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MEMORANDUM

TO: Water Engagement Initiative (WEI)

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DATE: December 15, 2022

FILE: 1316-07

RE: Nechako Reservoir Spillway – Desktop Assessment of Fish Entrainment – V2

1 INTRODUCTION

During Main Table and Technical Working Group meetings of the Nechako Water Engagement Initiative (WEI), concerns were raised regarding potential effects of Rio Tinto Alcan (RTA) operations on fish populations in the Nechako Reservoir. In particular, there was interest to understand whether fish were being "lost" from the reservoir through the Skins Lake Spillway. The process of fish moving downstream through a hydroelectric facility is termed "entrainment".

This memo provides a desktop entrainment risk assessment for the Skins Lake Spillway using the BC Hydro *Fish Entrainment Risk Screening and Evaluation Methodology* (BC Hydro 2006). The following sub-sections provide a background of the Skins Lake Spillway (including hydrological considerations), as well as fish habitat and community information near this location, while the subsequent sections provide the assessment methodology and results, as well as a discussion of the consequence of potential entrainment on the relevant fish populations.

1.1 Background

1.1.1 Skins Lake Spillway

The Nechako Reservoir is a large hydroelectric storage reservoir impounded by the Kenney Dam (which has no discharge facility) located approximately 200 km west of Prince George, BC (Map 1). The reservoir is operated by RTA to produce energy for the Kitimat aluminium smelter (RTA 2011). It has an area of ~890 km^2 and inundates a ~420 km-long chain of six major lake and river systems (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).

The Skins Lake Spillway, which was constructed in 1953, is located in a small embayment mid-way along Ootsa Lake on the northeastern side of the reservoir (Map 1, Figure 1). The spillway is composed of a two-bay radial gate structure with gates that measure 10.7 m by 10.7 m each (Mercier, pers. comm. 2021, KCB 2020). The gates open from the bottom, conveying water from depth in the reservoir to the surface at the spillway. Water passing through the spillway is discharged to a downstream plunge pool, then flows continue downstream through the Cheslatta River and Skins Lake, Cheslatta Lake, and Murray Lake before discharging into the Nechako River (Map 1).

Reservoir elevation and gate discharge varies through the year in response to precipitation, power demand, and instream flow requirements. Spillway discharge increases with gate opening height and reservoir elevation, which varies but is greatest in the summer months (Figure 2). The discharge is controlled to power flow requirements at the Kemano Hydroelectric Project and instream flow needs for salmon in the Nechako River (Mercier, pers. comm. 2021). Between July 20 and August 20, additional flows are released to cool downstream waters for spawning Sockeye Salmon migrations following the Summer Temperature Management Program (STMP, Roberts *et al.* 1997), as per the 1987 agreement (NFCP 2021).

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. Gate change frequency varies from two times in December to 73 times in July, while the spillway gate area opening varies from 4.0 m^2 in December to 26.4 m^2 in July (Table 1). Velocity in the spillway varies little (average 7.1 m/s in December to 9.7 m/s in September and November due to the independent gate operations, with a single gate consistently providing flow over lower flow ranges and the second gate used only when higher flows must be discharged).

Figure 1. Skins Lake Spillway on the Nechako Reservoir, showing the two radial gates and the plunge pool.

