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MEMORANDUM

TO: **Nechako Water Engagement Initiative**

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DATE: **December 15, 2022**

FILE: **1316-07**

RE: **Nechako River Fish Stranding Screening Assessment**

1. INTRODUCTION

During Main Table and Technical Working Group meetings of the Nechako Water Engagement Initiative (WEI), concerns were raised about potential effects of Rio Tinto operations on fish populations in the Nechako Reservoir. In particular, there was interest in understanding whether fish were being stranded downstream of the Skins Lake Spillway from rapid flow reductions during reservoir operations. Flow reductions can lead to fish isolation in shallow pools and stranding in dewatered substrate, ultimately causing mortality. Of particular concern were the rapid and longer-scale changes in flow rates and corresponding water level resulting from Summer Temperature Monitoring Program (STMP) releases from Nechako Reservoir through Skins Lake Spillway (SLS).

This memo provides a screening level assessment of fish stranding risks downstream of the Skins Lake Spillway. The following sub-sections provide background about the reservoir system, spillway, fish habitat, and fish community in downstream reaches; analysis of hydrology data characterizing changes in flow, known as ramping; and a discussion of the consequences of changes in flow and water level to the relevant fish populations.

1.1. Background

The Nechako Reservoir is a large hydroelectric storage reservoir impounded by the Kenney Dam and located approximately 200 km west of Prince George, British Columbia (Map 1). The reservoir is operated by Rio Tinto Alcan to produce energy for the Kitimat aluminium smelter. It has an area of ~890 km^2 and inundates an ~420 km long chain of six major lake and river systems (the Ootsa, Whitesail, Knewstubb, Tetachuck, Natalkuz, and Tahtsa). There are two reservoir outflows: the powerhouse intake portal to the west into the Kemano River watershed, and the Skins Lake Spillway to the east into the Nechako River watershed (Map 1). There is no discharge facility at the Kenney Dam.

The Skins Lake Spillway, which was constructed in 1953, is located in a small embayment mid-way along Ootsa Lake on the northern side of the reservoir. Water passing through the spillway is discharged to a downstream plunge pool and then flows downstream through the Cheslatta River and Skins Lake, Cheslatta Lake, and Murray Lake before discharging into the Nechako River (Map 1). Mean annual discharge (1990-2020) from the spillway is ~75 m^3/s and varies from 38.2 m^3/s in January to 204.9 m^3/s in July.

Flows through the Skins Lake Spillway are regulated to meet hydroelectricity production requirements and instream flow requirements for fish within the Nechako River. Changes in flow release at the spillway affect both flow and water level downstream. Changes in flow are called ramping, and the rate of these changes is called the ramping rate.

The largest flow reductions from the Skins Lake Spillway occur in the summer between July 20th and August 20th, when water from the Nechako Reservoir is released through the spillway to cool water temperatures for migrating sockeye salmon in the Nechako River. However, flow reductions have the potential to affect fish and habitat throughout the year. Flow reductions may strand fish immediately on dewatered stream margins, or isolate fish in side channels and pools, where they may suffer increased mortality from predation or poor water quality. Larger flow changes and higher ramping rates increase the risk of fish isolation, stranding, and mortality.

1.2. Objective and Scope of Work

The objective of this memo is to document and assess the flow ramping rate downstream of the Skins Lake Spillway at various locations, and to evaluate the potential risk of fish stranding by comparison to known ramping rate thresholds. The focus of this memo is on the ramping rate (i.e., the rate of change in flow and water level), but we note that the magnitude of flow change also affects fish stranding risk and is more important than ramping rate on some rivers (Irvine *et al.* 2015).

To evaluate the risks of fish stranding we:

- Calculated the rate and frequency of flow ramping where continuous data were available and compared these to generic standard ramping criteria set by Fisheries and Oceans Canada (DFO);
- Identified the influence of Skins Lake Spillway releases on ramping events downstream;
- Used attenuation analyses of Skins Lake Spillway releases to infer the magnitude of ramping events directly below the spillway where no gauge data were available;
- Characterized daily and annual water level (stage) change over larger available dataset; and
- Qualitatively evaluated the risk to fish from ramping based on the evaluation of ramping events, characterization of fish and fish habitat, and experience on previous ramping assessments on other rivers.

2. PROJECT SETTING

The assessment was conducted in two geographic areas, the Cheslatta-Murray watershed and the Nechako River.

2.1. Cheslatta-Murray System

2.1.1. Hydrology

Water released from the Skins Lake Spillway is discharged downstream to a plunge pool and then flows downstream through the Cheslatta River and Skins Lake, Cheslatta Lake, and Murray Lake before discharging into the Nechako River (Map 1). Tributary inflows are minor and are attenuated by Skins Lake and Cheslatta Lake. Flow and water level are monitored by Water Survey Canada (WSC) at the west end of Cheslatta Lake (Map 2). Rio Tinto also monitors water level at the west end of Cheslatta Lake.

2.1.2. Fish and Fish Habitat

The Cheslatta River extends from the Skins Lake Spillway downstream for 1.5 km to Skins Lake, providing fish rearing and holding habitat and possibly spawning habitat. Skins Lake provides littoral and pelagic lake habitat of 512 ha with a maximum depth of 21.0 m (Hatfield 1998). The Cheslatta River then continues downstream of Skins Lake, providing approximately 23 km of riverine habitat until its confluence with Cheslatta Lake, which provides approximately 3,500 ha of littoral and pelagic lake habitat with a maximum depth of 73 m (Golder 2005). Review of satellite imagery of Skins Lake and the Cheslatta River shows high-risk stranding habitat exists (i.e., low gradient banks, extensive gravel/cobble bar formations, and side channels, Figure 1 and Figure 2).

At the downstream end of the Cheslatta River lies Cheslatta Falls, a ~28 m high impassable barrier to fish migration that marks the upstream limit of anadromous fish access. At the base of this falls lies the Nechako-Cheslatta confluence, from which the Nechako River flows for ~250 km to Prince George.

Over a dozen fish species have been confirmed in Skins Lake and Cheslatta Lake, most of which are also found within the Nechako Reservoir (Hatfield 1998, Golder 2005, BC MOE 2021a, BC MOE 2021b; Table 1). Of note, information on Kokanee downstream of the Skins Lake Spillway (i.e., Skins Lake, Cheslatta Lake) is limited to a few observations and one report (Harder 1986) from the 1980s and 1990s.

Figure 1. Aerial photographs of Skins Lake shoreline taken on November 21, 2019 showing low-gradient, stranding-sensitive shoreline habitat.

Figure 2. Aerial photographs of upper Cheslatta River shoreline taken on November 21, 2019 showing stranding-sensitive low-gradient banks, gravel bars, and side channel habitat.

2.2. Nechako River

2.2.1. Hydrology

The Nechako River flows ~250 km from its confluence with the Cheslatta River to Prince George. The downstream extent of this screening assessment was limited to Isle Pierre located between Vanderhoof and Prince George (Map 1). The major tributaries to the Nechako River are the Nautley River and Stuart River, with numerous smaller tributaries also contributing flow that in combination attenuates flow reductions.

Flow and water level are monitored by Water Survey Canada (WSC) at Nechako River at Cheslatta Falls, Nechako River at Vanderhoof, and Nechako River at Isle Pierre (Map 2).

2.2.2. Fish and Fish Habitat

The Nechako River supports both resident and anadromous fish in adult and juvenile forms. The fish community and fish habitat within the Nechako River downstream of Cheslatta Falls have been extensively documented.

At least 20 fish species have been observed within the Nechako River downstream of Cheslatta Falls, of which three are anadromous pacific salmon (Sockeye (*Oncorhynchus nerka*), Coho (*Oncorhynchus kisutch*), and Chinook (*Oncorhynchus tshawytscha*); Table 1). Chinook and Coho Salmon spawn in the Nechako River, whereas Sockeye Salmon migrate through the Nechako en-route to spawning grounds. Two populations of adult Sockeye Salmon (the Early Stuart and Late Stuart stocks) using the Nechako River are listed as Endangered, while a third (the Francois population) is listed as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (BC MOE 2021b). The Nechako Chinook population is part of the Mid-Fraser Summer Chinook Conservation Unit, which has been designated as Threatened (BC MOE 2021b). Furthermore, the Nechako Coho population is part of the Interior Fraser Conservation Unit, which is considered threatened (COSEWIC 2021); however, there is insufficient data to assess biological status (PSF 2021).

Fish species may be affected by flow reductions during all life stages; however, juvenile forms are at greater of stranding due to their slow swimming speed, tendency to hide in cover, and use of shallow habitats at risk of dewatering. The Nechako River has extensive high stranding risk habitats (e.g., low-gradient banks, extensive gravel/cobble bar formations, and side channels; Figure 3).

Table 1. Fish species present in the Cheslatta-Murray System and Nechako River by location and their provincial and federal status.

