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MEMORANDUM

TO: **Nechako Water Engagement Initiative *Technical Working Group***

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DATE: **September 19, 2023**

FILE: **1316-09**

RE: **Fish Access to Nechako River Tributaries and Side Channels – V2**

1. INTRODUCTION

During Nechako Water Engagement Initiative (WEI) Main Table and Technical Working Group (TWG) meetings, concerns were raised about potential effects of Rio Tinto (RTA; formerly Alcan) operations on fish populations in the Nechako River. One priority is to better understand how changes in flow affect fish access to Nechako River tributaries and side channels. The TWG asked Ecofish Research Ltd. (Ecofish) to review literature and summarize the status of current knowledge regarding this potential concern and develop recommendations for WEI consideration. This memo provides an overview of potential flow-related impacts on fish access to tributary and side channel habitats within the Nechako River downstream of Cheslatta Falls. It then offers practicable recommendations to inform water management decisions and minimize the negative effects of operational flows on fish access to these habitats.

2. BACKGROUND

2.1. Nechako River Hydrology

A hydrological overview of the Nechako watershed is provided by Beel *et al.* (2022), summarized here. The Nechako Reservoir is located approximately 200 km west of Prince George, British Columbia (BC) and was created to provide water for RTA's Kemano Hydroelectric Project, which was constructed in the 1950s to provide energy to operate an aluminium smelter in Kitimat, BC. The reservoir was formed by the construction of Kenney Dam on the Nechako River (at the east end of the reservoir), which inundated a chain of six major lake and river systems (Ootsa, Whitesail, Knewstubb, Tetachuck, Natalkuz, and Tahtsa, ~420 km total length).

The Nechako Reservoir is ~910 km^2 with a normal annual drawdown of ~3 m (10'); low water is in late spring, and high water occurs in late summer. All flow from the Nechako Reservoir to the Nechako River is currently via Skins Lake Spillway, which directs flow into the Cheslatta watershed, from where water flows into the Nechako River, downstream of Cheslatta Falls, located 9 km downstream of Kenney Dam (Map 1). The Nechako Reservoir provides the majority of flow in the upper Nechako River (there is minimal local inflow); here, flow is reduced to ~30% of pre-dam conditions and mean flow ranges from ~40 m^3/s - 240 m^3/s (Figure 1). The Nautley River (~95 km downstream of the dam) combined with local inflows make moderate inflow contributions and mean discharge in the Nechako River at Vanderhoof (~150 km downstream of the dam) ranges from ~65 m^3/s to 270 m^3/s. The Stuart River also contributes significant inflow, and by Isle Pierre (~215 km downstream of the dam) mean flows range from ~120 m^3/s to 560 m^3/s. The Nechako River flows into the Fraser River at Prince George ~275 km downstream of the dam. The Nechako River has a hydrograph dominated by snowmelt with a summer freshet.