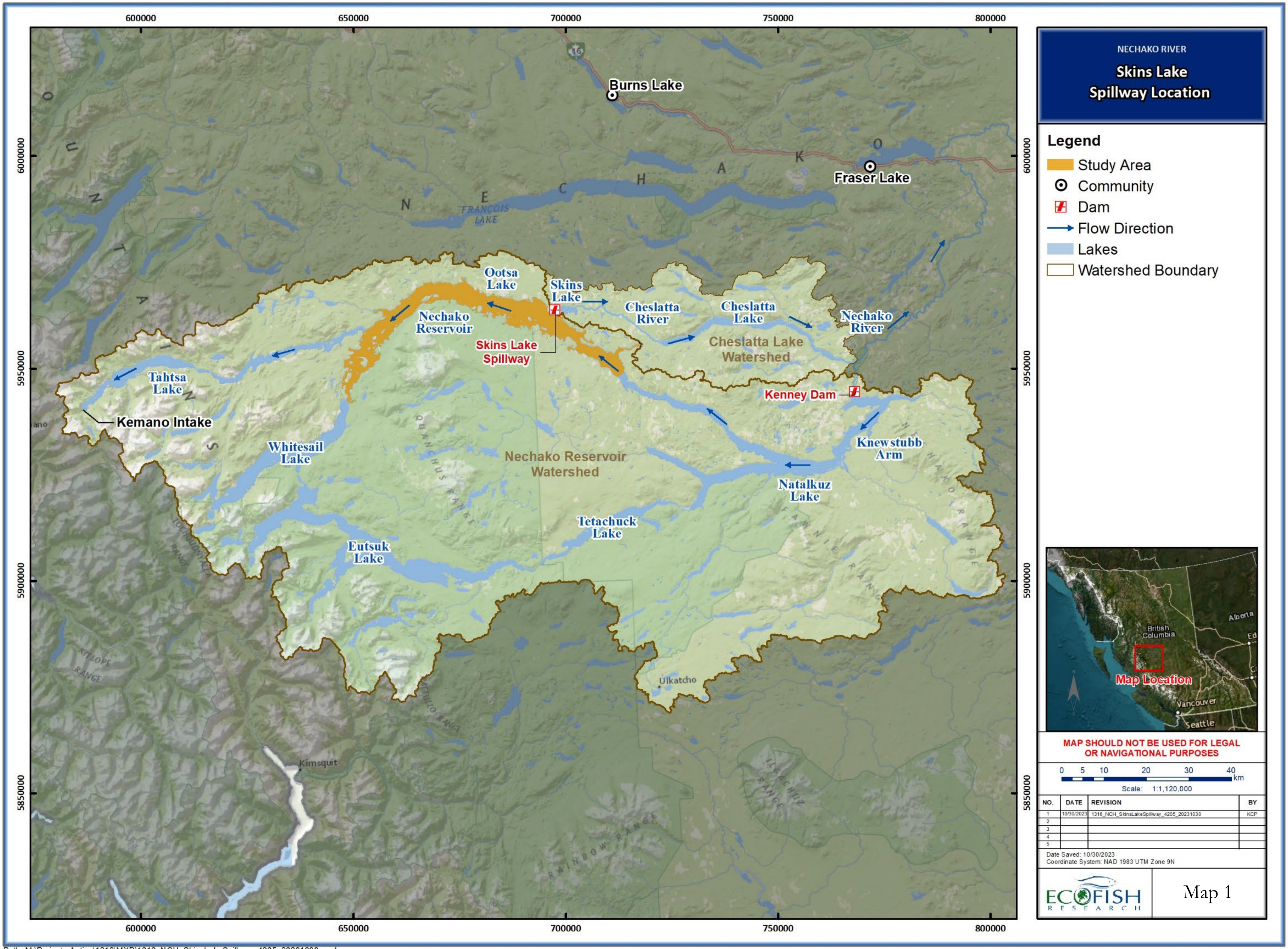

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Figure 2. Time series of the Nechako Reservoir elevation and Skins Lake Spillway discharge in representative years.