Location	Life History	Fish Species[1]	Scientific Name	Provincial/Federal Status[4]
Nechako Reservoir	Resident	Brassy Minnow[2]	*Hybognathus hankinsoni*	-/-
		Bridgelip Sucker	*Catostomus columbianus*	Yellow/-
		Burbot	*Lota lota*	Yellow/-
		Kokanee	*Oncorhynchus nerka*	-/-
		Lake Chub[3]	*Couesius plumbeus*	Yellow/-
		Largescale Sucker	*Catostomus macrocheilus*	Yellow/-
		Longnose Sucker	*C. catostomus*	Yellow/-
		Mountain Whitefish	*Prosopium williamsoni*	Yellow/-
		Northern Pikeminnow	*Ptychocheilus oregonensis*	Yellow/-
		Prickly Sculpin	*Cottus asper*	Yellow/-
		Pygmy Whitefish[4]	*P. coulterii*	Yellow/-
		Rainbow Trout	*O. mykiss*	Yellow/-
		Slimy Sculpin[3]	*C. cognatus*	Yellow/-
		White Sucker[3]	*C. commersonii*	Yellow/-
Murray-Cheslatta Lakes	Resident	Bull Trout	*Salvelinus confluentus*	Blue/Special concern
		Burbot	*L. lota*	Yellow/-
		Dolly Varden	*S. malma*	Yellow/-
		Kokanee	*O. nerka*	-/-
		Lake Chub	*C. plumbeus*	Yellow/-
		Lake Trout	*S. namaycush*	Yellow/-
		Lake Whitefish	*Coregonus clupeaformis*	Yellow/-
		Largescale Sucker	*C. macrocheilus*	Yellow/-
		Longnose Sucker	*C. catostomus*	Yellow/-
		Mountain Whitefish	*P. williamsoni*	Yellow/-
		Northern Pikeminnow	*P. oregonensis*	Yellow/-
		Rainbow Trout	*O. mykiss*	Yellow/-
		Redside Shiner	*Richardsonius balteatus*	Yellow/-
		Sculpins	*Cottus sp.*	Yellow/-
Nechako River	Anadromous	Chinook Salmon	*O. tshawytscha*	-/Threatened
		Coho Salmon	*O. kisutch*	-/Threatened
		Sockeye Salmon	*O. nerka*	-/Endangered (Early and Late Stuart stocks), Special concern (Francois stock)
	Resident	Brassy Minnow	*H. hankinsoni*	-/-
		Bull Trout	*S. confluentus*	Blue/Special concern
		Burbot	*L. lota*	Yellow/-
		Lake Chub	*C. plumbeus*	Yellow/-
		Largescale Sucker	*C. macrocheilus*	Yellow/-
		Leopard Dace	*Rhinichthys falcatus*	Yellow/Not at risk
		Longnose Sucker	*C. catostomus*	Yellow/-
		Mountain Whitefish	*P. williamsoni*	Yellow/-
		Northern Pikeminnow	*P. oregonensis*	Yellow/-
		Peamouth Chub	*Mylocheilus caurinus*	-/-
		Prickly Sculpin	*C. asper*	Yellow/-
		Pygmy Whitefish	*P. coulterii*	Yellow/-
		Rainbow Trout	*O. mykiss*	Yellow/-
		Redside Shiner	*R. balteatus*	Yellow/-
		Slimy Sculpin	*C. cognatus*	Yellow/-
		White Sturgeon	*Acipenser transmontanus*	Red/Endangered
		White Sucker	*C. commersonii*	Yellow/-

[1]FIDQ 2021, MOE 2021a, MOE 2021b, Robertson, pers. comm. 2021, NFCP 2005, COSEWIC 2021, Avison 2019, Hamilton and Schmidt 2005, Triton 2000 a,b, Triton 2005, Envirocon 1989.

[2]Found in the plunge pool of the Skins Lake Spillway and could potentially have been entrained from the Nechako Reservoir (Tolton 2011)

[3]Species noted in tributaries to the Nechako Reservoir (Triton 2000 a,b, Triton 2005) that could also use the Nechako Reservoir lacustrine habitats.

[4]Traditional Knowledge has indicated that Pygmy Whitefish are known to be present in the Nechako Reservoir area. (Robertson pers. comm. 2021).

"-" indicates no Federal or provincial status (BC MoE 2021b). Yellow=secure, Blue=special concern, Red=candidates for, Extirpated, Endangered, or Threatened status.

Figure 3. Aerial photographs of Nechako River shoreline taken on November 21, 2019 showing stranding-sensitive low-gradient banks, gravel bars, and side channel habitat.

3. METHODS

To estimate ramping rates, we analysed data on flow and water level (referred to hereafter as stage) on continuous (five-minute) and daily time frequencies. Stage data were acquired from WSC gauges positioned at Cheslatta Lake (data from 2012) and in the Nechako River downstream of Cheslatta Falls (data available from 2012 to 2020) at the following stations (Map 2):

- West end of Cheslatta Lake (WSC 08JA018);
- Nechako River below Cheslatta Falls (WSC 08JA017);
- Nechako River at Vanderhoof (WSC 08JC001); and
- Nechako River at Isle Pierre (WSC station 08JC002).

Attenuation of flows was assessed by comparing flow releases from the Skins Lake Spillway to continuous stage data from Cheslatta Lake and the Nechako River in 2012. We characterized the magnitude and frequency of flow releases from the Skins Lake Spillway between 2010 and 2020 (data provided by Rio Tinto). Point estimates were calculated from reservoir elevation, and the height of flow release gates at the spillway was assumed to be constant between consecutive estimates. We then compared Skins Lake Spillway data to the daily average stage change in Cheslatta Lake to understand attenuation. This also allowed us to estimate the magnitude of stage changes upstream within Skins Lake and the Cheslatta River where no data were available.

We characterized pre-2012 stage patterns within the Cheslatta-Murray watershed using data on the daily mean Cheslatta Lake stage from 1981 to 2011 (provided by Rio Tinto and calculated for 2012 from continuous data). We compared 2012 stage levels in the watershed to those of previous years to confirm whether 2012 was representative of conditions within Cheslatta Lake during the STMP.

We used continuous WSC data to calculate hourly ramping rates. Up-ramping and down-ramping rates were calculated for each gauge datum as the difference between that stage (cm) and the maximum stage in the previous hour (cm), using the following procedure:

1. The maximum stage observed over the past hour for each data point i was calculated as:

   $$hmax(t_i) = \max\left(h(t_{i-k}), \dots, h(t_{i-1})\right)$$

   where h is stage, k is the number of data points recorded per hour, and t is time.

2. The maximum stage decrease over the past hour relative to time $\mathrm{t_i}$, $\Delta\mathrm{hmax}(\mathrm{t_i})$, was calculated as:

   $$\Delta hmax(t_i) = h(t_i) - hmax(t_i)$$

3. If the maximum stage change, Δhmax(ti), exceeds the ramping criterion (-2.5 cm/hr), the data are flagged as a potential ramping event.

4. The ramping event is confirmed if the ramping rate remains below the ramping criterion for a minimum of 10 minutes.

Ramping rates were calculated during the STMP period (i.e., July 1st to September 15th). We compared these rates to the standard DFO ramping rate criteria for run-of-river hydroelectric projects (i.e., -2.5 cm/hr, for the fry-present period, -5 cm/hr when fry are not present; Catthcart 2005) to identify the frequency and magnitude of exceedances.

4. RESULTS

4.1. Comparison of WSC Gauges and Skins Lake Spillway Releases

Over the STMP period, water levels across gauges generally followed Skins Lake Spillway flow releases, as evident in both Cheslatta Lake and the Nechako River, with the ramping signal attenuating with distance downstream (Figure 4, Figure 5, Figure 6). Skins Lake Spillway flow releases, and corresponding Nechako River flows during the STMP vary among years (i.e., multiple reductions and releases in 2014 and 2019). Skins Lake Spillway flow releases arrived at Cheslatta Lake in ≤1 hr, at Cheslatta Falls in 6-14 hrs, at Vanderhoof in 1-2 days, and at Isle Pierre in 2-3 days.

Figure 4. a) 2012 stage (m), b) daily total stage change (cm/day), c) daily mean stage change (cm/day), d) down-ramping rate (cm/hr) during STMP flow release period at gauges in the Nechako River (below Cheslatta Falls, at Vanderhoof, and at Isle Pierre), and e) flow releases (m^3/s) at the Skins Lake Spillway.

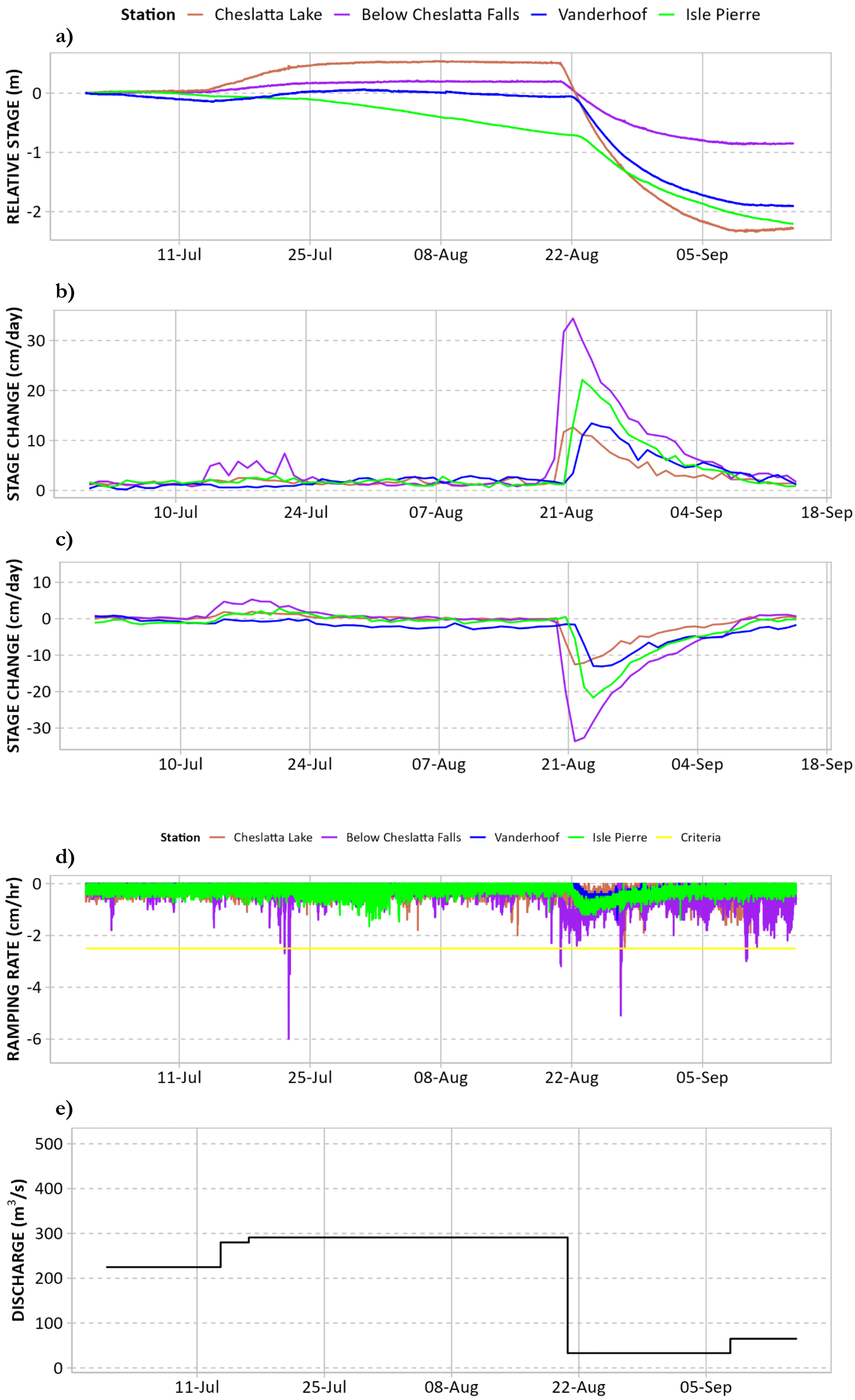

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Figure 5. a) 2014 stage (m), b) daily total stage change (cm/day), c) daily mean stage change (cm/day), d) down-ramping rate (cm/hr) during STMP flow release period at gauges in the Nechako River (below Cheslatta Falls, at Vanderhoof, and at Isle Pierre), and e) flow releases (m^3/s) at the Skins Lake Spillway.