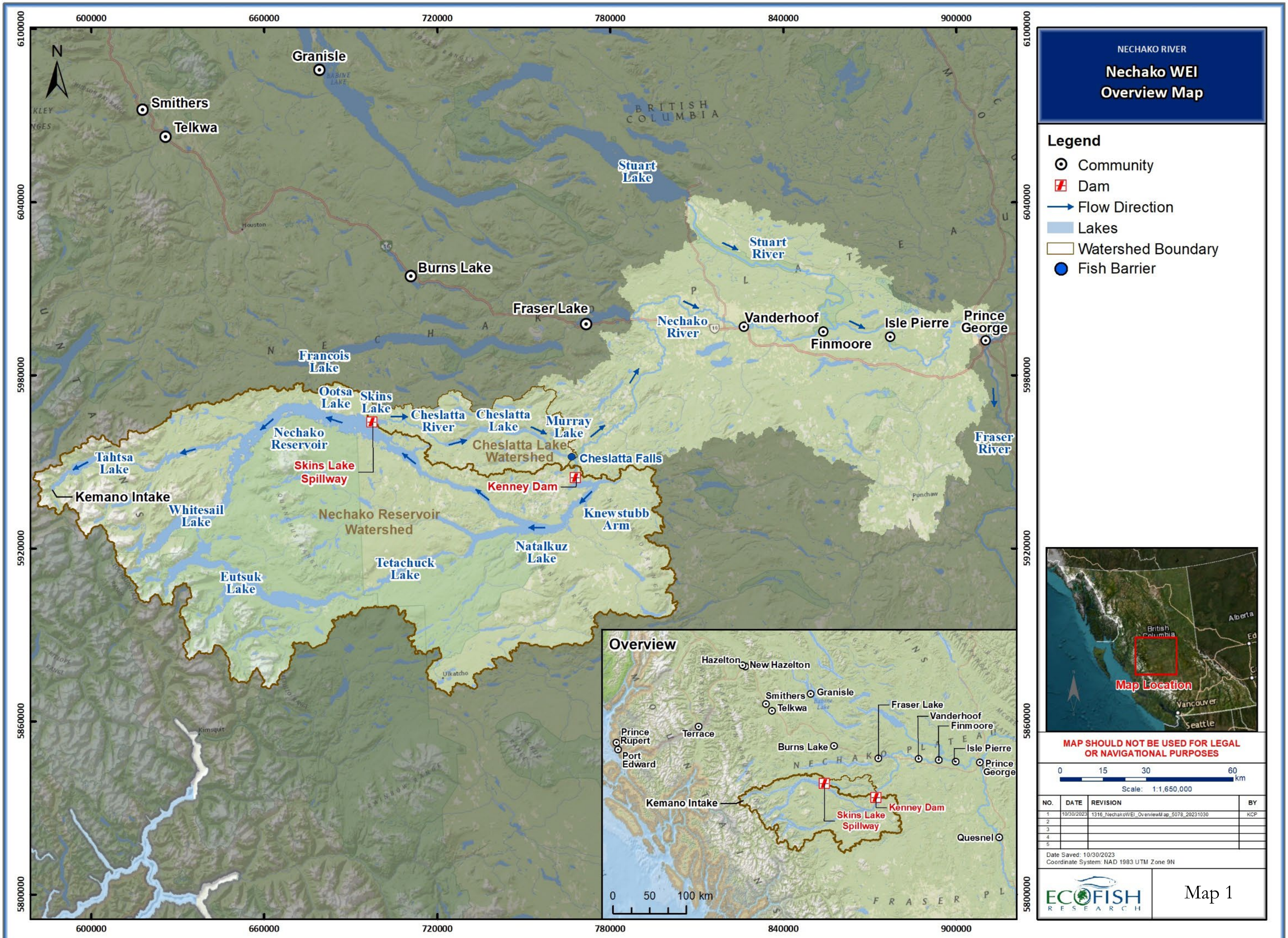

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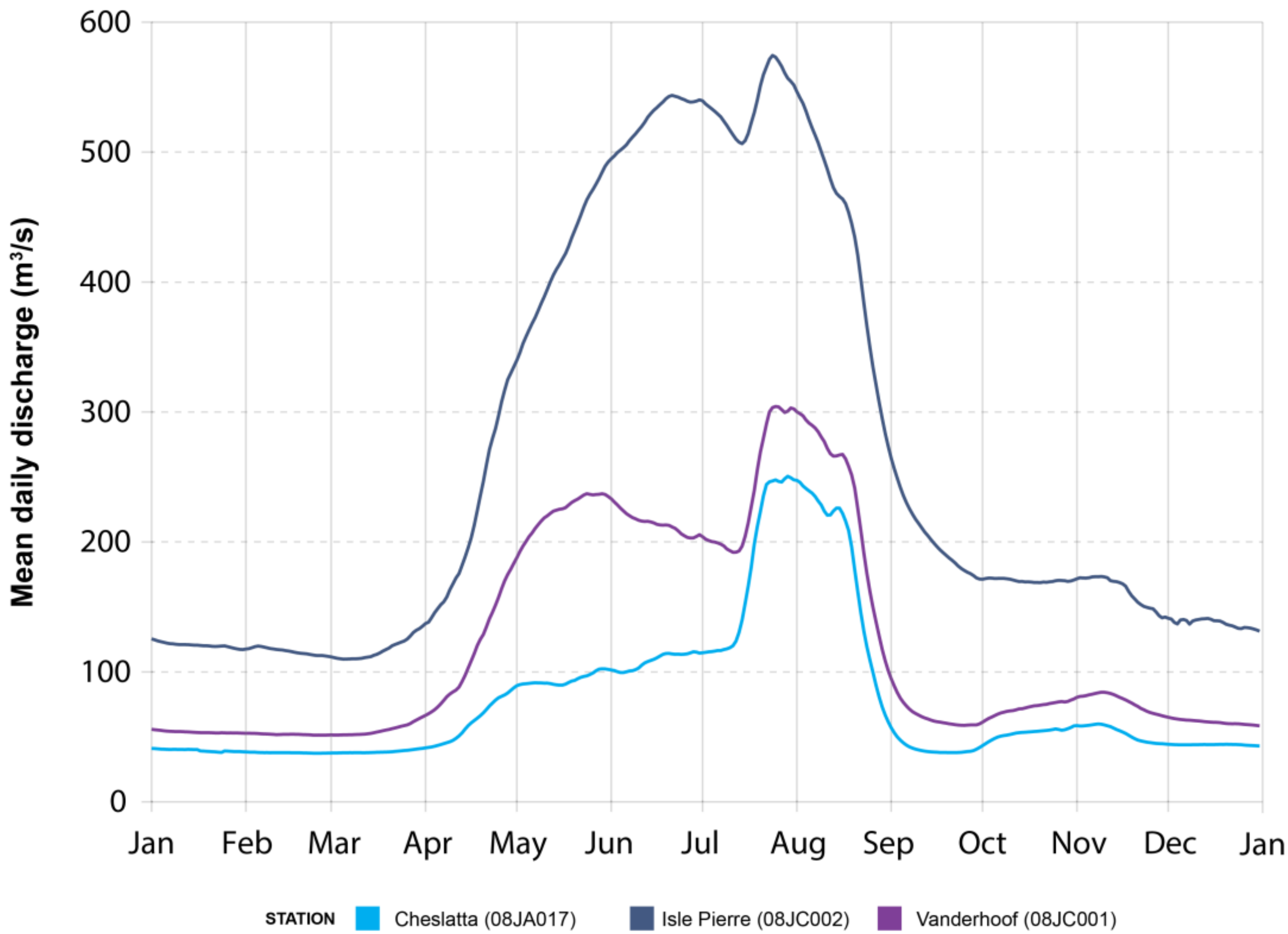
Figure 1. Mean daily discharge during 1990 - 2020 at selected Nechako River monitoring stations.



2.2. Nechako River Fish Community

The Nechako River provides habitat for a diverse assemblage of 22 fish species (Table 1). The timing and duration of fish use of these habitats varies between species and life stages. For example, some species complete all life cycle stages within the Nechako watershed by necessity (e.g., sculpins), while others migrate between the Nechako watershed and other systems to complete specific life history stages (e.g., Bull Trout, Pacific Lamprey, Pacific salmon). Separate memos provide a summary of the native distribution, conservation status, population trends, and life history strategies for all Nechako River fish species (see Chudnow and Kurtz 2022a, resident fish[1]; Chudnow *et al.* 2022a, White Sturgeon; Chudnow *et al.* 2022b, Chinook Salmon).

Table 1. Nechako River fish species.

Family	Common Name	Scientific Name
Burbots	Burbot	*Lota lota*
Lampreys	Pacific Lamprey	*Entosphenus tridentatus*
Minnows	Brassy Minnow	*Hybognathus hankinsoni*
	Lake Chub	*Couesius plumbeus*
	Leopard Dace	*Rhinichthys falcatus*
	Longnose Dace	*Rhinichthys cataractae*
	Northern Pikeminnow	*Ptychocheilus oregonensis*
	Peamouth Chub	*Mylocheilus caurinus*
	Redside Shiner	*Richardsonius balteatus*
Salmonids	Bull Trout	*Salvelinus confluentus*
	Chinook Salmon	*Oncorhynchus tshawytscha*
	Coho Salmon	*Oncorhynchus kisutch*
	Mountain Whitefish	*Prosopium williamsoni*
	Rainbow Trout	*Oncorhynchus mykiss*
	Sockeye Salmon	*Oncorhynchus nerka*
Sculpins	Prickly Sculpin	*Cottus asper*
	Slimy Sculpin	*Cottus cognatus*
Suckers	Bridgelip Sucker	*Catostomus columbianus*
	Largescale Sucker	*Catostomus macrocheilus*
	Longnose Sucker	*Catostomus catostomus*
	White Sucker	*Catostomus commersonii*
Sturgeons	White Sturgeon	*Acipenser transmontanus*

[1]Under the WEI, all fish species within the Nechako watershed excluding White Sturgeon and anadromous salmon are considered resident fish (Chudnow and Kurtz 2022a).