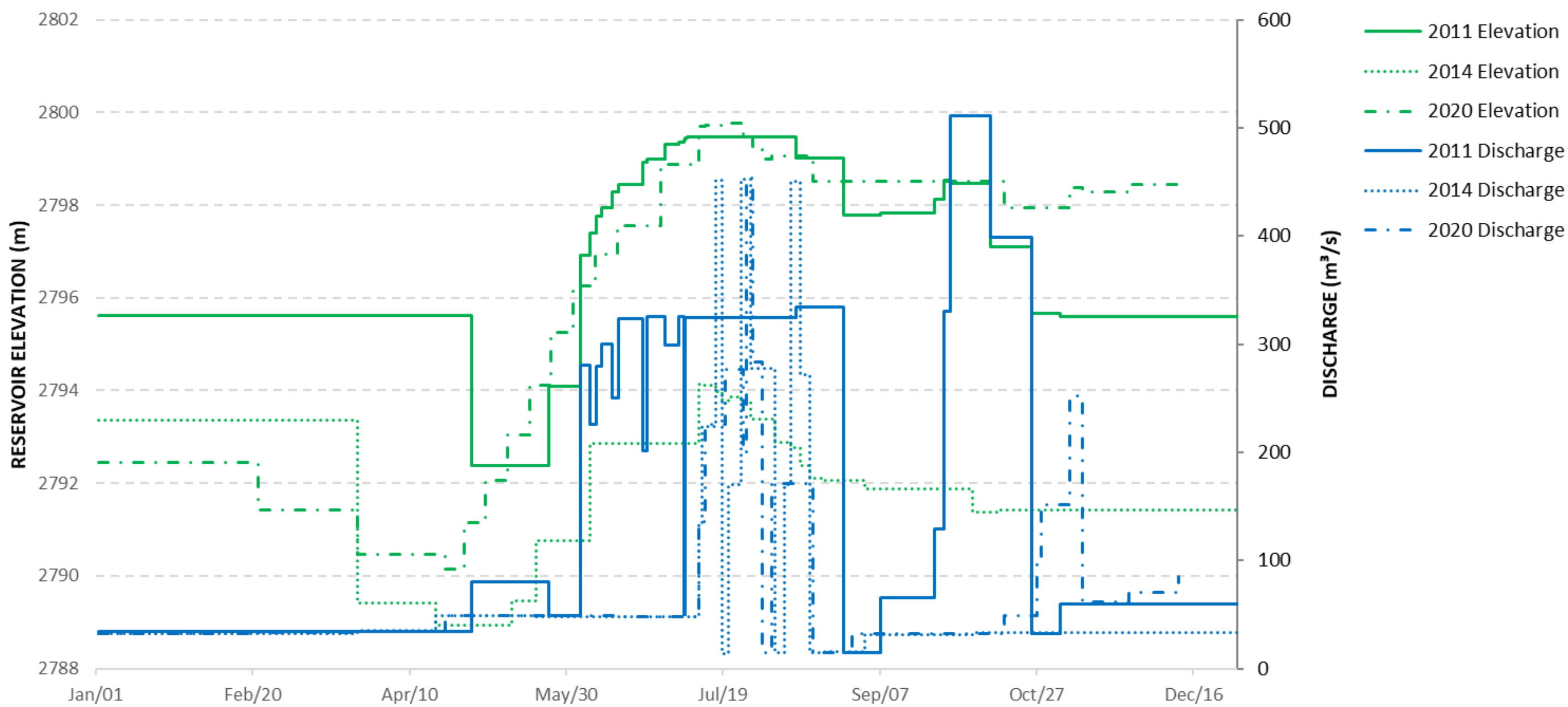


Table 1. Summary statistics by month for the Skin Lake Spillway showing discharge, gate change frequency, flow area and current velocity at the gates (Mercier, pers. comm. 2021).

Month	Total Gate Changes	Discharge (m^3/s)			Flow Area (m^2)			Velocity (m/s)		
		10%tile	Average	90%tile	10%tile	Average	90%tile	10%tile	Average	90%tile
Jan	6	31.0	45.7	82.6	3.0	4.6	8.5	9.7	8.7	10.4
Feb	10	32.7	45.5	102	3.1	4.7	11.3	9.2	9.2	10.6
Mar	11	29.8	49.2	84.3	2.9	5.0	7.9	9.4	9.1	10.4
Apr	31	48.7	130	243	5.0	14.4	27.7	8.6	8.9	9.9
May	53	48.5	195	344	4.8	22.1	40.1	8.4	9.1	10.2
Jun	58	48.6	208	468	4.6	22.9	55.9	8.4	9.5	10.7
Jul	73	14.8	230	453	1.3	26.4	57.2	7.9	9.4	11.0
Aug	61	14.5	173	453	1.3	20.6	57.6	7.8	9.6	11.4
Sep	15	29.4	87.5	250	2.8	9.7	27.7	9.2	9.7	11.0
Oct	14	32.4	93.8	256	3.0	10.2	28.6	8.9	9.5	11.1
Nov	15	30.3	63.3	107	2.8	6.4	10.5	9.6	9.7	11.1
Dec	2	39.2	39.9	80.0	3.7	4.0	7.9	10.2	7.1	10.6
Annual	**349**	**28.1**	**113.3**	**452.2**	**2.8**	**12.6**	**55.0**	**8.3**	**9.1**	**11.0**

1.1.2 Fish Habitat near the Skins Lake Spillway

In the Nechako Reservoir, fish habitat exists along the shoreline, littoral zone, and pelagic zones near the spillway providing habitat conditions typical of the reservoir. The steep shoreline with a slope that exceeds 10% directly adjacent to the spillway indicates low habitat suitability compared to more gradual sloping shorelines nearby (Map 2). Based on the slope and local effects of spillway excavation along the shoreline, the substrate is expected to be dominated by bedrock and boulder with a thin layer of fine sediment from the glacial lake waters.