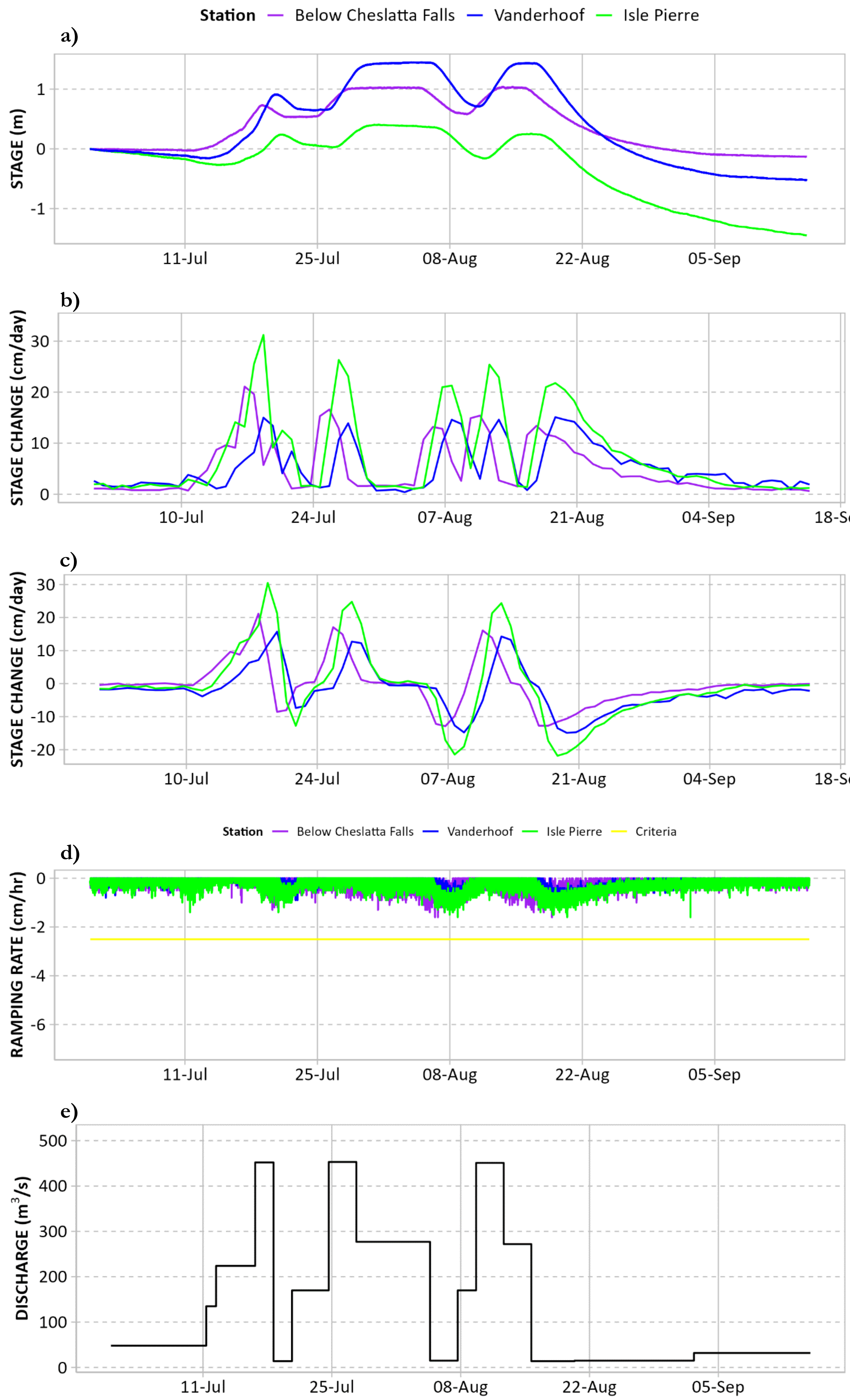
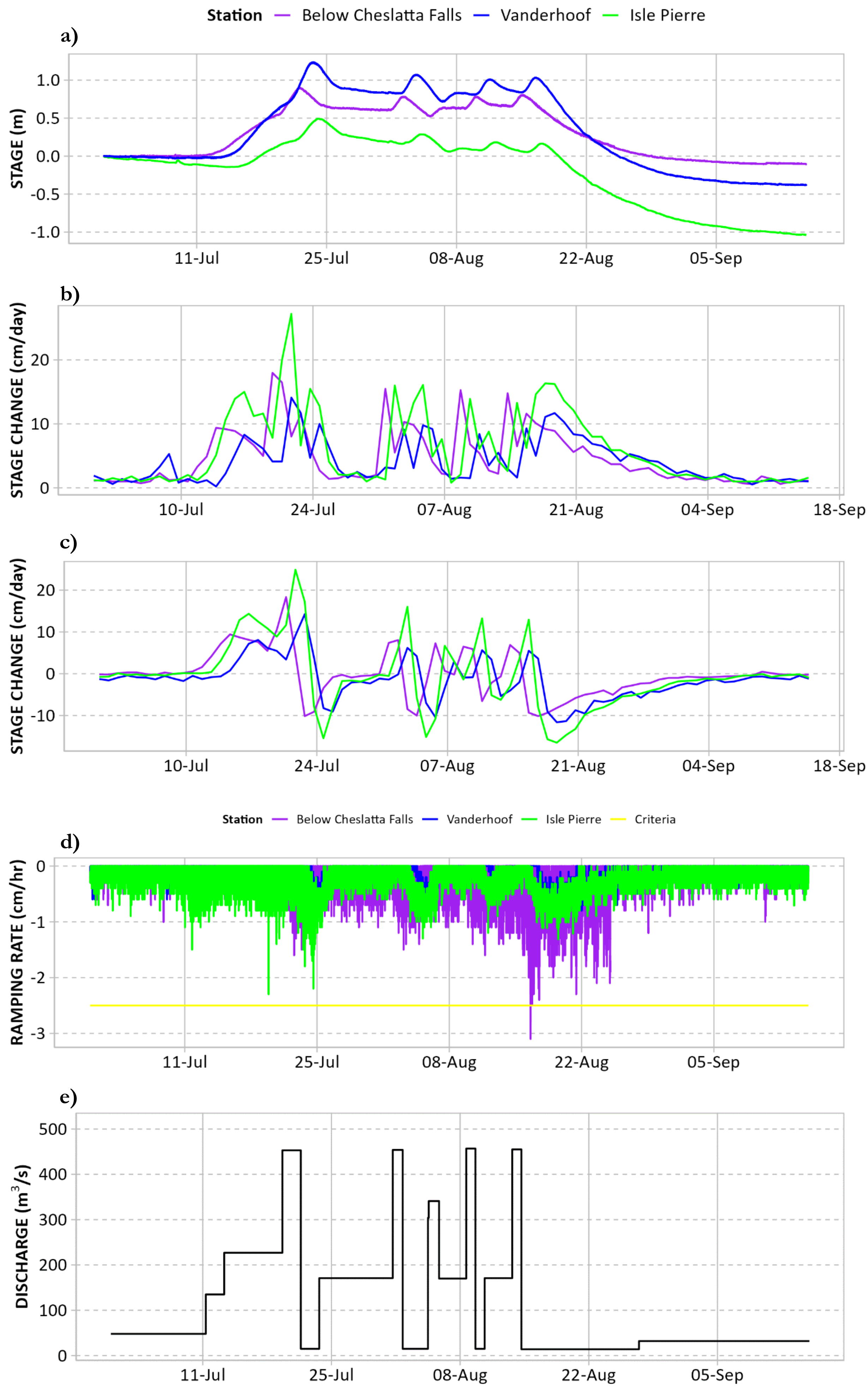


Figure 6. **A) 2019 stage (m), B) daily total stage change (cm/day), C) daily mean stage change (cm/day), and D) down-ramping rate (cm/hr) during STMP flow release period at gauges in the Nechako River (below Cheslatta Falls, at Vanderhoof, and at Isle Pierre), and E) flow releases (m^3/s) at the Skins Lake Spillway.**



4.2. Effect of SLS Releases on Downstream Stage

4.2.1. Cheslatta River Upstream of Cheslatta Lake

There are no flow or stage data for the Cheslatta River upstream of Cheslatta Lake, however, because the Cheslatta River is narrower than Cheslatta Lake, ramping rates are likely higher than in Cheslatta Lake.

4.2.2. Cheslatta Lake

Daily stage data in Cheslatta Lake from 1981 to 2012 (Figure 7) illustrate that on average Cheslatta Lake stage is:

- Relatively stable in the fall and winter;
- Increases by 0.5 m in April with spring freshet;
- Increases by 2 m on average at beginning of the STMP period in July and August;
- Decreases by 2 m in late August and mid-September; and
- Exhibits high flows pulses of 1 to 3 months in duration in some years, usually in the spring and summer, but in a few years in the fall and early winter.

Cheslatta Lake stage is highest during the STMP and is strongly correlated with SLS flow releases (Figure 8). During the STMP period there is considerable variability between years: 2010 is an example of large fluctuations in daily stage change following gate changes compared to a relatively stable year such as 2012 (Figure 4).