2.3. Current Level of Knowledge

In general, fish and fish habitat information specific to the Nechako River watershed is limited. Literature review identified only one study that occurred prior to Nechako Reservoir impoundment and provided reference to resident species (Lyons and Larkin 1952). While a significant body of post-dam research investigating population structure, abundance trends, local distribution, movements, and life stage-specific habitat use exists for both Chinook Salmon and White Sturgeon (see Chudnow *et al.* 2022a, 2022b), most of this work has been on the river mainstem, with minimal consideration of tributary or side channel habitats. In contrast, river-specific information is absent for most resident species (see Chudnow and Kurtz 2022a and Chudnow and Kurtz 2022b). Although several reports were identified relating to Bull Trout and Rainbow Trout, these related to recreational fisheries management and did not provide information regarding population structure, abundance trends, local distribution, or movements (e.g., Ableson 1985, 1990; Tredger *et al.* 1985; Slaney 1986; Ableson and Slaney 1990). For all other species, past work was primarily limited to fish presence assessed through reconnaissance surveys of the river mainstem and some tributaries (e.g., Tredger *et al.* 1985; ARC 1998). Across species, only two reports (Hamilton 1987; Reid Crowther and Partners Ltd. 1987) were identified that specifically referred to off-channel habitats, without specific consideration of individual species. As a result of these data limitations, the discussion of fish tributary and side channel habitat use below is largely focused on species for which Nechako River-specific information is available (i.e., Chinook Salmon and Rainbow Trout).

2.4. Tributary and Side Channel Habitat Use

Preferred habitat information for species known to inhabit the Nechako River indicates many may use tributaries and/or side channels for specific life history stages (i.e., spawning and/or rearing; Chudnow and Kurtz 2022a, Table 2). For many species, low velocity off-channel habitats provide important rearing opportunities as well as a source of food (e.g., as a source of invertebrate production; Reinhold *et al.* 2016). Several species are also generally known to make seasonal movements to tributary habitats for spawning, with early juvenile rearing occurring in tributary margins (e.g., Lake and Peamouth chubs, Mountain Whitefish, Rainbow Trout, and a subset of Largescale, Longnose, and White sucker populations; Scott and Crossman 1973; McPhail 2007).

Nechako River-specific information for Rainbow Trout has identified several tributaries as important for production (e.g., Clear, Greer, Swanson, and Copely (Targe) creeks; Tredger *et al.* 1985). Rainbow Trout tributary spawning occurs in spring, with egg incubation lasting for several weeks after deposition (McPhail 2007). Early juvenile rearing (i.e., fry) occurs almost exclusively in tributary streams (Envirocon Ltd. 1984), with parr found in both tributary and mainstem habitats primarily in the upper river in similar habitats to those used by juvenile Chinook Salmon (Envirocon Ltd. 1984; see Chudnow *et al.* 2022b for juvenile Chinook habitat description). Mountain Whitefish have also been observed within several Nechako River tributaries (Cluculz Creek, Swanson Creek, Envirocon Ltd. 1984; Tredger *et al.* 1985; ARC 1998); however, the body of work supporting our understanding of the species Nechako River-specific habitat use is highly limited. Unlike Rainbow Trout and Mountain Whitefish, Bull Trout have not been observed in Nechako River tributaries. Instead, available evidence suggests all Bull Trout found within the Nechako River leave the river following overwintering and early spring foraging, spawning, and rearing in tributaries of the upper Fraser River (Chudnow *et al.* 2023). Rainbow Trout, Mountain Whitefish, and Bull Trout use of off-channel habitats in the Nechako River has not been investigated.

Tributaries and side channels are also known to serve as early rearing habitat for the Nechako River Chinook Salmon population, prior to juvenile dispersal to habitats in the lower Nechako River and the Fraser River (Envirocon Ltd. 1984; Healey 1987; Jenkins 1993; Bradford and Taylor 1997, 2021). Adult Sockeye Salmon are also present within the Nechako River from mid-July to the end of August. These individuals primarily spawn in the Nadina, Stellako, and Stuart rivers (Rescan 1999; Helm *et al.* 1980); however, the species is also known to spawn in the Nechako River in September (BC MOE 2022). It is possible that Nechako River Sockeye Salmon use side channels for spawning and juvenile rearing. Coho Salmon have also been identified spawning in the Nechako River, given what is known about this species habitat preferences (McPhail 2007), it is likely individuals use side channels for juvenile rearing (BC MOE 2022).

Nechako River White Sturgeon are most prevalent in the Nechako River mainstem from Isle Pierre (rkm 67) to the Nautley River confluence (rkm 192), and three high use areas, including a single confirmed spawning site (near Vanderhoof), have been identified in the river (Envirocon Ltd. 1984; Sulak and Clugston 1999; RL&L 1999, 2000; DFO 2014). The population is currently undergoing recruitment failure (DFO 2014; NWSRI 2022), limiting opportunities to confirm early juvenile habitat use. Based on our understanding of spawner and early juvenile habitat use for other populations across the species range, it is probable that side channels provide important habitat for rearing (Bennett *et al.* 2005; Glova *et al.* 2008; McAdam 2012; Smyth *et al.* 2016).

Table 2. **Nechako River fish species that may use the tributaries and side channels for spawning or rearing.**

Family	Species	Side Channel Use	Tributary Use
Lampreys	Pacific Lamprey	rearing	spawning
Lings	Burbot	spawning, rearing	rearing
Minnows	Brassy Minnow, Lake Chub, Leopard Dace, Longnose Dace, Northern Pikeminnow, Peamouth Chub, Redside Shiner	spawning, rearing	rearing
Salmonids	Mountain Whitefish, Rainbow Trout, Chinook Salmon	spawning, rearing	spawning, rearing
	Sockeye Salmon, Coho Salmon	spawning, rearing	-
Sculpins	Prickly Sculpin, Slimy Sculpin	spawning, rearing	spawning, rearing
Sturgeons	White Sturgeon	spawning, rearing	-
Suckers	Bridgelip Sucker, Largescale Sucker, Longnose Sucker, White Sucker	spawning, rearing	-

3. METHODS

3.1. Literature and Information Review

A literature review and data search were conducted to locate all known information on the relationship between flow and Nechako River fish access to tributary and side channel habitats since the commencement of Kemano hydroelectric operations and flow releases through the Skins Lake Spillway. Literature was considered regarding the potential effects of flow management operations on connectivity generally, as well as specifically in the Nechako River. This information was then used to define potential pathways of effect, which were evaluated in the context of watershed-specific information.