The Cheslatta River system flows downstream from the Skins Lake Spillway, providing river and lake fish habitat. Immediately downstream of the spillway, the plunge pool provides depths of up to 13.5 m with turbulent velocities that are moderate to high depending on discharge (KCB 2020). Downstream of the plunge pool, a 1.5 km reach of the upper Cheslatta River to the confluence of Skins Lake provides 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 Consultants Ltd. 1998). Downstream of Skins Lake there is approximately 23 km of Cheslatta River habitat until the confluence with Cheslatta Lake, which provide littoral and pelagic lake habitat in approximately 3,500 ha with a maximum depth of 73 m (Golder Associates Ltd. 2005).

1.1.3 Fish Community near the Skins Lake Spillway

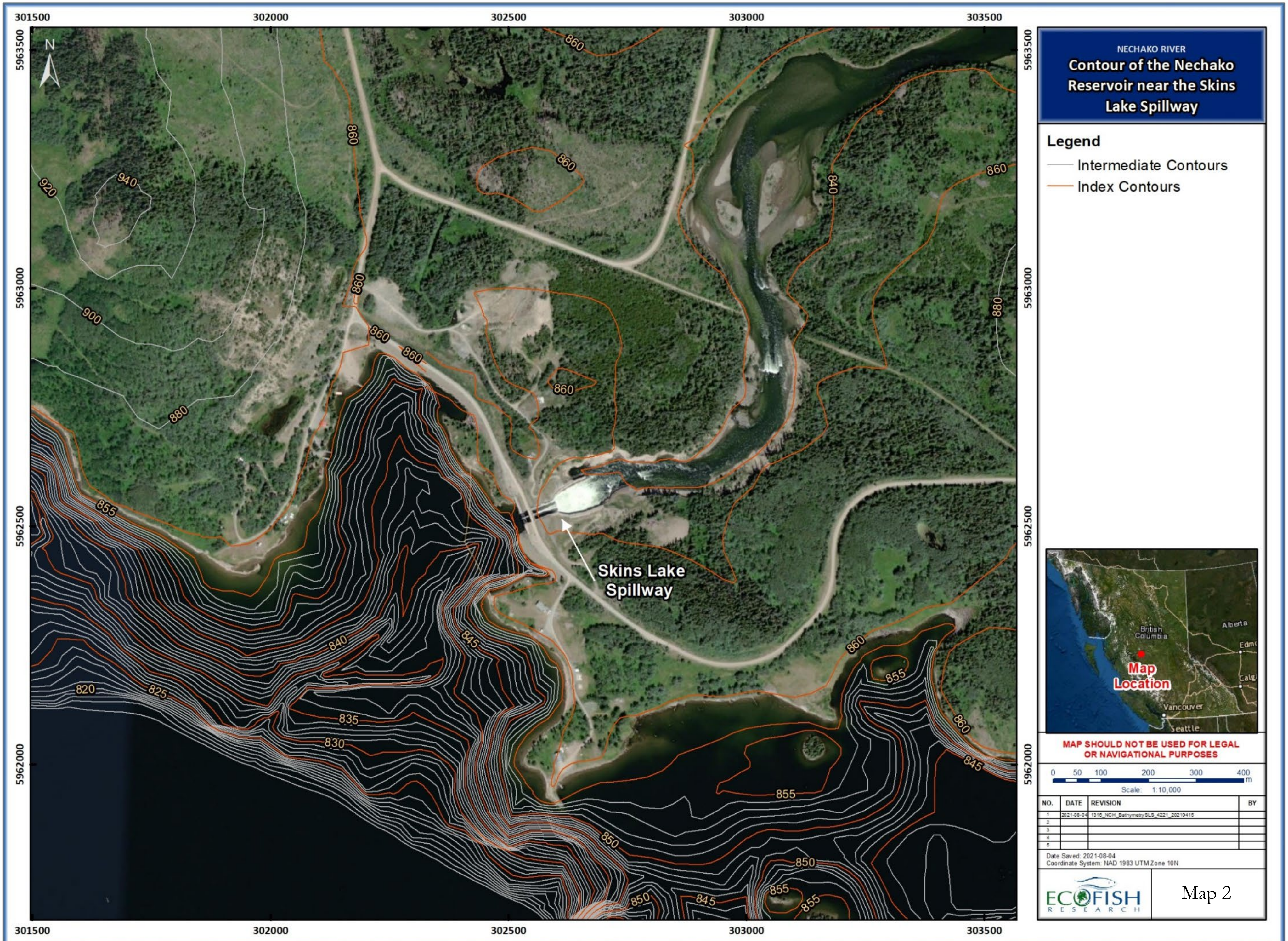
Fish species known to be present in the Nechako Reservoir include nine species: Bridgelip Sucker (*Catostomus columbianus*), Burbot (*Lota lota*), Kokanee (*Oncorhynchus nerka*), Largescale Sucker (*Catostomus macrocheilus*), Longnose Sucker (*Catostomus catostomus*), Mountain Whitefish (*Prosopium williamsoni*), Northern Pikeminnow (*Ptychocheilus oregonensis*), Prickly Sculpin (*Cottus asper*), and Rainbow Trout (*Oncorhynchus mykiss*) (Table 2; MOE 2021a, 2021b, Robertson, pers. comm. 2021, Avison 2019). Additional fish species noted in tributaries to the Nechako Reservoir include Lake Chub (*Couesius plumbeus*), Slimy Sculpin (*Cottus cognatus*), Longnose Dace (*Rhinichthys cataractae*), and White Sucker (*Catostomus commersonii*) (Triton 2000a, 2000b, 2005). It was assumed that these species could also use the Nechako Reservoir as they can be found in lakes, except for Longnose Dace, which are only found in stream habitat (McPhail 2007). In addition, a new species, Brassy Minnow (*Hybognathus hankinsoni*), was found in the plunge pool of the Skins Lake Spillway and could potentially have been entrained from the Nechako Reservoir (Tolton 2011).

