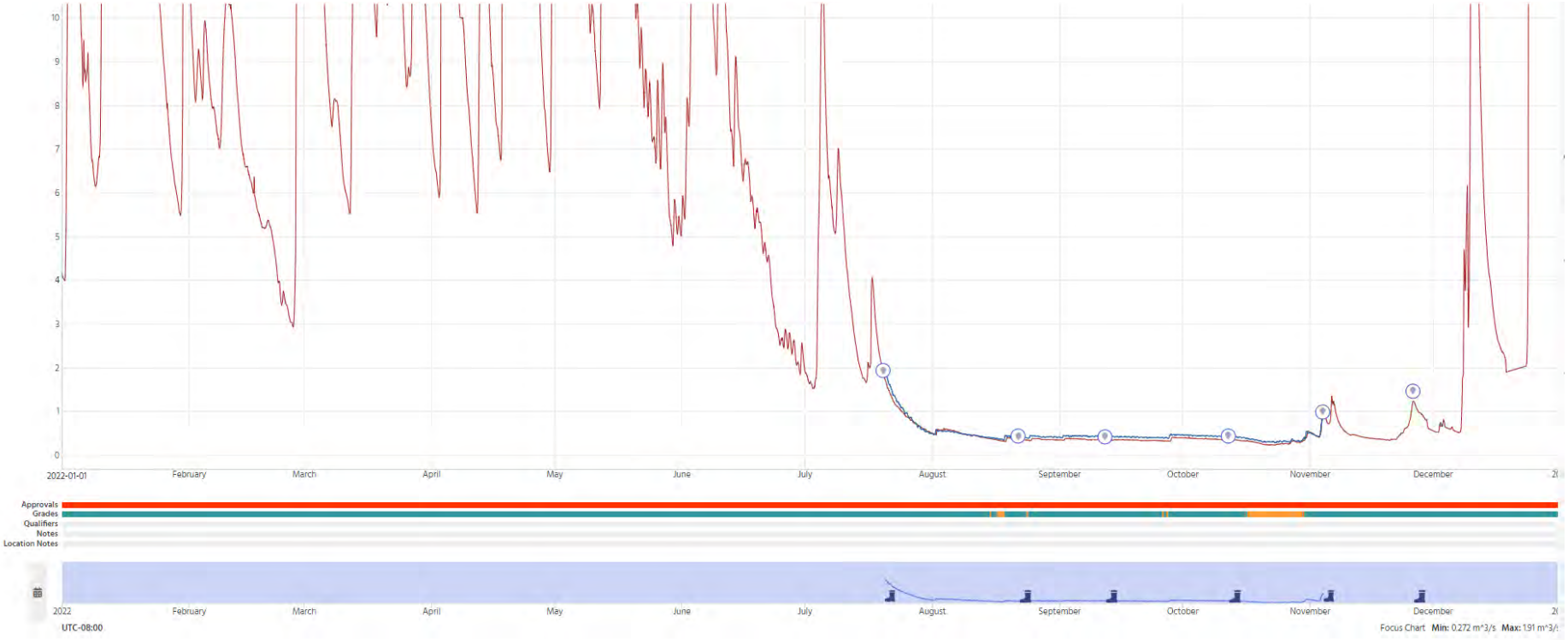


Figure 51. Tsolum River at McNaughton discharge data for 2022 (in blue), calculated using the active rating in Aquarius (PROVISIONAL DATA). Logger data only available from 2022-07-20 to 2022-11-04. Tsolum River near Courtenay (08HB011 – Water Survey of Canada) for comparison (in red).

Table 13. Tsolum River at McNaughton 2022 discharge summary.

Date/Time (PST)	Discharge (m^3/s)	Stage (m)	Control Condition	Discharge deviation (%)	Discharge uncertainty (%)	Notes
2022-07-20 12:00	1.89	8.944	Clear	-0.76	3.1	Ministry, TRRS, BCCF
2022-08-22 9:30	0.398	8.773	Clear	+1.35	5.5	TRRS
2022-09-12 11:30	0.385	8.777	Unspecified	-5.69	4.1	TRRS
2022-10-12 11:00	0.400	8.777	Clear	-2.01	3.2	TRRS
2022-11-04 12:00	0.950	8.857	Clear	+1.71	3.6	BCCF, TRRS
2022-11-26 11:30	1.43	8.904	Clear	+0.36	3.6	TRRS

July 25, 2019

August 22, 2022

November 4, 2022

November 26, 2022

Figure 52. Tsolum River at McNaughton, looking downstream at control (right bank riffle) from next to station.