Literature was identified by consulting the provincial Ecological Reports Catalogue (Province of BC 2022) and other online databases (e.g., Nechako Fisheries Conservation Program, NFCP 2022). Specific efforts were undertaken to review British Columbia Utilities Commission (BCUC), Fisheries and Oceans Canada (DFO), Kemano Completion Project (KCP), Nechako Environmental Fund (NEEF), and Nechako Fisheries Conservation Program (NFCP) reports, as well as to review key watershed-specific studies including fish habitat assessments (e.g., Tredger *et al.* 1985; ARC 1998), and background information reports[2] prepared by Helm *et al.* (1980), Rescan (1999), and 4Thought Solutions Inc. (2005). Information was also collected via online searches including Google, Google Scholar, federal government databases (e.g., CSAS, DFO 2021; Federal Science Libraries Network, DFO 2022), and organizational databases (e.g., NEEF 2022; NFCP 2022; UNBC 2022).

3.2. Side Channel Mapping

In 2021, Ecofish conducted a Google Earth imagery exercise to identify potential Nechako River side channels. Imagery was mostly dated between May and September of 2012 to 2021, depending on the section of the Nechako River. Side channels were visually identified using the Google Earth measuring tool as "defined channels visible on the imagery along river left or river right that had an average width of less than 25 m width[3] and a visible inlet and outlet (either wet or dry)". This definition may have underestimated the number of side channels but is still expected to provide an estimate of their abundance and distribution in the river. Each side channel identified was then defined as wet or dry as follows:

- *Wet* - Both the inlet and outlet appeared wetted and there was no visible flow interruption within the side channel as viewed on the imagery.
- *Dry* - The inlet and/or outlet appeared dry, or both the inlet and outlet appeared wetted but there were dry areas within the side channel which appeared based on visual inspection to interrupt flow as seen on the imagery.

3.3. Reconnaissance Field Survey

Ecofish completed a reconnaissance field survey of the Nechako River on October 6, 2022. The purpose of this survey was to verify our understanding and assumptions related to various fish and wildlife habitats; this included visual observations (but not detailed study) of fish habitat conditions and fish access into tributaries and side channels. The survey included two river sections (upstream section: from the Greer Creek boat access point upstream to Cheslatta Falls and downstream section: extending from Vanderhoof approximately 7 km upstream and 6 km downstream), reported in Regehr *et al.* (2023). During this survey, three tributaries and 13 side channels were visited. Regehr *et al.* (2023) provides a detailed discussion of survey findings, summarized herein when relevant. Note, that the information presented in Regehr *et al.* (2023) is the result of opportunistic observations only. The observations were not randomized, stratified, or

[2] These reports summarize geomorphological, biological, and hydrological information regarding the Nechako River watershed, with a focus on interactions with water management.

[3] All watercourses greater than 25 m width were assumed to be channel braids and not represent side channel habitat.

otherwise part of a detail study design and hence the information is incomplete. Therefore, due care must be applied when interpreting this information.

4. RESULTS

4.1. Overview of Potential Pathways of Effects

Many Nechako River fish species are reliant on tributary and/or side channel habitats for portions of their life history (e.g., for spawning or rearing) or as a food source (i.e., transport of organic matter and invertebrates to the mainstem; Poff *et al.* 1997). The ability of these habitats to support fish is dependent on the degree of their hydrological connectivity with the river mainstem. There are three main types of connectivity in a river (Table 3). Of these, lateral connectivity is particularly important because it provides fish access to complementary habitats, including low velocity areas.

Table 3. Definition of three main hydrological connectivity types. Sourced from Amoros and Bornette (2002).

Connectivity Type	Definition
Longitudinal	Connection between upstream and downstream areas
Vertical	Connection/exchange of surface and groundwater
Lateral	Connection of the mainstem with tributaries, side channels, and floodplain areas

The degree of connectivity both within a watercourse and in relation to off-channel habitats is affected by the interaction between flow and stream morphology, which in turn determines the quantity and quality of habitat available for fish (Raleigh *et al.* 1986). In general, flows approximating the natural flow regime will provide and maintain the most suitable fish habitats. Hydropower operations can alter the natural flow regime both in terms of the magnitude of water released and the timing of releases (Trussart *et al.* 2002). Although some hydroelectric facilities release constant flow year-round, variation is common. Further, even when hydroelectric flow release is constant, meteorological conditions and unregulated downstream inflows can impose flow variability (Blachut 1988; Davie and Mitrovic 2014). Regulated rivers have been found to have less habitat connectivity compared to unregulated rivers (Ward and Stanford 1995; Bowen *et al.* 2003). Beyond the direct impacts of reduced habitat availability on the fish community, river regulation can also have secondary impacts on habitat connectivity and habitat quality as the result of increased erosion, altered floodplain vegetation successional trajectories, and reduced channel migration (Ward and Stanford 1995).

4.2. Identified Pathways of Effect

Here, we identify key pathways through which RTA operations could potentially effect Nechako River fish access to tributary and side channel habitats. Based on available evidence, potential pathways of effect can be summarized as:

1. Tributary mouth or side channel inlet dewatering;
2. Barrier exposure;
3. Debris and sediment transport processes; and
4. Vegetation encroachment.

Each pathway has the potential to effect multiple species, and/or life history stages, and are described separately in further detail below. It is important to note that the relative importance of tributary and side channel habitats to some fish populations is variable. For these species, density dependent inter- and intra- species dynamics play a role in determining population distribution and tributary and/or side channel habitat use. For example, when abundance is high, more individuals may access tributary or side channel habitats for spawning or rearing than would be expected when population abundance is low (i.e., habitat is not a limiting factor).

4.2.1. Tributary Mouth or Side Channel Inlet Dewatering

When river mainstem water elevation is low, channel braiding can occur in low gradient tributary mouths. This could result in sub-surface flow or water levels that are to too shallow to provide fish access to tributaries. Similarly, when river mainstem water elevation is low, it may fall below the elevation of side channel inlets, preventing fish movement.

4.2.2. Barrier Exposure

Fish access into tributaries and/or side channels can be affected when Nechako River discharge exposes previously submerged barriers to fish passage. For example, low flows can expose drop offs, woody debris, or shallow, low gradient areas at tributary mouths or side channel inlets and/or outlets, reducing connectivity or completely blocking fish access to these habitats. In contrast, high flows can provide access to habitats that may be inaccessible at lower flows (e.g., by flooding low gradient braided tributary mouths or dewatered side channel inlets, or by overtopping beaver dams). However, high flows can also restrict fish access by creating velocity barriers (i.e., when flows are above individual's or species' swimming capabilities) or through secondary habitat impacts (i.e., resulting erosion, scour, or sediment or woody debris deposition). For example, low mainstem river flow can result in tributary downcutting (i.e., as tributaries adjust to changes in river elevation) which can create barriers to fish passage through increased tributary gradient or the formation of drops or falls (NHC 2000; Hamilton and Schmidt 2005).