Figure 7. **Daily stage at the Cheslatta Lake gauge from 1981 to 2012.**

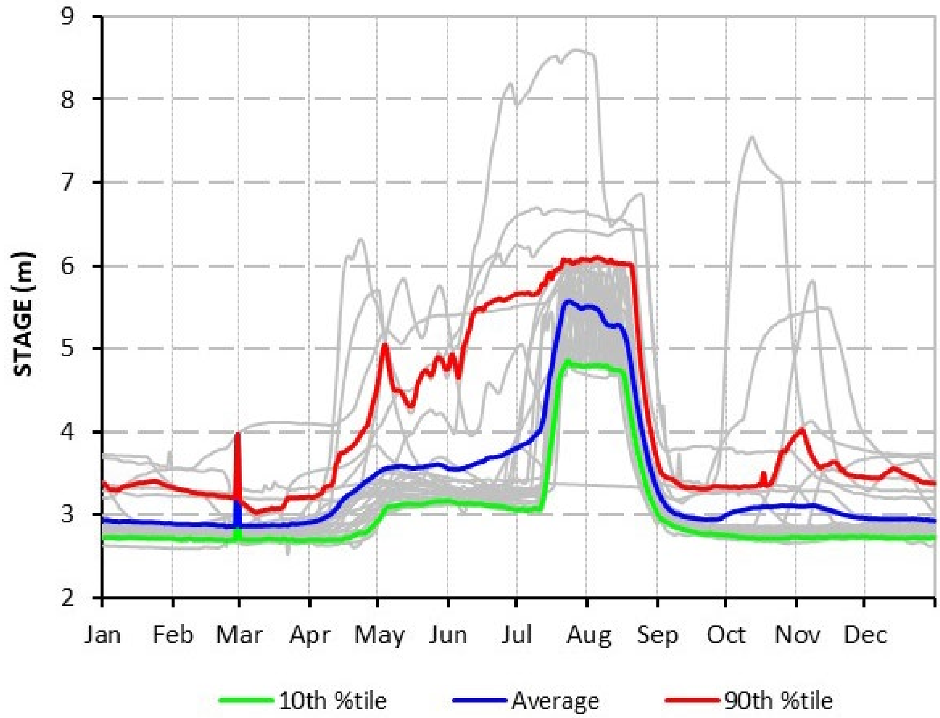
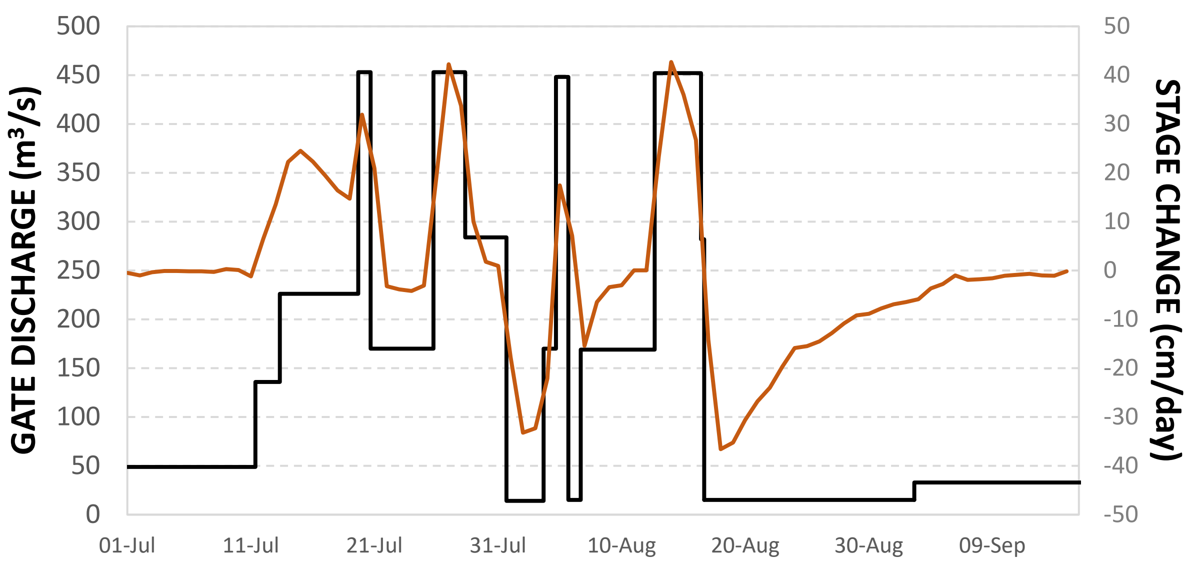


Figure 8. **Estimated flow releases from the SLS (black line) compared to daily stage changes within Cheslatta Lake (copper line) during the STMP period in 2010.**



4.2.3. Cheslatta River Downstream of Cheslatta Lake

There are no flow or stage data for the Cheslatta River downstream of Cheslatta Lake; however, because the Cheslatta River is narrower than Cheslatta Lake, ramping rates are likely higher than in Cheslatta Lake.

4.2.4. Nechako River

SLS flow releases will be attenuated along the Cheslatta River and Cheslatta and Murray lakes, reducing the magnitude of stage change in the Nechako River. Plots of stage at the three Nechako River gauges over the STMP period (Figure 4 to Figure 6) indicate that Nechako stage follows SLS flow releases and demonstrates that attenuation increases with distance downstream. Variance between years in the SLS flow releases during the STMP period is reflected in Nechako River stage, showing multiple large stage changes in some years.

4.3. Ramping Rates

Ramping rates in Cheslatta Lake and the Nechako River are low and within generic standard ramping rates identified for hydroelectric projects (Catthcart 2005) >99% of the time. Down-ramping rates exceed -2.5 cm/hr rate 0.367% of the time in Cheslatta Lake, and only 0.036% of the time in the Nechako River (Table 2). Plots of ramping rates by season are provided in Figure 9 to Figure 12. In Cheslatta Lakes both down-ramping and up-ramping rates increase in the winter months, likely a result of the influence of ice cover, whereas in the Nechako River ramping rates are higher in the summer, reflecting the influence of seasonal peak flows.

Although there are no stage data for Cheslatta River, stage changes at Cheslatta Lake suggest that the magnitude of stage change in the Cheslatta River, which is narrower, exceed generic standard ramping criteria during the STMP period.

Table 2. Frequency of down-ramping and up-ramping rates by ramping rate criteria in Cheslatta Lake and Nechako River.

WSC Station	Name	% of Ramping Rates				
		Below -5 cm/hr	Between -5 and -2.5 cm/hr	Between -2.5 and 2.5 cm/hr	Between 2.5 and 5 cm/hr	Above 5 cm/hr
08JA018	West end of Cheslatta Lake	0.003%	0.364%	99.215%	0.415%	0.002%
08JA017	Nechako River below Cheslatta Falls	0.001%	0.003%	99.994%	0.001%	0.000%
08JC001	Nechako River at Vanderhoof	0.001%	0.035%	99.896%	0.066%	0.002%
08JC002	Nechako River at Isle Pierre	0.004%	0.009%	99.974%	0.011%	0.002%

Figure 9. **Frequency of ramping rates by season at the west end of Cheslatta Lake (WSC JA018) from 2012 to 2020.**

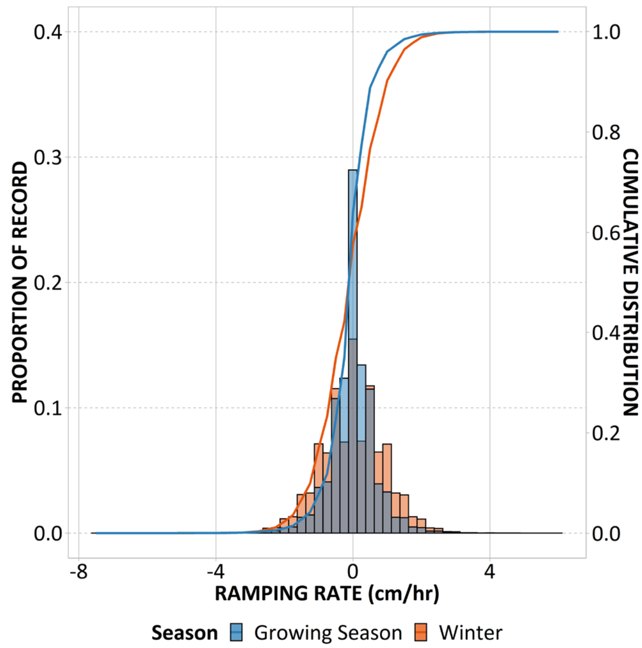


Figure 10. **Frequency of ramping rates by season in the Nechako River below Cheslatta Falls (WSC JA0017) from 2012 to 2020.**

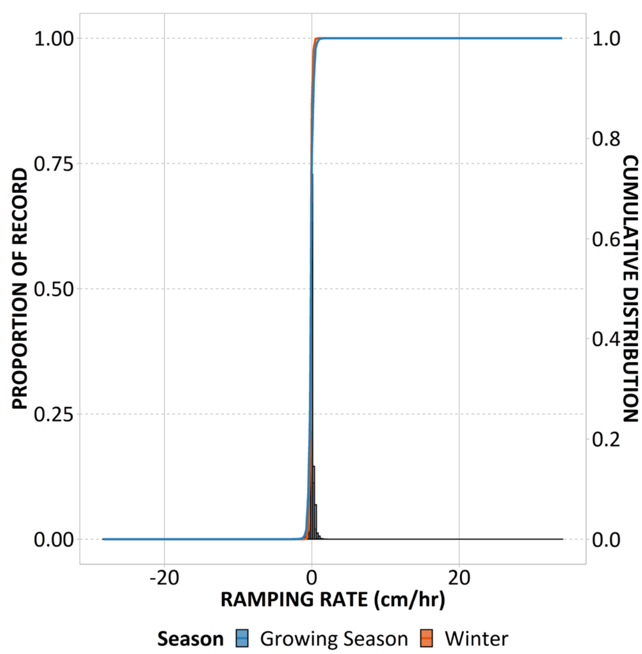


Figure 11. Frequency of ramping rates by season in the Nechako River at Vanderhoof (WSC JC001) from 2012 to 2020.