October 12, 2012

August 22, 2022

Figure 53. Tsolum River at McNaughton, looking across from right bank to the boulder where logger is mounted.

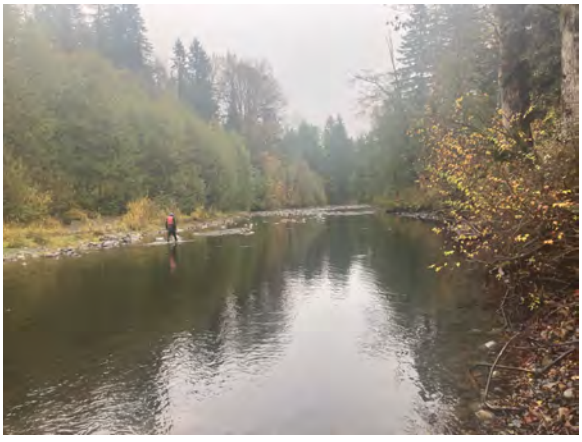
October 29, 2012

May 22, 2018

July 7, 2020

July 20, 2022

August 22, 2022



November 4, 2022

Figure 54. Tsolum River at McNaughton, looking downstream from right bank near walking path.

June 18, 2015

May 22, 2018

September 23, 2019

November 4, 2022

Figure 55. Tsolum River at McNaughton, looking upstream at riffle from right bank near walking trail.

October 12, 2012

November 4, 2022

Figure 56. Tsolum River at McNaughton, looking downstream at boulder where logger is mounted.