4.2.3. Debris and Sediment Processes

The relationship between flow and debris and sediment transport processes in a river are complex. For example, low flows can prevent future debris deposition at tributary mouths or side channel inlets but can also prevent downstream transport of previously accumulated debris. While high flows can transport large debris or boulders, which can either block access to, or remove existing barriers at tributary mouths or side channel inlets/outlets (Opperman *et al.* 2006; Spreitzer *et al.* 2018). Low flows also result in decreased sediment flushing and increased sediment accumulation at tributary mouths and within side channels, potentially resulting in connectivity loss. While high flows can flush accumulated sediment from these areas, it can also lead to increased erosion and scour, resulting in the development of drops at tributary mouths or side channel inlets, limiting fish access.

4.2.4. Vegetation Encroachment

Reduced sediment flushing and increased sediment deposition at low flows can also provide habitat for vegetative growth (i.e., vascular plants and/or macrophytes) along stream margins, tributary mouths, and side channels. The WEI has identified specific concerns regarding the potential effects of invasive reed canary grass (*Phalaris arundinacea*) on the Nechako River fish community, and the potential effect of RTA operations on the species' growth and distribution[4]. Reed canary grass has been confirmed within the Nechako River. Although the species has not been studied in the Nechako watershed specifically, literature from other watersheds has concluded the species is prolific, spreads rapidly, and can overtake native riparian vegetation (Barnes 1999; Adams and Galatowitsch 2005; Anderson 2012). Within the context of fish access to tributary and side channel habitats, reed canary grass could limit fish access by increasing sedimentation, impeding water flow, and preventing scouring (Coops and Van der Velde 1995; Heutte *et al.* 2003; Gebauer 2013).

4.3. Tributary Access

4.3.1. Literature Results

The WEI has noted several Nechako River tributaries of concern with regard to fish access including Cutoff Creek, Copely (Targe) Creek (observed sub-surface flow and large gravel bar eliminating access), Twinn Creek (perched culvert at the mouth), and Swanson Creek (observed loss of functionality and riparian zone), as well as Kluk, Knight, Moss, and Tahultzu creeks (Salewski, pers. comm. 2021). Further, several additional tributaries have been identified as having potential fish access issues (e.g., Murray Creek upstream culverts, NEWSS 2011; Stoney Creek watershed stream crossings, Avison 2021). However, as these potential barriers to fish passage (i.e., for Murray and Stoney creeks) are located upstream of tributary mouths' they are considered out of scope for the discussion herein.

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[4] This topic is given specific consideration in Wright (2022).

Overall, information regarding Nechako River tributary fish habitat is highly limited (i.e., two main reports identified with only a few tributaries surveyed and limited mention of flow-related effects, Tredger *et al.* 1985; ARC 1998, and a single reconnaissance survey as part of the WEI process in October 2022, Regehr *et al.* 2023). Existing information suggests only Cutoff Creek may experience fish access constraints affected by the Nechako River. For other streams, beaver activity and low tributary flows (i.e., not flows within the Nechako River) were identified as the primary issues affecting fish access (Tredger *et al.* 1985; ARC 1998; Regehr *et al.* 2023). Accumulated sediments due to tributary channel erosion also identified at a single tributary (i.e., Swanson Creek (Tredger *et al.* 1985; ARC 1998)). Table 4 summarizes existing information on tributary mouth habitat, fish species presence, and fish access concerns. If access concerns were reported, the potential pathways of effect related to Nechako River flow regulation are included.

Table 4. Key Nechako River tributaries surveyed with fish use and tributary access information at the confluence.

Tributary Name	Habitat Information Near Mouth	Fish Species Known to Use Tributary	Information on Tributary Access	Potential Pathway of Effect
Cluculz Creek[1,2]	Low gradient with fair spawning gravel and little off channel habitat.	Burbot, Chinook Salmon (juvenile), Largescale Sucker, Longnose Dace, Peamouth Chub, Northern Pikeminnow, Rainbow Trout, Redside Shiner, sculpin, whitefish.	No issues noted.	N/A
Cutoff Creek[1,2,3]	Low gradient swampy ponds and pools. Beaver dams in lower 2 km and subsurface flow. May contain good overwintering habitat if access is maintained to the Nechako River.	Chinook Salmon (juvenile), dace, Largescale Sucker, Northern Pikeminnow, Peamouth Chub, Rainbow Trout, Redside Shiner, sculpin, whitefish	Issues with tributary access noted due to channel configuration and beaver dams. Backwatering of the Nechako River can provide access.	Depth mediated barrier exposure, debris or sediment transport processes
Greer Creek[1,2,3]	Bank erosion with highly meandering channel. Low gradient with fine sediment. Potential Rainbow Trout habitat with many side channels, although lack of spawning gravel recruitment. Trout population may originate in headwaters.	Chinook Salmon (juvenile), Largescale Sucker, Leopard Dace, Longnose Dace, Northern Pikeminnow, Rainbow Trout, Redside Shiner, sculpin, whitefish.	No issues noted.	N/A
Old Nechako Canyon Creek[3]	Low gradient creek, good salmonid habitat.	Chinook Salmon (juvenile), Mountain Whitefish, Rainbow Trout.	No issues noted.	N/A
Sinkut River[1,2]	Low gradient, unconfined, and influenced by Nechako River high flow backwatering. Woody debris from beaver activity, poor to fair spawning gravel. Side channels dry at low flow. LWD provides good Rainbow Trout habitat.	Burbot, Chinook Salmon (juvenile), Largescale Sucker, Leopard Dace, Longnose Dace, Rainbow Trout, Redside Shiner, sculpin.	Poor hydraulics in lower reach during summer low tributary flows.. No barriers to access noted.	N/A
Smith Creek[2,3]	Only 350 m from mouth accessible due to beaver dams.	Burbot, Chinook Salmon (juvenile), Largescale Sucker, Longnose Dace, Northern Pikeminnow, Rainbow Trout, Redside Shiner, White Sucker.	No issues noted.	N/A
Swanson Creek[1,2,3]	Low gradient. Good Rainbow Trout habitat in 1984. Channel severely aggraded from flooding in 1993, large deposits of gravel near the mouth[5], channel dewaters in several places.	Chinook Salmon (juvenile), Largescale Sucker, Leopard Dace, Longnose Dace, Mountain Whitefish, Northern Pikeminnow, Rainbow Trout, Redside Shiner, sculpin.	Gravel fan at mouth, in some years sub-surface flow isolates Swanson Creek from the Nechako River.	Depth mediated barrier exposure, debris or sediment transport processes
Tahultzu Creek[3]	Beaver dams restrict access for Nechako River fish.	-	Beaver dams completely restrict access at confluence.	Debris transport processess
Targe (Copely) Creek[1,3]	Beaver dams. Subsurface flow resulting in non-connected pools or mouth dewatering during low flow[5]. Low habitat use by juvenile Rainbow Trout in lowest reach, population may be Copley Lake fish.	Burbot, Chinook Salmon (Juvenile), Largscale Sucker, Longnose Dace, Northern Pikeminnow, Rainbow Trout, Redside Shiner, sculpin, White Sucker, whitefish.	Fall spawners (whitefish and anadromous salmon) would be excluded from the creek due to beaver dams and low flows. Access for spring spawners during freshet when flows top beaver dams.	Barrier exposure, debris or sediment transport processes
Twin Creek[4]	Subsurface flow resulting in non-connected pools in lower reach.	-	No issues noted.	N/A
Unnamed Creek (~10.5 km upstream of Prince George)[1]	Low elevation flood plain at confluence with the Nechako River. Influenced by Nechako River backflows, beaver activity, good overwintering rearing fish habitat.	Rainbow Trout, juvenile Chinook Salmon	Notes difficult access to Nechako River from the creek.	N/A