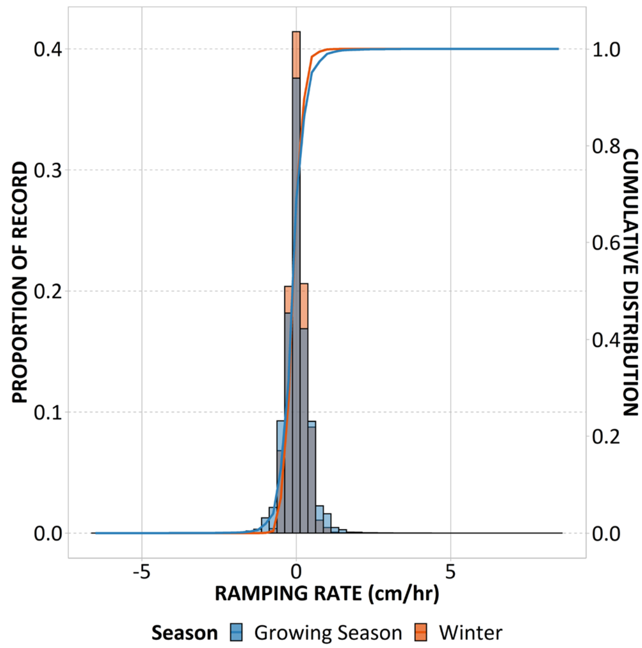
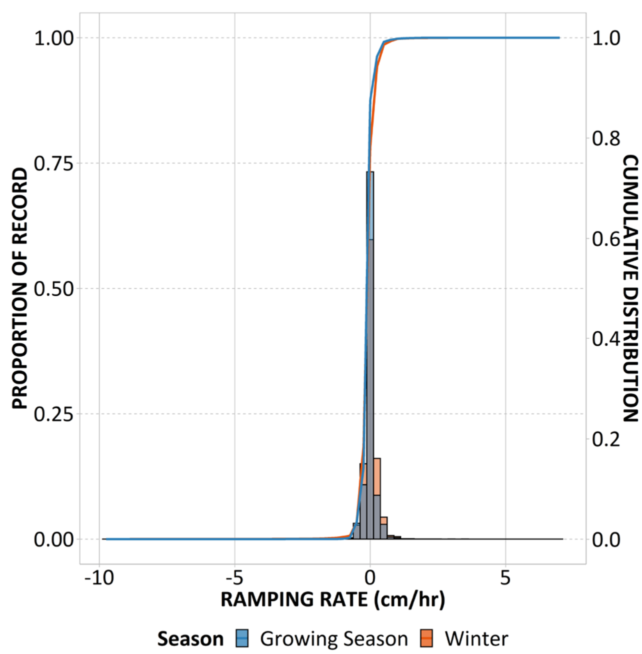


Figure 12. Frequency of ramping rates by season in the Nechako River at Isle Pierre (WSC JC002) from 2012 to 2020.



Down-ramping and up-ramping rates from 2012 to 2020 during the STMP period for gauges located below Cheslatta Falls are plotted in Appendix A. Exceedances were infrequent and generally of short duration (15-60 minutes), with a maximum of 8 events observed in a single year (at Cheslatta Lake) but fewer down-ramping events in the Nechako River (four Below Cheslatta Falls, one at Vanderhoof, and none at Isle Pierre).

5. DISCUSSION/RISK TO FISH SYNTHESIS

5.1. Cheslatta-Murray System

SLS flow changes during the STMP cause large changes in Cheslatta Lake levels; however, ramping rates are attenuated by lake morphology. Although there are no flow or stage data for the Cheslatta River, ramping rates likely exceed DFO criteria because of the narrower channel compared to Cheslatta Lake.

The presence of high-risk stranding habitat and presumed presence of fry and juvenile resident salmonids and other species indicates that that fish stranding is likely in the Cheslatta River, particular in the upper sections where attenuation will be limited.

5.2. Nechako River Downstream of Cheslatta Falls

- SLS flow changes are attenuated by Cheslatta Lake before they reach the Nechako River.
- Ramping rates in the Nechako River rarely exceed DFO generic criteria. Stranding risk from rapid flow changes in the Nechako River is low.
- Regardless of the rate of flow ramping, large decreases in river stage may strand fish in side/off channel habitats if they lose connectivity to the mainstem as flows decrease. Large seasonal decreases in flow took place naturally prior to the diversion of the Nechako River; however, the seasonal changes are likely accelerated at the end of the STMP period, when river stage decreases by >1 m over days to weeks in some years. Fry and juvenile salmonids and other fish species that occupy shallow river margins and side/off channel habitats will be sensitive to dewatering during flow decreases, and may be isolated and stranded, leading to mortality.

6. CONCLUSION

- Hydrometric station data indicate that ramping rates are low within Cheslatta Lake and the Nechako River; however, ramping rates in the Cheslatta River likely exceed standard generic ramping criteria.
- Although ramping rates are low in the Nechako River, large decreases in flow following the STMP period are expected to isolate and strand fry and juvenile salmonids and other fish species in shallow margin and side/off channel habitats.

Yours truly,

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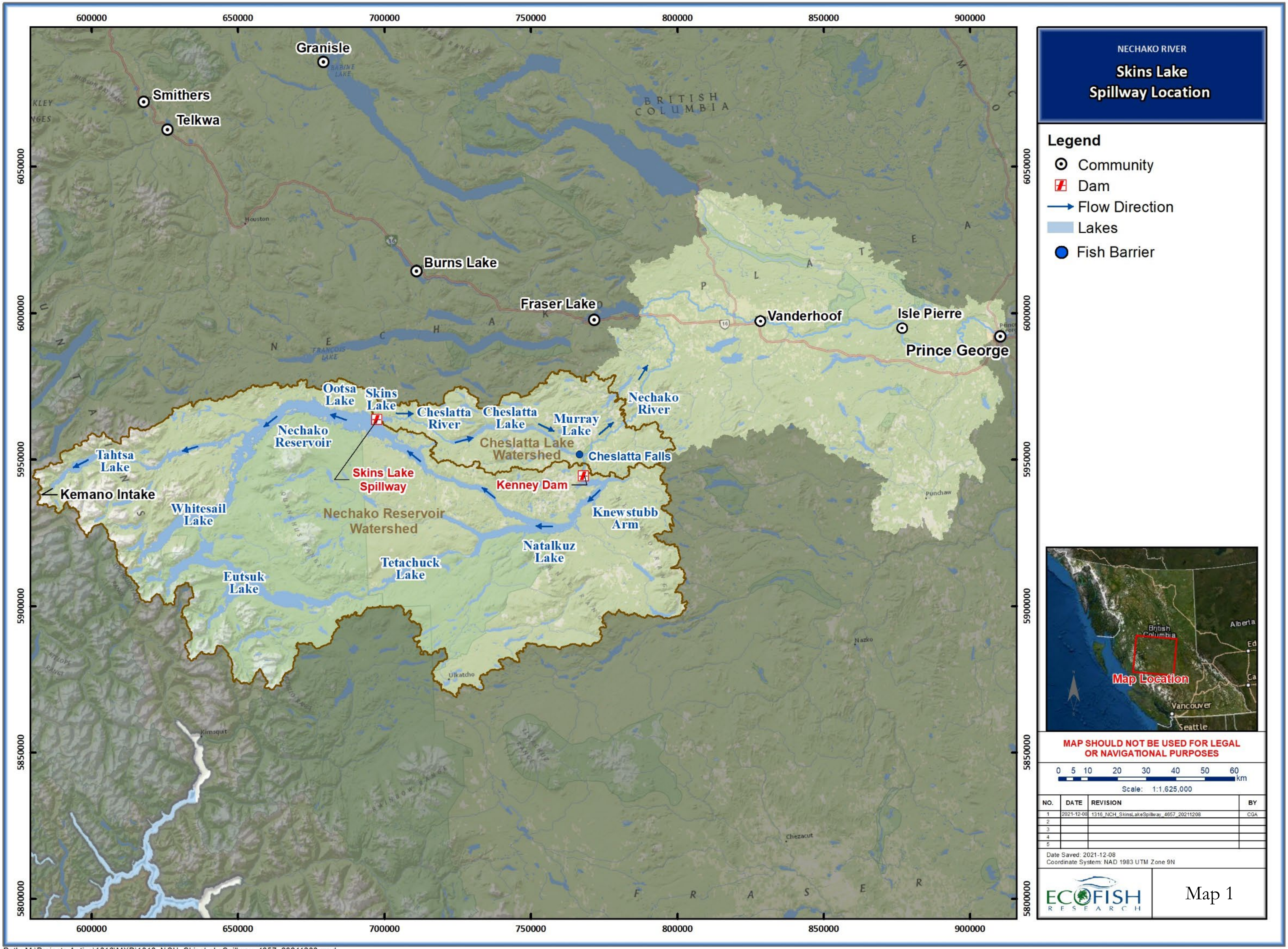
PROJECT MAPS