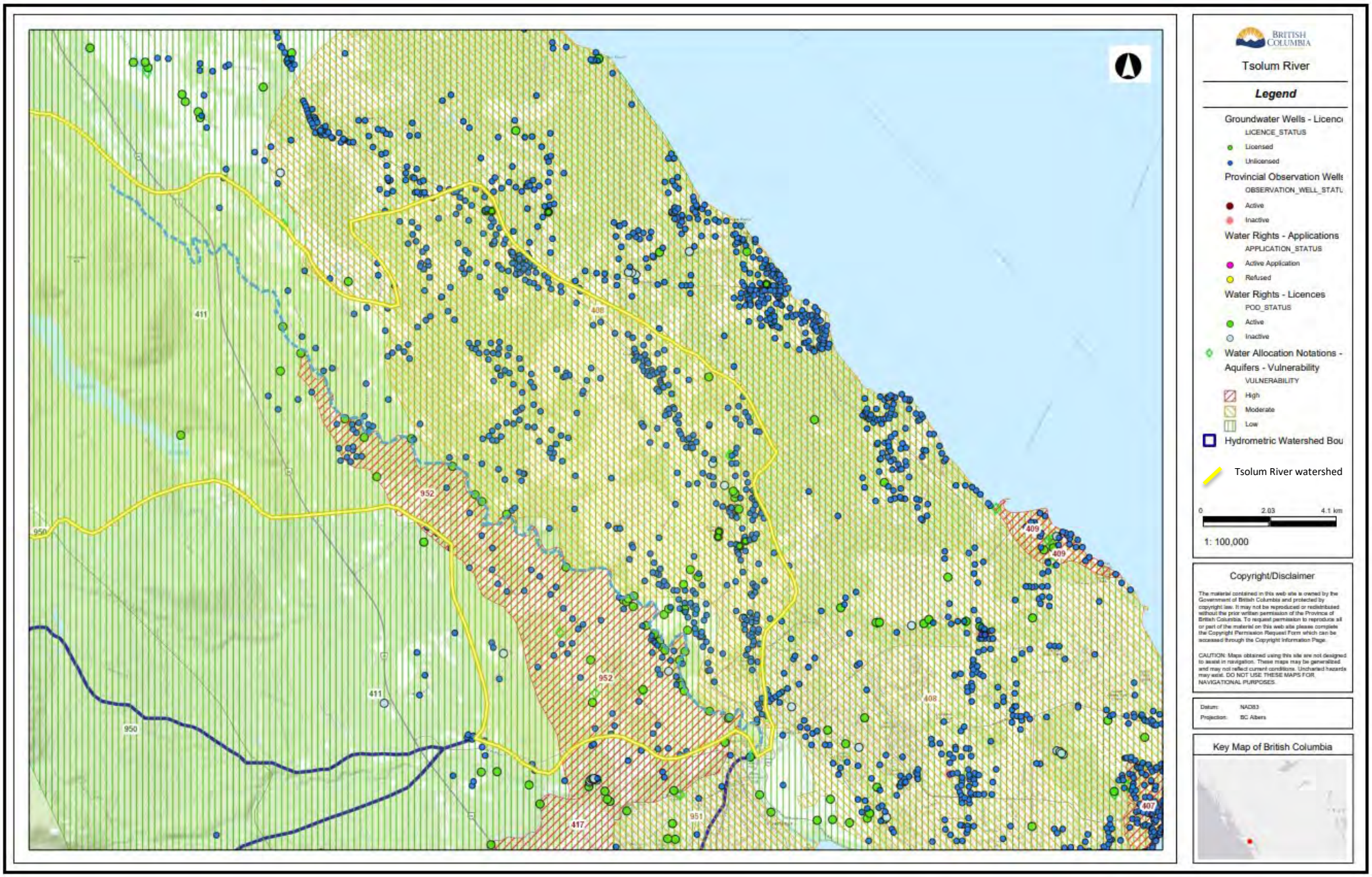


Figure 57. Tsolum River groundwater wells & licensed water demand (current to February 2023).