References: [1] ARC 1998, [2] BC MOE 2022, [3] Tredger *et al*. 1985, [4] Regehr *et al.* 2023

[5] Observed/verified by Regehr *et al.* 2023

N/A - no pathway related to RTA operations noted.

4.3.2. Verification

Regehr *et al.* (2023) identified lack of connectivity both at the tributary mouth (Figure 2) and further upstream (Figure 3) at Copely (Targe) Creek. The survey, therefore, concluded low tributary flow was the primary factor limiting habitat connectivity at the tributary mouth; however, some influence of mainstem Nechako River flow may contribute to observed dewatering at the confluence (Regehr *et al.* 2023). No connectivity loss was observed at the mouth of Twin Creek (Regehr *et al.* 2023; Figure 4). However, immediately upstream, barriers to fish access due to low flow and lack of water connectivity within Twin Creek itself were observed (Figure 5). No barriers (i.e., drops, falls), sediment berms, woody debris, or vegetation were observed at either creek.

Figure 2. Copely (Targe) Creek confluence with the Nechako River (looking downstream) during the fall low flow period. Photographed on October 6, 2022.

Figure 3. Looking upstream at Copely (Targe) Creek, upstream of the confluence with the Nechako River, showing isolated pools as the result of low tributary flow during the fall low flow period. Photographed on October 6, 2022.

Figure 4. Twin Creek confluence (looking downstream) with the Nechako River during the fall low flow period. Photographed on October 6, 2022.

Figure 5. Looking upstream at Twin Creek, upstream of the confluence with the Nechako River, showing isolated pools as the result of low tributary flow during the fall low flow period. Photographed on October 6, 2022.

Due to concerns about landowner presence, the 2022 reconnaissance survey was unable to access Swanson Creek on foot (Regehr *et al.* 2023). From what was visible from the river, there appeared to be low to sub-surface flow at the tributary mouth with the presence of a sediment berm (Figure 6). The survey identified low tributary flow as the primary factor limiting habitat connectivity at the mouth of Swanson Creek; however, some influence of mainstem Nechako River flow in combination with accumulated sediment may contribute to dewatering at the confluence (Regehr *et al.* 2023). No other barriers to fish passage (i.e., drops or falls), woody debris, or vegetation affecting fish passage was observed.

Figure 6. **Confluence of Nechako River and Swanson Creek viewed from the river mainstem during the summer low flow period. Photographed on October 6, 2022.**

In summary, although information is limited, it appears most issues related to fish access to tributary habitat are due to low flows within the tributaries themselves and/or barriers to fish passage (e.g., beaver activity, culverts) in upstream areas. Issues with fish access to tributaries that may be related to changes in flow appear limited to two potential pathways of effect (barrier exposure and sediment/debris transport processes). However, there is uncertainty regarding the potential magnitude of these pathways on fish access given that past work is limited primarily to two investigations which occurred over 20 years ago (i.e., Tredger *et al.* 1985; ARC 1998) which did not target confluence access, in addition to preliminary reconnaissance work by Regehr *et al.* (2023).

4.4. Side Channel Access

4.4.1. Literature Results

Literature review did not identify any Nechako River-specific data regarding the effect of flow on connectivity between the river mainstem and side channel habitats. Only two studies conducted in the 1980s explicitly focused on Nechako River side channel habitat (Hamilton 1987; Reid Crowther and Partners Ltd. 1987). However, this work focused on the relationship between river flow and side channel habitat quantity and did not specifically consider fish access.

When considering the Nechako River watershed more broadly, geomorphic changes, particularly to the sediment regime have been identified as some of the most significant effects of flow regulation

(Rood and Neill 1987). Increased erosion has led to increased fine sediment throughout the river and decreased the river's capacity to transport sediment (Rood and Neil 1987; Hay and Company Consultants Inc. 2000; McAdam 2012; NHC 2016; Gateuille *et al.* 2019). Bedload transport has been found to be higher in the upper river (NHC 2016), suggesting sediment becomes stored within side channels and is transported downstream at a lower rate. It is possible that this mechanism could result in fish access issues is sediment accumulate within side channel inlets and flows are too low to maintain connectivity with the mainstem. Nechako River flow regulation in combination with increased sedimentation has also resulted in vegetation encroachment along the river's margins (channel width reduced 29% to 40% across three study reaches) and decreased the number and length of back-channels (Rood and Neil 1987). To date, the extent of, and impacts of vegetation encroachment on fish access to side channels has not yet been thoroughly investigated.

4.4.2. Verification

The Google Earth imagery exercise identified approximately 125 side channels in the Nechako River between Cheslatta Falls and the confluence with the Fraser River that were visible on the imagery in the summer months (Figure 7). Results suggest most side channels are located upstream of Vanderhoof (86 out of 125; 69%). Of the side channels that were observed in the summers (at moderate to high flows) between 2012 to 2021, 41% appeared dry on the imagery (i.e., 35 of 86 side channels upstream of Vanderhoof, 16 of 39 side channels downstream of Vanderhoof). The highest proportion of dry side channels were located upstream of Vanderhoof. Many dry side channels appeared to be partially or completely filled with vegetation, particularly in the river's upstream reaches (Figure 8). However, the mechanism responsible for this vegetative growth is not known. The assessment indicates that most side channels have some fish access at moderate to high flows, but does not identify critical flow levels when fish access will be prevented (i.e., the side channel is dewatered). This assessment also does not identify side channel habitat quality.

Figure 7. Distribution of Nechako River side channels (red circles) identified through Google Earth imagery.