Fish species present in Skins Lake, 1.5 km downstream of the Skins Lake Spillway include Whitefish *sp.* Rainbow Trout, Sculpin *sp.* Burbot, Northern Pikeminnow, and Mountain Whitefish (Hatfield Consultants Ltd. 1998, MOE 2021a) all of which are also found in the Nechako Reservoir. Further downstream of the spillway, the fish species known to be present in Cheslatta Lake are (i.e., Northern Pikeminnow, Longnose Sucker, Lake Chub, Largescale Sucker, whitefish *sp.*, sucker *sp.*, Rainbow Trout, Mountain Whitefish, Lake Whitefish, Kokanee, and Burbot), all of which are also present in the Nechako Reservoir, as well as Redside Shiner (*Richardsonius balteatus*), and Lake Trout (*Salvelinus namaycush*), (Golder Associates Ltd. 2005, MOE 2021a). Of special consideration, information on Kokanee downstream of the Skins Lake Spillway (i.e., Skins Lake, Cheslatta Lake) is limited to a few observations (Harder 1986) from the 80s and 90s. Traditional knowledge does not show any history of Kokanee in the Cheslatta River and associated lakes (Robertson, pers. comm. 2021). Thus, it is expected that presence of this species downstream of the spillway is associated with entrainment from the Nechako Reservoir.

Table 2. The 13 fish species likely to be present in the Nechako Reservoir, as well as their provincial and federal status (MOE 2021a, 2021b, Avison 2019, Triton 2000a, 2000b, 2005).