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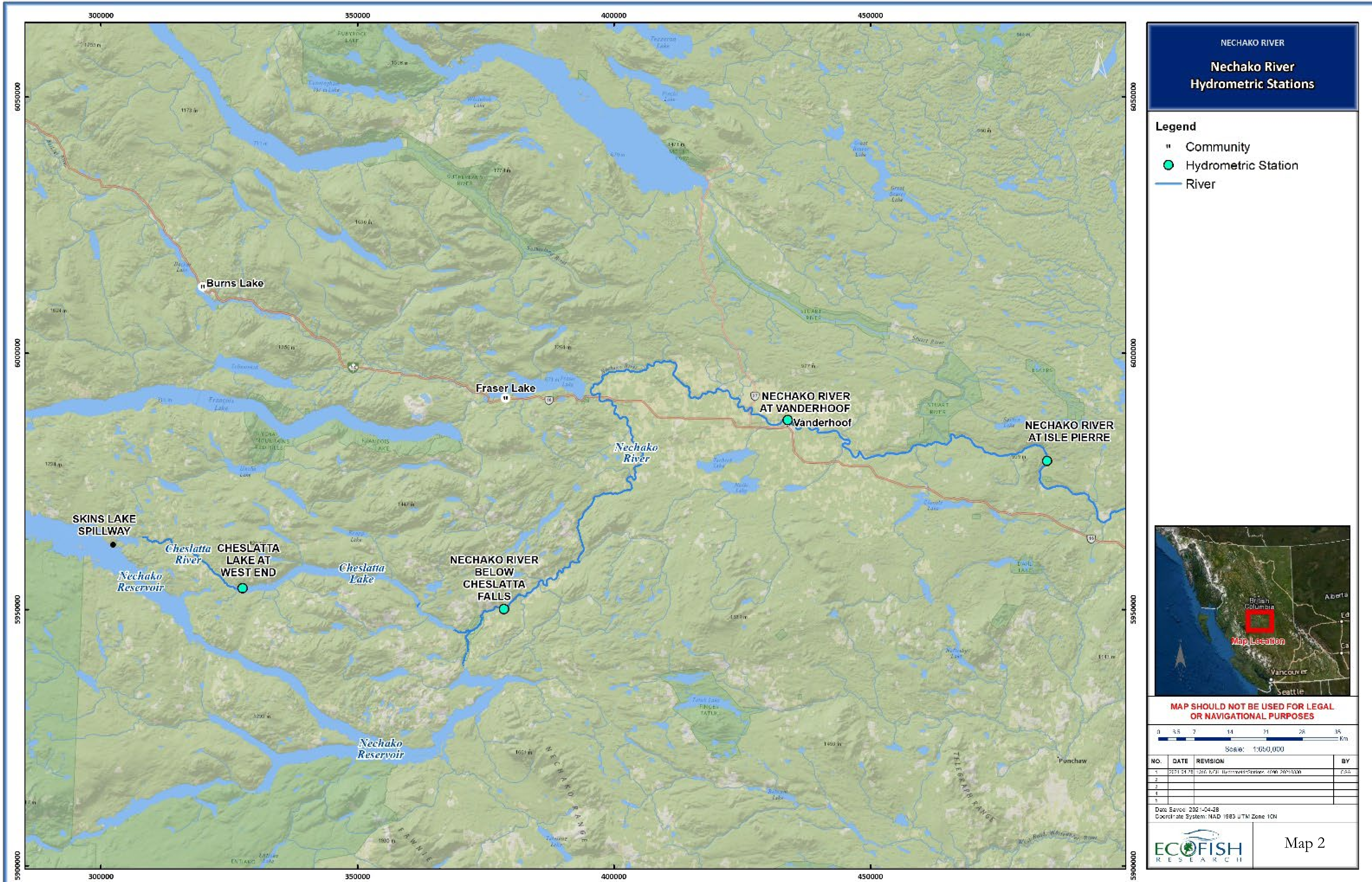

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APPENDICES

Appendix A. Down-ramping and up-ramping rates during the STMP period for gauges located below Cheslatta Falls, 2012 to 2020.