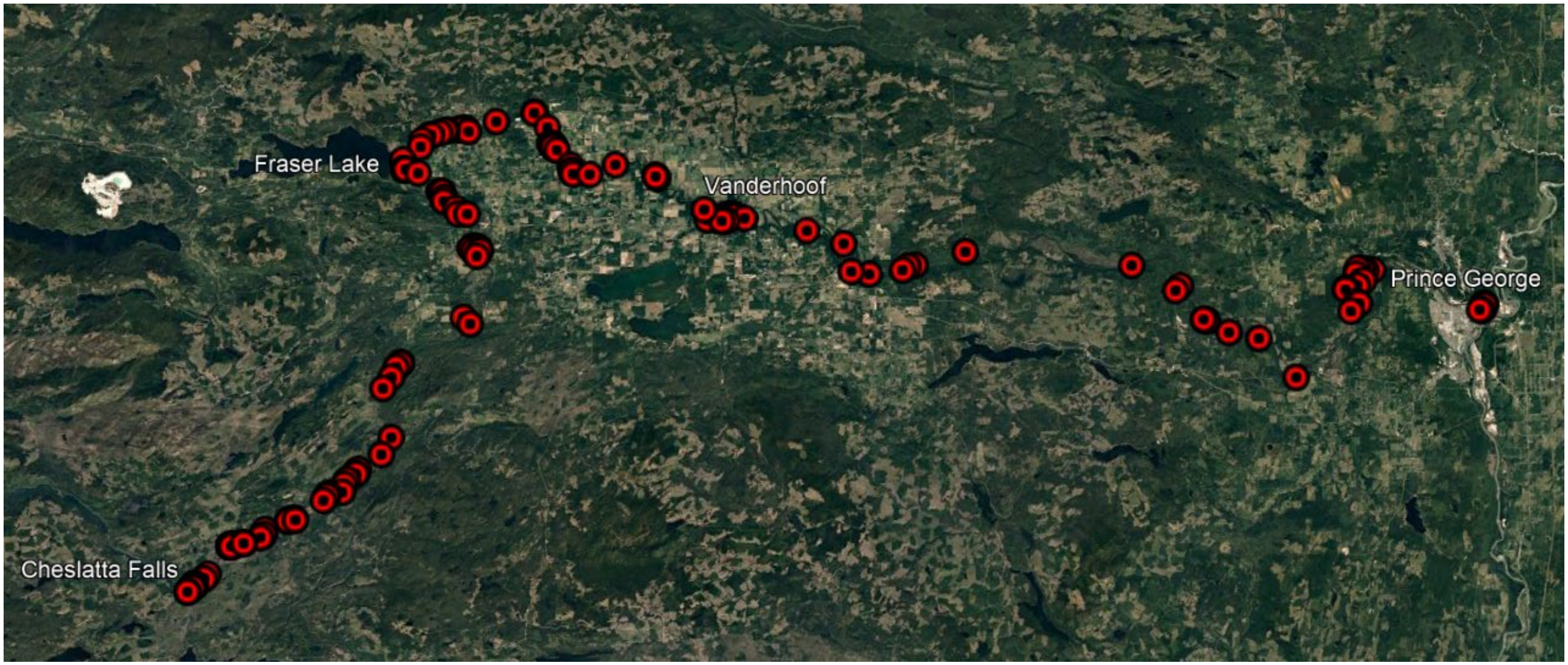

Figure 8. Example of a side channel that appeared dry and vegetated in May 2021.

Regehr *et al.* (2023) visited 13 side channels (Table 5). Most (i.e., 12 of 13) provided at least partial access for fish (either the inlet, outlet, or both were wetted). However, the extent or quality of useable habitat was generally not assessed, and dewatered inlet channels restricted fish access and useable habitat. Further, this survey may have been biased toward wetted channels as they were more easily differentiated from the river mainstem when viewed from the vessel. No obvious barriers to fish access (i.e., drops, woody debris, sediment berms, vegetation) were observed at any side channels visited. It therefore appears that flows at the time of survey were not sufficient to maintain connectivity in the side channels found to contain dewatered areas (i.e., inlet dewatering as the result of the side channel inlet being located at higher elevation than mainstem water elevation). For one side channel visited in the upper river (i.e., side channel #11 in Regehr *et al.* 2023), dewatering[5] appeared recent and resulted in substantial portion of the side channel being dry and inaccessible to fish (Figure 9).

In the lower survey section including the Nechako River Migratory Bird Sanctuary, side channels were variously fully wetted, partially wetted, or completely dry. Of note, the channels and bars in the bird

[5] Although little flow change is evident at the closest Water Survey Canada gauge (Nechako River Below Cheslatta Falls 08JA017), there was definite evidence of stage change (i.e., wet but dewatered algae and gravel). This timing corresponds with SLS gate changes in the days preceding the survey (SLS release dropped from 60 m^3/s on September 29, 2022, to 49 m^3/s on October 1, 2022) and there are several days' time lag between SLS and the upper river.

sanctuary area, understood to previously be cobble and gravel, were found to contain finer substrate (sand, silt) and were heavily colonized by Reed Canarygrass (*Alaris arundinacea;* Figure 10; Figure 11). The extent to which vegetation in this area could limit or prevent fish passage was not clear at the time of survey.

Table 5. Side channels investigated during the Nechako River reconnaissance survey on October 3 (side channel #1) and October 6 (Side channels #2–13) (Regehr *et al.* 2023).

Survey Section	Site Number	Wetted Status	
		Inlet	Outlet
Lower	1†	Dry	Dry
	2†	Wet	Wet
	3	Wet	-
	4	Wet	-
	5	-	Wet
Upper	6	Wet	-
	7	-	Wet
	8	Wet	-
	9	-	Partially wet
	10	-	Partially wet
	11†	Dry	Wet
	12	-	Wet
	13	Wet	-

" - " Inlet or outlet was not observed by survey.

† Side channel was investigated on foot.

* Water present, but may not result in connectivity.

Figure 9. View of dry side channel habitat during the fall low flow period. Photographed on October 6, 2022.

Figure 10. View of side channel outlet showing extensive reed canary grass in the braided area upstream of Vanderhoof. Photographed on October 6, 2022.

Figure 11. Extensive area with reed canary grass adjacent to the Nechako River in the braided area upstream of Vanderhoof. Photographed on October 6, 2022.

In summary, it appears that Nechako River side channels may be most affected by reduced flow in the upper portion of the river (i.e., between Cheslatta Falls and Vanderhoof) and may be impacted by vegetation encroachment, specifically Reed Canarygrass in the lower surveyed section of the river near Vanderhoof. Based on data limitations, none of the four potential pathways of effect could be excluded from consideration as potentially impacting fish access to side channel habitats.

5. DISCUSSION

5.1. Potential Limiting Factors

Four potential pathways of effect of flow on Nechako River fish access to tributary and side channel habitats have been identified. Each pathway is summarized separately, although interactions and trade-offs between the pathways should be considered when evaluating potential PMs.