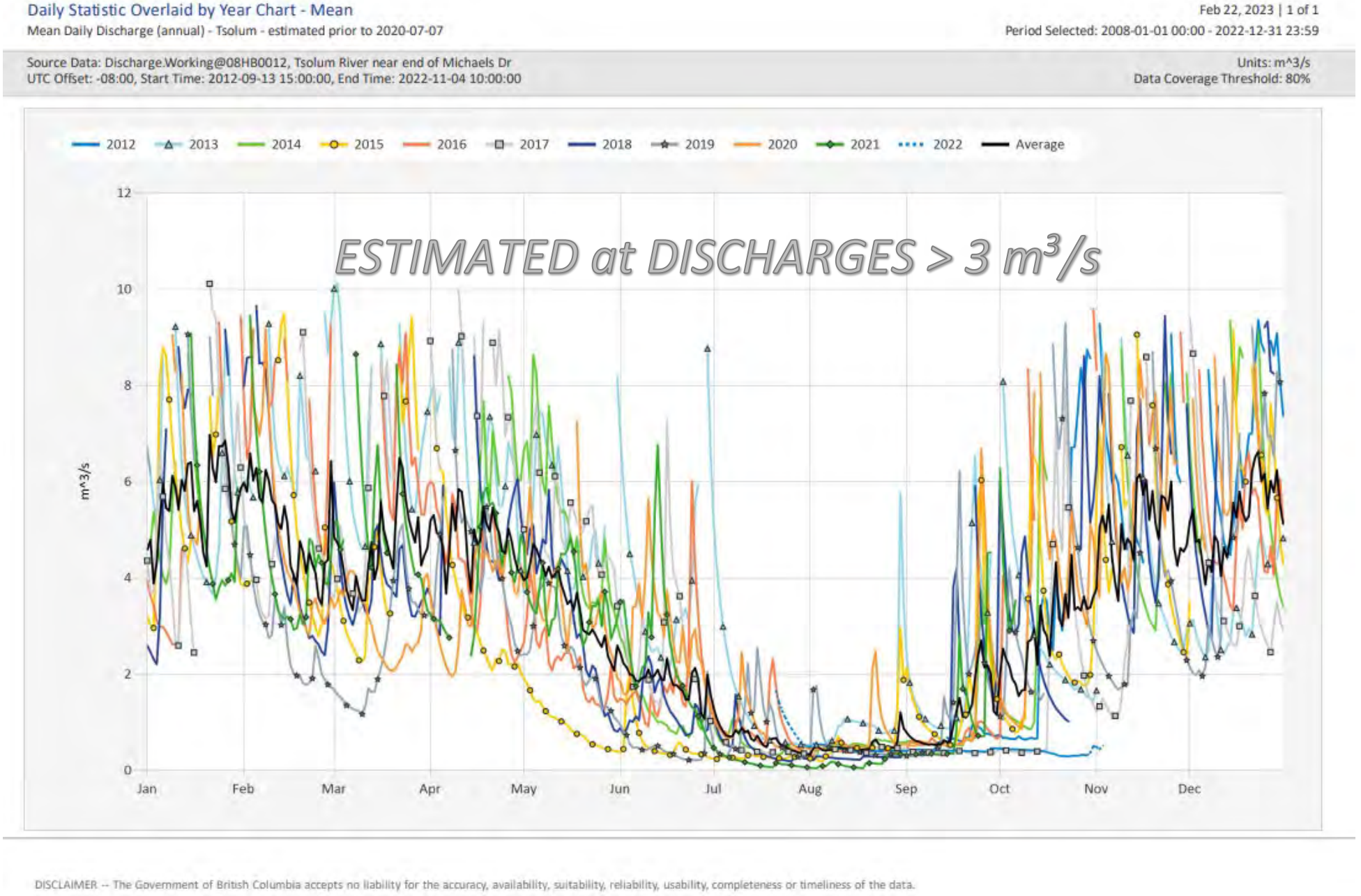


Figure 58. Tsolum River at McNaughton estimated discharge from September 2012 - November 2022 (PROVISIONAL DATA).