LIST OF FIGURES

Figure 1. 2013 down-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

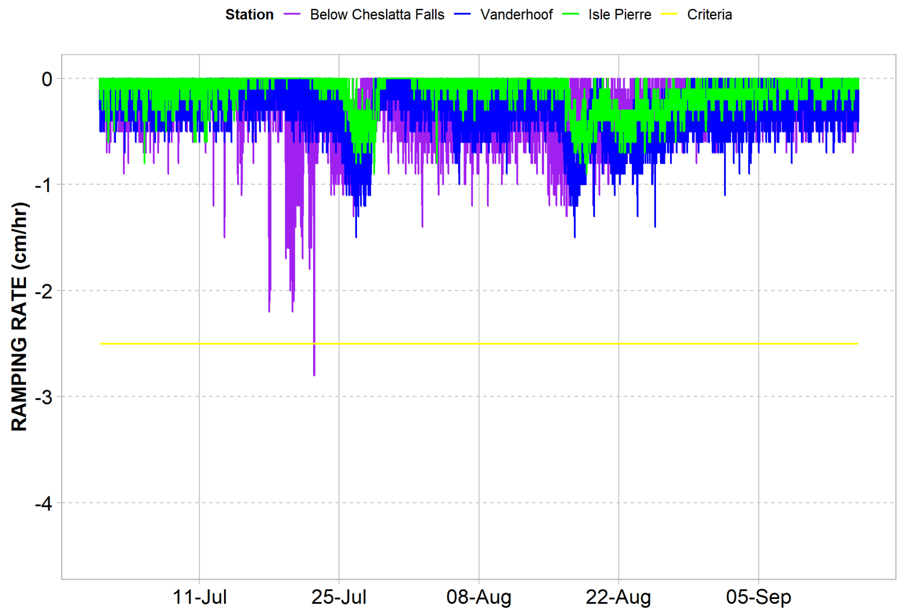

Figure 2. 2014 down-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

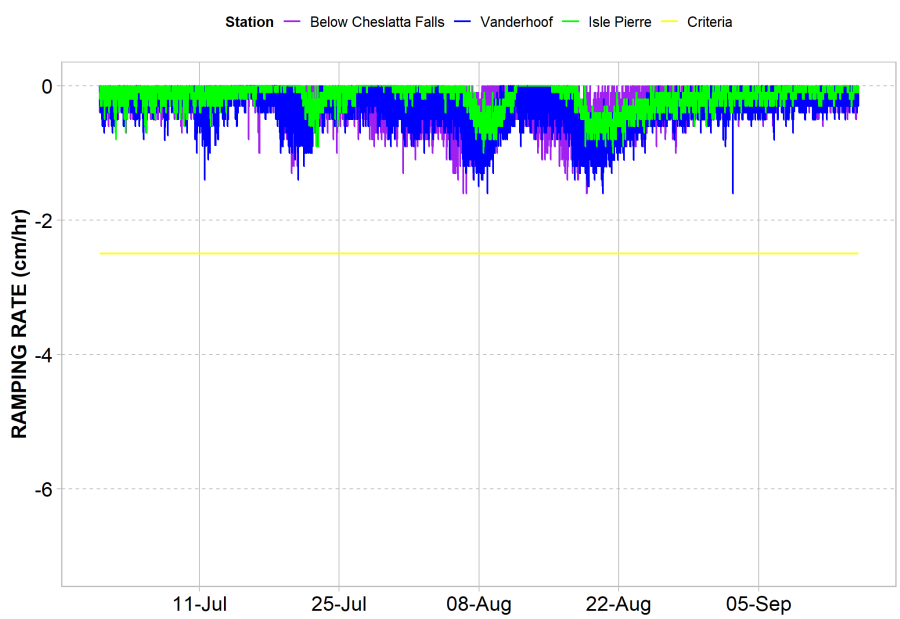

Figure 3. 2015 down-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

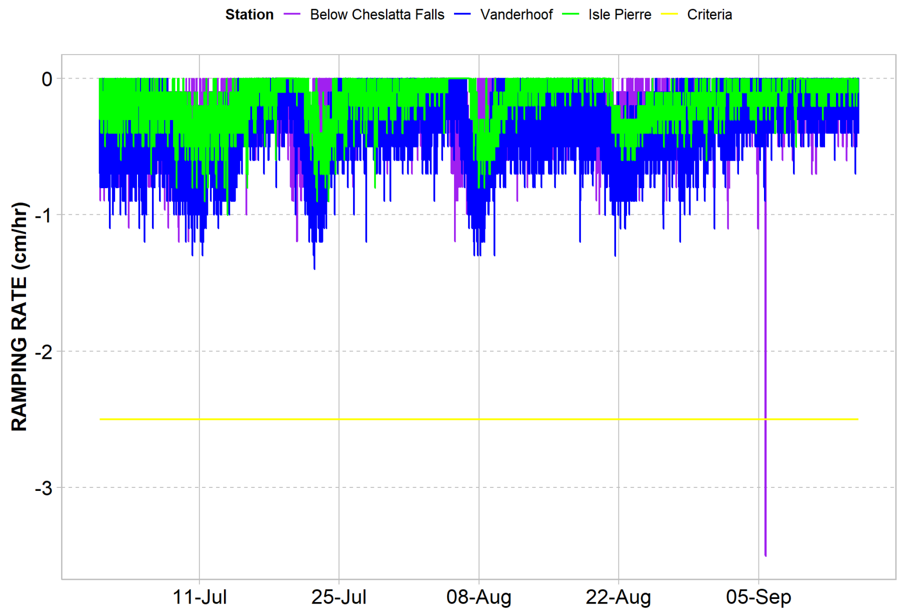

Figure 4. 2016 down-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

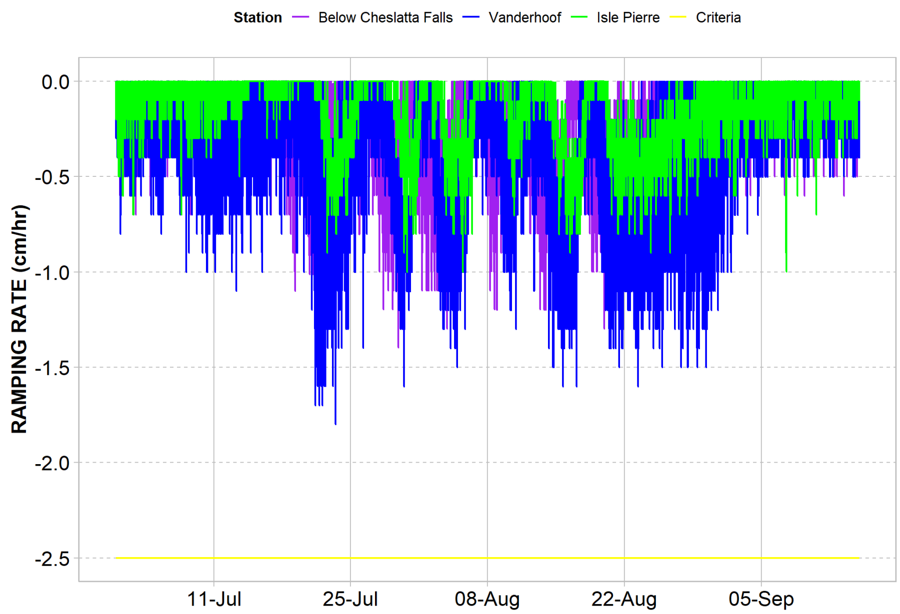

Figure 5. 2017 down-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

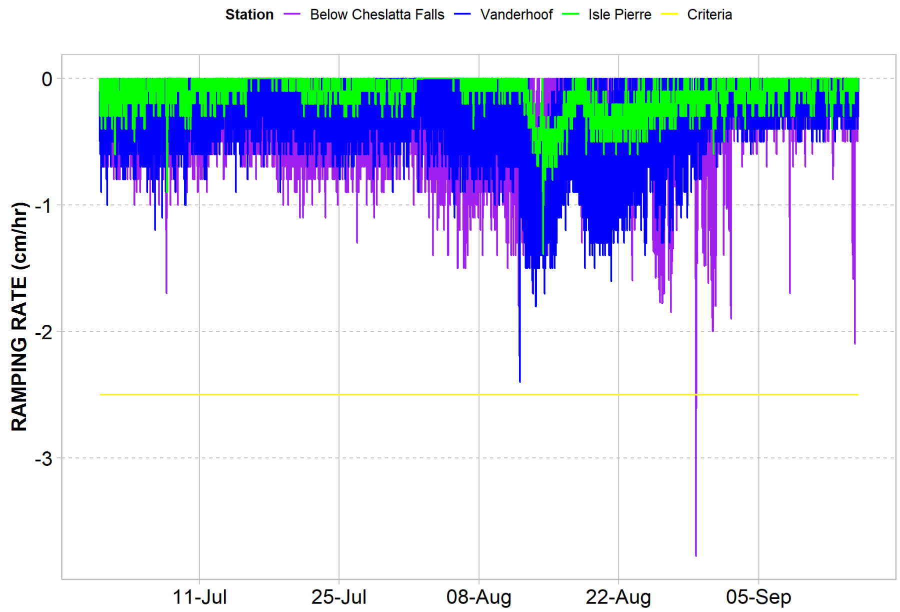

Figure 6. 2018 down-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

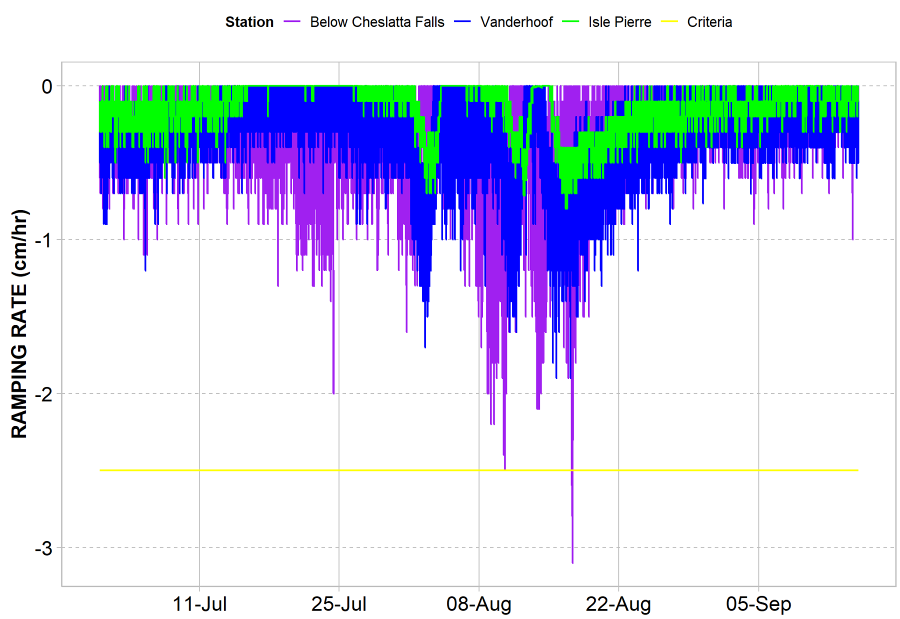

Figure 7. 2019 down-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

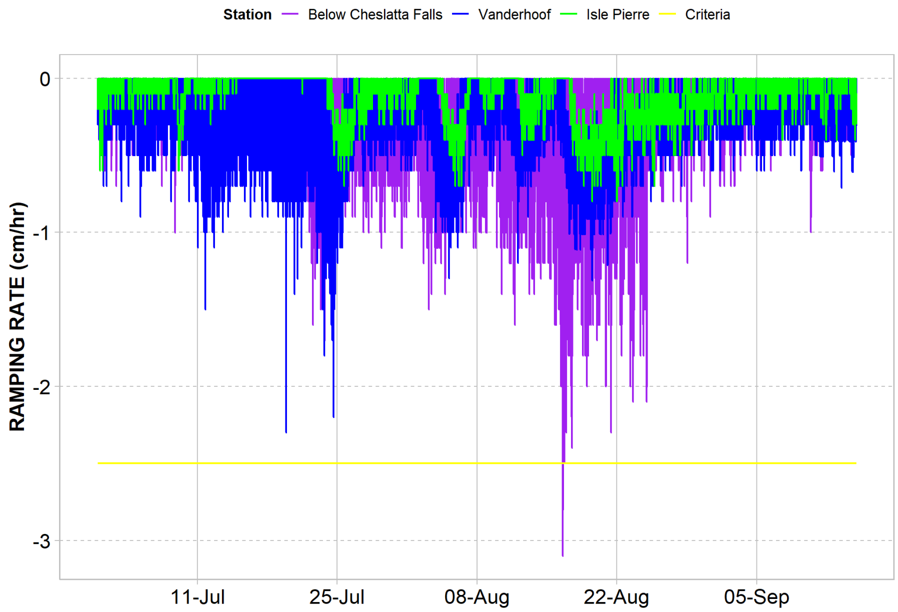

Figure 8. 2020 down-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

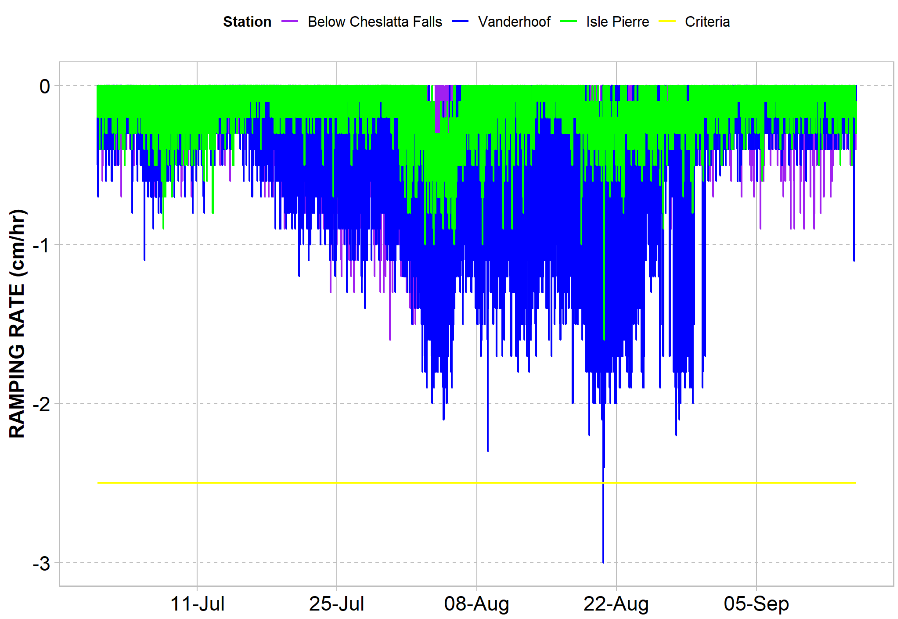

Figure 9. 2013 up-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