- *Tributary mouth or side channel inlet dewatering* – The 2022 reconnaissance survey provides initial evidence that tributary mouth and side channel inlet dewatering may affect fish access to these habitats at some times, in some areas (e.g., Copely (Targe) Creek and possibly Swanson Creek and three of 13 side channels visited). The primary mechanism resulting in tributary dewatering appears to be low tributary flow potentially exacerbated by low mainstem river elevation (i.e., in the case of Copely (Targe) Creek) or sedimentation (i.e., Swanson Creek, see Debris and Sediment Processes below). For side channels, dewatering was observed during the 2022 reconnaissance survey when mainstem river elevation was below the elevation of side channel inlets. In the case of one side channel visited on foot, dewatering appeared recent and corresponded to Skins Lake Spillway gate changes in days preceding the survey.

Given the lack of past work that has explicitly considered fish access to tributary mouths and side channels, the limited number of tributaries and side channels visited on foot by the 2022 reconnaissance survey, and the potential bias toward wetted side channels that were more easily identified from the vessel during the 2022 reconnaissance survey, substantial uncertainty remains regarding this potential pathway of effect.

- ***Barrier exposure*** – No evidence was identified suggesting that low flows specifically contribute to barrier exposure at tributary mouths or side channel inlets. However, past investigations were limited solely to a subset of tributaries (i.e., no side channels investigated) and occurred over 20 years ago since which time the morphology of tributary and mainstem river confluences may have changed (e.g., lateral main channel movement, tributary downcutting). While no barriers to fish passage were observed during the 2022 reconnaissance survey, the survey was only able to visit a small number of tributaries and side channels on foot (two tributaries and two side channels (Regehr *et al.* 2023). As a result of data limitations, uncertainty remains regarding the magnitude of this potential pathway of effect.
- ***Debris and sediment transport processes*** – Literature review identified beaver dams at tributary confluences that were reported to limit fish access at the time of survey. However, this was not observed in tributaries visited as part of the 2022 reconnaissance survey (Regehr *et al.* 2023). Given the limited number of tributaries visited by Regehr *et al.* 2023, and previous evidence of debris impacts to fish tributary access, uncertainty remains regarding this potential pathway of effect.

  Tributary channel erosion and resultant sediment deposition were also identified as possibly affecting at least some Nechako River tributaries (e.g., Swanson Creek; ARC 1998; BC MOE 2022; Tredger *et al.* 1995; Regehr *et al.* 2023). Although there is no clear evidence that sediment processes are impacting fish access to tributaries, given the lack of recent comprehensive studies, uncertainty remains with respect to this pathway of effect.

  No evidence of debris or sediment impacts on fish access to Nechako River side channel habitat was identified by literature review or the 2022 reconnaissance survey. However, given data limitations and the potential bias toward wetted side channels that were more easily identified from the vessel during the 2022 reconnaissance survey, substantial uncertainty remains regarding this potential pathway of effect.

- *Vegetation encroachment* – No evidence of vegetation encroachment affecting fish access to tributary habitats was identified. However, a limited number of tributaries were visited during the 2022 reconnaissance survey and past surveys have not explicitly considered tributary mouth barriers to fish passage.

  Literature review found evidence of increased vegetative growth within Nechako River margins. However, no discussion of the impacts of this growth on fish access to side channel habitats was identified. Although the Google Earth exercise identified the presence of multiple side channels throughout the river that were heavily vegetated, this was not observed in the upper river during the 2022 reconnaissance survey. It is possible that vegetated side channels were more difficult to identify from the vessel, and that they were therefore not observed during the 2022 survey. In the lower river, the 2022 reconnaissance survey identified extensive vegetation throughout island and side channel habitats just upstream of Vanderhoof; however, the extent of any resulting access issues is unclear. Given data limitations, uncertainty remains regarding the relationship between fish access, vegetation, and flow, particularly as it relates to side channel access.

5.2. Uncertainties and Data Gaps

There are several data gaps and uncertainties that limit our understanding of the relationship between flow and fish access to Nechako River tributaries and side channels. These existing uncertainties (outlined below) significantly limit our ability to develop specific, robust performance measures and therefore, preclude development of meaningful flow-related performance measures in structured decision making under the WEI at this time.

Quantifying the relationship between flow and fish access to tributary and side channel habitats requires a clear understanding of fish habitat use. Although several Nechako River fish populations have been studied extensively (e.g., Chinook Salmon and White Sturgeon), to date there has been no Nechako River-specific research quantifying the importance of tributary or side channel habitats to river fish nor regarding the relationship between fish access to these habitats across a range of flows.

Information provided to the TWG indicates concerns regarding fish access issues in some tributaries identified in previous studies, however several tributaries identified have not been considered by past work. Studies to date (Tredger *et al.* 1985; ARC 1998) provide useful preliminary information regarding Nechako River tributary habitat. However, this work was limited in scope and no contemporary information exists, excluding limited opportunistic observations during the 2022 reconnaissance survey.

Similarly, data regarding the relationship between flow and fish access to Nechako River side channel habitats is highly limited. Literature review did not identify any specific information relating fish access to inlet dewatering or the presence of debris, sediment, or vegetation. While the 2022 reconnaissance survey provides valuable information regarding side channel connectivity under low flows, the survey provides only a single snapshot in time, and may have been biased toward wetted channels due to the crews' ability to more easily identify these areas as side channel habitat. Further, although the Google Earth imagery exercise provides a preliminary assessment of mainstem and side channel connectivity throughout the Nechako River, the analysis has several limitations:

- Some of the imagery was over a decade old and channel morphology will likely have changed since the photos were taken;
- Side channel connectivity changes annually, seasonally, and within seasons. Since images provide a snapshot in time, they do not capture temporal dynamics of flow to and within side channels; and
- Where riparian tree cover was heavy or imagery was not clear, it was difficult to positively identify side channels, and their condition (i.e., wet or dry).

Given the data gaps discussed above and the physical changes that have occurred in the Nechako River, associated tributaries, and side channels as the result of flow regulation and other factors (see NFCP 2005) and more broadly across freshwater ecosystems in recent decades (see Carpenter *et al.* 2011; Reid *et al.* 2019), collecting contemporary information is of high importance for performance measure development, particularly for side channel access, given the issue has been identified as a WEI priority.

6. CLOSURE

This memo has reviewed the potential for changes in flow to affect fish access to Nechako River tributary and side channel habitats. Outcomes of the review were to identify data gaps that could be addressed with further study. No performance measures for the WEI are recommended at this time due to data gaps identified.

Yours truly,

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