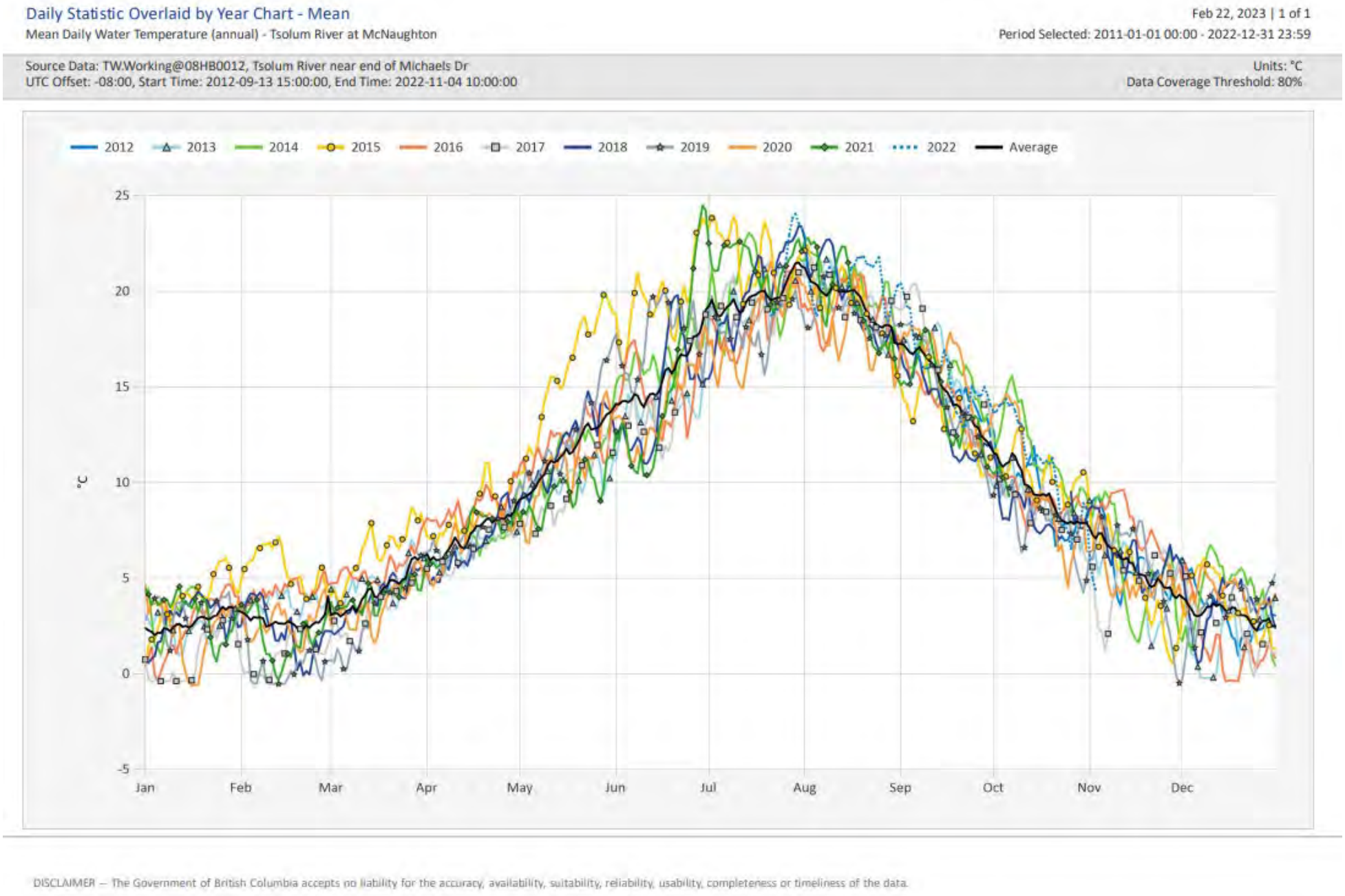


Figure 59. Tsolum River at McNaughton water temperature data from September 2012 - November 2022.

IV. CONCLUSION

This document summarizes the seven pilot gauging stations included in the Vancouver Island Community Flow Monitoring Network (CFMN) for 2022. Of the seven pilot stations, four met or exceeded Grade "C" while three remained at Grade "U" (Table 14). Of the Grade "U" stations, two were discontinued after station review and capacity assessment. These will be replaced by different stations in 2023.

Table 14. Community pilot flow station RISC data grade summary for 2022.

Station name	Station ID	2022 data grade	Continuing
Tsolum River near End of Michaels Drive	08HB0012	A-B	Y
Beach Creek at Hemsworth Road	08HB0031	B-C	Y
Cook Creek at HWY 19A	08HB0032	C	Y
Wilfred Creek at HWY 19A	08HB0024	C	Y
Grandon Creek at Crescent Rd	08HB0011	U	Y
Rosewall Creek near HWY 19A Bridge	08HB0008	U	Maybe
Black Creek near HWY 19A and Enns Rd Intersection	08HD0001	U	N

Preliminary project findings indicate this pilot has been highly successful to date, with more than 250 volunteer hours and 100 provincial staff support hours contributed since April 2022. Data accuracy varied between groups and individual data collectors, but showed an improving trend over past years. Continued progress of the CFMN will lead to improved data collection and better conservation action outcomes for partner groups.

Expansion to other regions for this community-supported monitoring model currently seems positive and feasible. Further insight will come as the pilot program grows and develops through 2025. Some of the main lessons learned and recommendations from Year 1 of this pilot project are below:

Lessons Learned

1) Volunteers benefit greatly from a step-by-step guide, lots of regular practice, and regular feedback from experienced equipment operators to feel confident with protocols.
2) Data submission needs to be confirmed/acknowledged, and feedback provided soon after submission.
3) Streamlining station equipment and data submission protocols (e.g. data sheets, submission format, etc.) will significantly help expedite the processing of data to Aquarius.
4) Volunteer appreciation events and "perks" help provide a sense of community and excitement about monitoring and stewardship.

Recommendations for 2023

1) A set of standard operating procedures should be printed and provided to assist volunteers in the field.
2) A website to house project resources (e.g. SOP, contact information) should be developed.
3) Further refinement of data sheets and submission protocols (based on user feedback) should be ongoing.
4) In addition to the twice-annual Network meetings and in-person training events, a volunteer appreciation event should be held. At the event, perks such as T-shirts/hoodies or prize items could be distributed.
5) BCCF has started compiling a lending library and will distribute equipment to groups in need of new or replacement gear in 2023.

V. ACKNOWLEDGEMENTS

Funding to support Year 1 of this program was provided by the BC Community Gaming Grant, Habitat Conservation Trust Foundation, Freshwater Fisheries Society of BC, Pacific Salmon Foundation, RBC Foundation Tech for Nature, BC Ministry of Environment, and dozens of community volunteers.

Special thanks to Ed and Katherine Wasiak, Ray Woroniak & family, Mike Mesford, Paul Anders, Simon Martin, Hamish Murray, Norm Wiens, Caroline Heim, Randy Lousier, Bill Thomson, Ally Badger, Lilian Sebastian, Eli Riedl, Neil Goeller, Jon Jeffery, and Jamison Romano for your participation and support of monitoring in 2022.

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