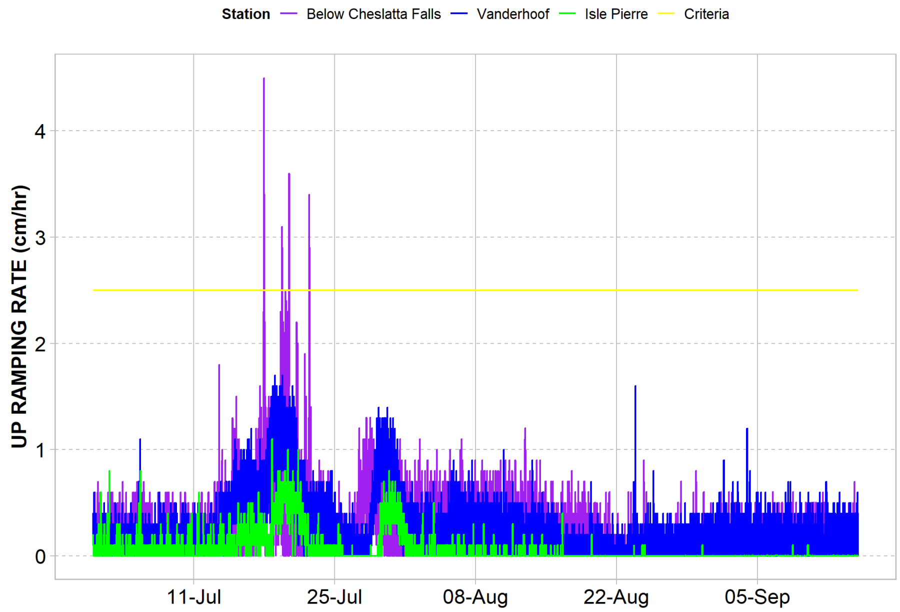

Figure 10. 2014 up-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

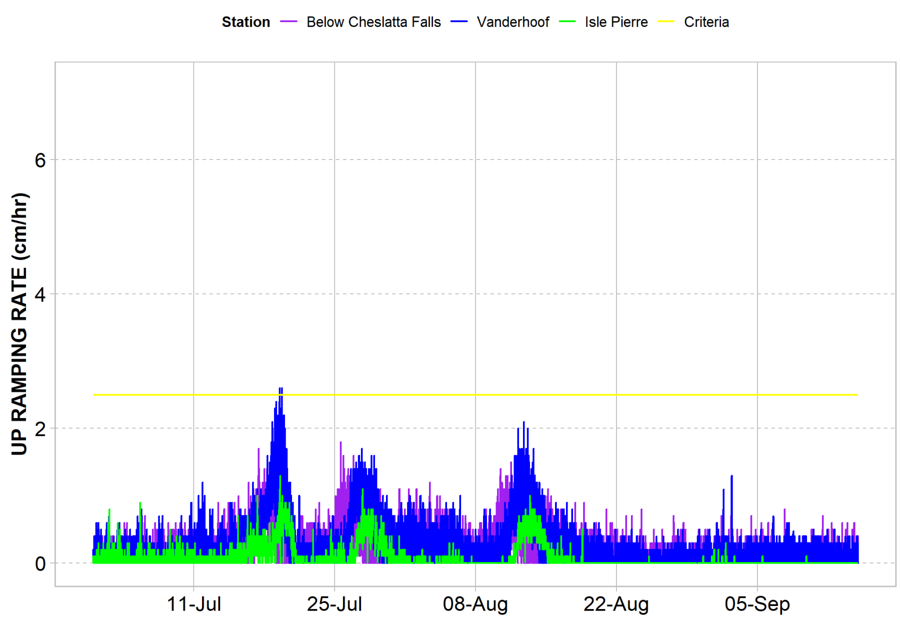

Figure 11. 2015 up-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

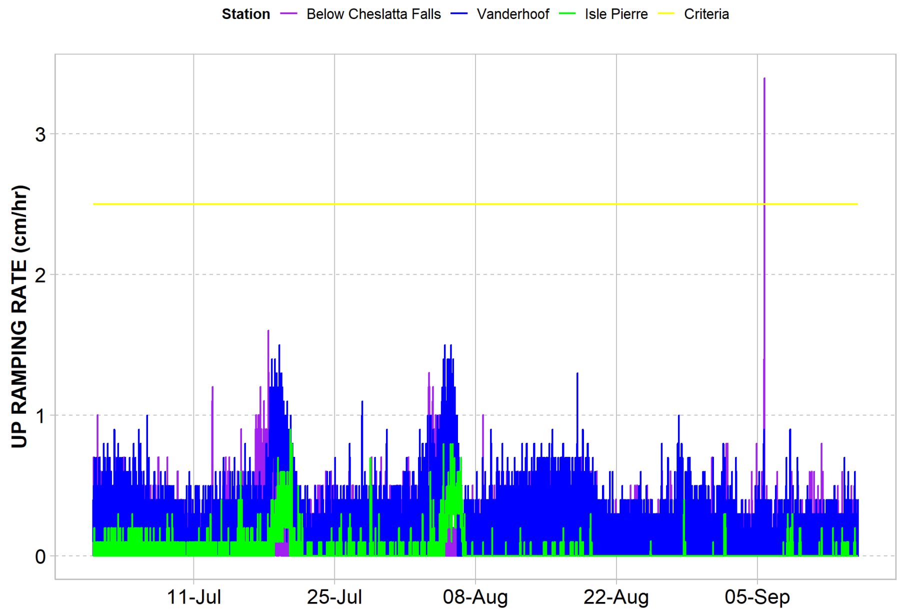

Figure 12. 2016 up-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

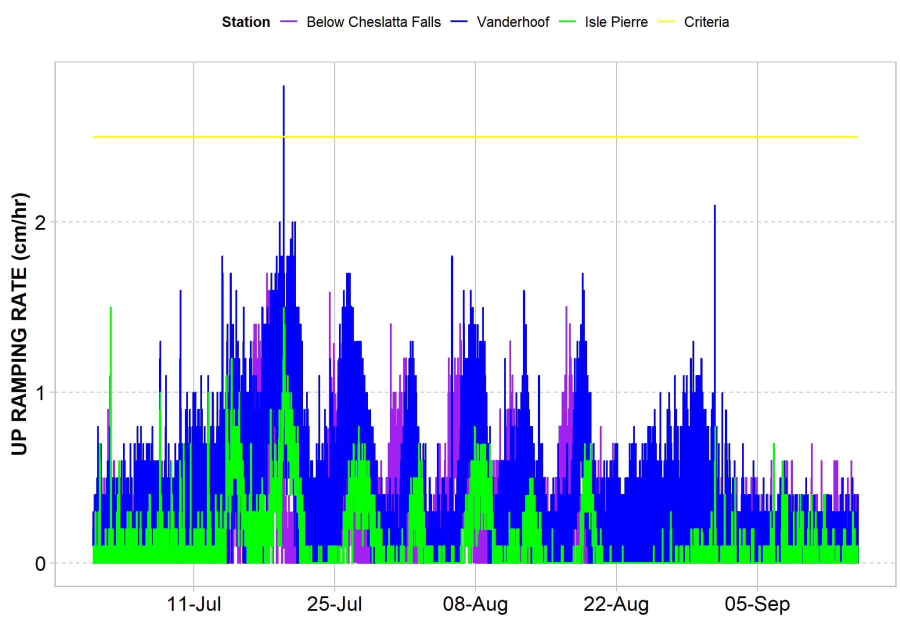

Figure 13. 2017 up-ramping rates (cm/hr) during STMP flow release period as measured at gauges below Cheslatta Falls, at Vanderhoof and Isle Pierre.

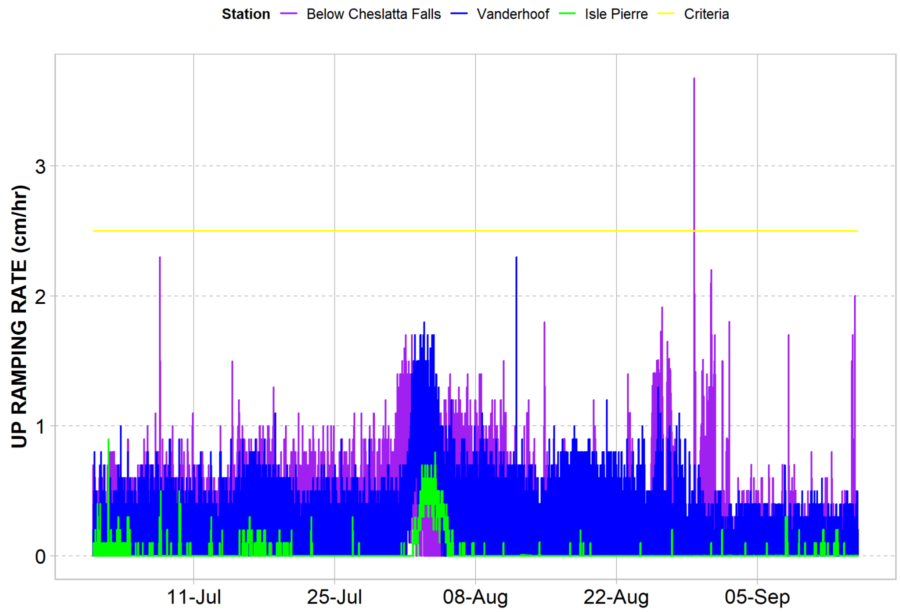

Figure 14. 2018 up-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

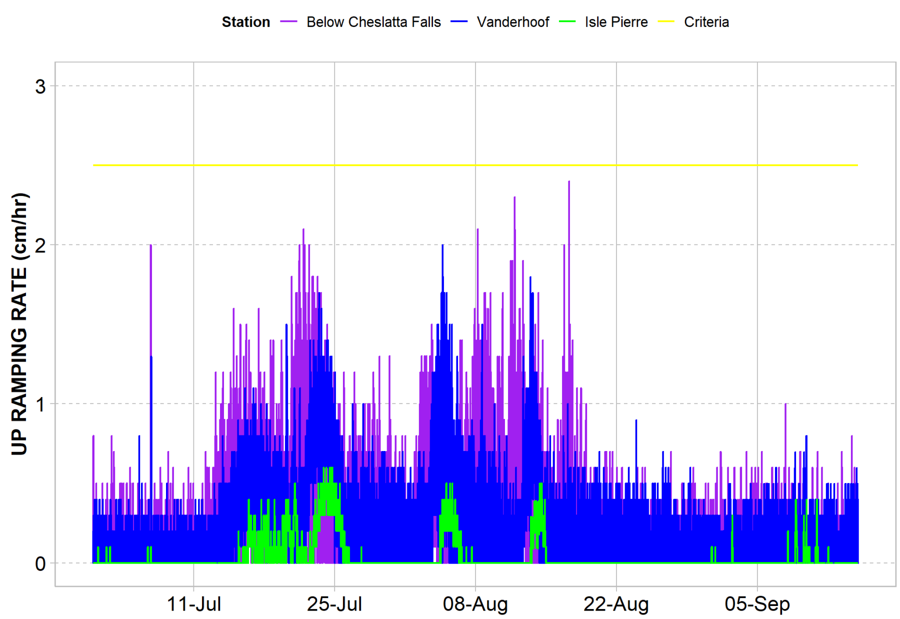

Figure 15. 2019 up-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.

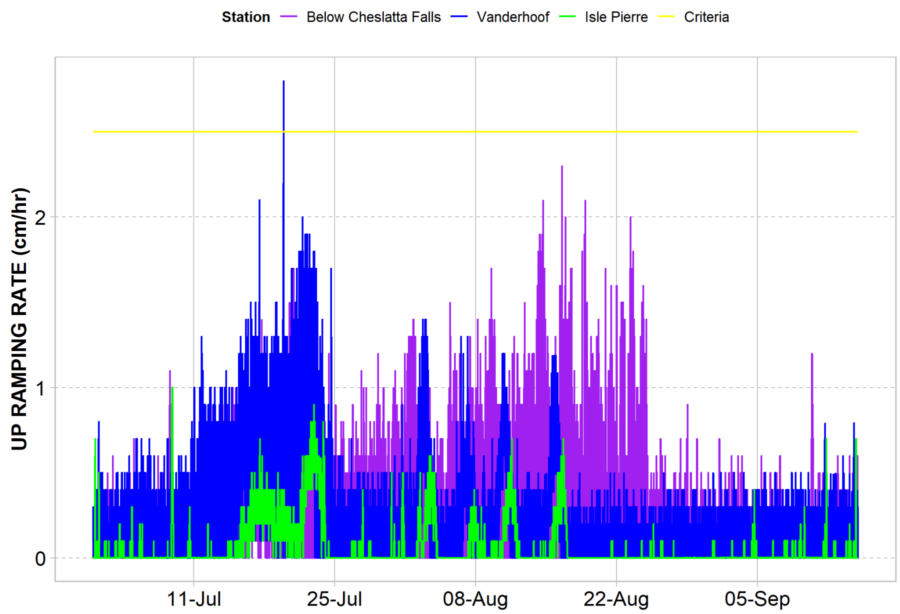

Figure 16. 2020 up-ramping rates (cm/hr) during STMP flow release period as measured at gauges located below Cheslatta Falls, at Vanderhoof and Isle Pierre.