Fish Species	Scientific Name	Provincial Status[1]	Federal Status (COSEWIC)
Brassy Minnow	*Hybognathus hankinsoni*	None	None
Bridgelip Sucker	*Catostomus columbianus*	Yellow	None
Burbot	*Lota lota*	Yellow	None
Kokanee	*Oncorhynchus nerka*	None	None
Lake Chub	*Couesius plumbeus*	Yellow	None
Largescale Sucker	*Catostomus macrocheilus*	Yellow	None
Longnose Sucker	*Catostomus catostomus*	Yellow	None
Mountain Whitefish	*Prosopium williamsoni*	Yellow	None
Northern Pikeminnow	*Ptychocheilus oregonensis*	Yellow	None
Prickly Sculpin	*Cottus asper*	Yellow	None
Rainbow Trout	*Oncorhynchus mykiss*	Yellow	None
Slimy Sculpin	*Cottus cognatus*	Yellow	None
White Sucker	*Catostomus commersonii*	Yellow	None

[1]Yellow=not of concern, Blue=concern because of characteristics that make them particularly sensitive to human activities or natural events; Red=Endangered or Threatened under the *Wildlife Act*



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2 FISH ENTRAINMENT ASSESSMENT METHODS

2.1 BC Hydro Methodology

To provide a desktop assessment, we evaluated fish entrainment following a process used previously by Fisheries and Oceans Canada (DFO) to assess the significance of entrainment at hydroelectric projects. This process has been used at other hydroelectric facilities within the province, both for BC Hydro and other utilities. The *Fish Entrainment Risk Screening and Evaluation Methodology* was developed to provide a transparent and understandable evaluation process for fish entrainment (BC Hydro 2006). This method consists of a two-stage process that includes an Overview Risk Screening (ORS) and a Risk Assessment and Evaluation (RAE).

The ORS is a high-level desktop biological and facility screening assessment used to identify overall concerns with fish entrainment. The assessment is based on available fish information such as species and life stages present, habitat use and behaviour, physiology, and abundance and distribution, combined with infrastructure information such as velocity at the intake and operational regime. The result of this assessment leads to a classification of entrainment risk as low, moderate, or high.

If the rating is low, no further action is needed. In turn, if the final rating is moderate then further evaluation is needed for the relevant fish species, as well as a management plan. However, the facility may not require mitigation. Alternatively, if the risk of entrainment is classified as high, then a RAE will be required, which is a more detailed quantitative analysis that includes components like a cost-benefit evaluation of risk mitigation and management (BC Hydro 2006). Inadequate biological or operational data may require additional field studies to support the assessment. The outcome of a high rating will also require monitoring, mitigation, and a management plan for fish entrainment (BC Hydro 2006).

This report provides a desktop assessment of entrainment and thus is limited to the screening stage of the methodologies (i.e., ORS). The goal of the ORS is to establish:

- The likelihood of fish entrainment within the Project intake – The "*Entrainment Likelihood Rating*" is obtained by assessing whether the fish community is predisposed to entrainment (Species-Life Stage Hazard Screening) and whether operation of the facility is likely to lead to fish entrainment (Physical Hazard Screening).

- The ecological significance of fish entrainment on the fish community – The "*Ecological Significance Rating*" is obtained by assessing the value and abundance of the fish that may be entrained (Value-Abundance Rating), as well as the proportion of the population that may be impacted (Proportion of Population Impacted Rating).

- The consequences of entrainment on fish – The "*Fate/Consequence Rating*" is obtained by assessing the effects of entrainment on the fish that may be entrained.

- The frequency of occurrence of fish entrainment.

The evaluation of these factors is then used to provide a "*Final Risk Screening Rating*" for the Project. Further details on this methodology can be found in BC Hydro (2006).

2.2 Study Area

The study area for the fish entrainment assessment is the Northeastern portion of the Nechako Reservoir in the approximately 340 km^2 area known as Ootsa Lake (Map 1). This study area centered on the north-central location of the Skins Lake Spillway within Ootsa Lake but was limited in extent in consideration of the large size of the large reservoir and the expectation that fish population ranges will not extend across the entire reservoir.

2.3 Literature Review

The literature that was consulted to provide this assessment of fish entrainment consists of:

- Skins Lake Spillway hydraulic modelling reporting:
  - Skins Lake Spillway CFD Model – Hydrological Report (KCB 2020).
  - Backup Tunnel Project Environmental Assessment (RTA 2013).
- Nechako Reservoir fish community reporting:
  - Traditional knowledge shared by the Cheslatta Carrier Nation (Robertson, pers. comm. 2021).
  - Fish Entrainment Report (Triton 2005).
  - Kemano completion Project environmental studies: Potential for entrainment of fishes through the proposed power plant intake in West Tahtsa Lake and water release facilities at Kenney Dam (Envirocon 1989).
  - Fish ecology in Ootsa Lake (Brooks 2000).
  - Nechako Reservoir impacts of timber salvage on fish and fish habitat (Winsby *et al.* 1998).
  - Fish salvages from the Skins Lake Spillway (Tolton 2011, Avison 2018, 2019).
- Government resources such as the Fish Inventories Data Queries (FIDQ) and the Ecological Reports Catalogue (EcoCat).
- Fish species habitat use information:
  - BC fish and fish habitat use literature (e.g., McPhail 2007).
  - Other published scientific literature.

- Scientific literature on fish entrainment (including BC Hydro entrainment assessments) and fish swimming capabilities (e.g., BC Hydro 2007, 2019).

2.4 Assessment Assumptions and Limitations

This assessment is based on the available information and was limited by some uncertainties, which include, among others:

- Fish distribution and relative abundance information were primarily obtained from two studies conducted in the 1997 and 1998 in Ootsa Lake. It was assumed that these data were representative of fish distribution in Ootsa Lake, including at the Skins Lake Spillway area.
- The fish habitat information at the Skins Lake Spillway is limited and was assumed based on satellite imagery, a contour map and general shoreline habitat descriptions.
- Spillway discharge data provided by RTA is not measured directly but derived from the reservoir level and the gate opening. It was assumed to provide an accurate representation of the discharge expected within the Skins Lake Spillway.
- Evidence of barotrauma or gas bubble disease was not observed at the spillway, but its presence was evaluated based on known habitat conditions, as well as literature on the subject.
- The presence of fish salvaged in the Skins Lake Spillway with no identifiable evidence regarding their origin (i.e., entrained in the spillway or having moved upstream from the Skins or Chesletta Lakes).

3 FISH ENTRAINMENT ASSESSMENT (RESULTS)

3.1 Likelihood of Fish Entrainment

The first step of the ORS was to determine the likelihood of entrainment based on habitat preferences and behavior. Habitat preferences by fish species and life-stages (Species-Life Stage Hazard Screening), the behavioural and physiological characteristics of the species and life-stages (e.g., migration patterns, swimming ability), and the physical and operational characteristics of the intake (Physical Hazard Screening) were determined using available literature combined with operational information from RTA on the Skins Lake Spillway.

3.1.1 Species-Life Stage Hazard Screening

Fish species that have a high risk of entrainment within the Skins Lake Spillway were identified based on a professional interpretation of the following attributes, which led to a hazard risk screening of low, moderate, or high:

- Fish species and life stages present in the Nechako Reservoir and likely to be present near the Skins Lake Spillway entrance.
- Habitat use and preference, which indicates whether a fish species and life stage uses littoral, limnetic and/or profundal zones of the reservoir, which provides an indication of the risk of using habitats near the spillway entrance.
- Movement behaviour, which would indicate the propensity of a fish to migrate near and/or use the spillway entrance location.

An assessment of behavioural and physiological characteristics that can affect the potential for fish entrainment such as conspecific behaviour, use of the water column and swimming ability are addressed in Section 3.1.2.2. Of note, other physiological (e.g., sensory ability of fish to detect a hazard) and environmental factors (e.g., water temperature stress may reduce the ability of fish to react to a hazard) were not assessed because: (1) the fish species present in the reservoir are assumed to have similar sensory abilities, and (2) the reservoir water temperature is expected to fluctuate slowly within the reservoir compared to a stream, and thus have negligible effect on entrainment potential into the spillway.

3.1.1.1 Fish Species and Life Stages Evaluated

Fish sampling near the Skins Lake Spillway is limited; however, for the purpose of this step of the risk assessment, all 13 fish species identified in Table 2 were assumed to be present in the reservoir. This is consistent with the new *Fisheries Act*, which now considers all fish species rather than just fish species of commercial, recreational, and aboriginal value (DFO 2021). However, because whitefish and sculpin species may be difficult to differentiate and use similar habitats, they were combined into Whitefish sp. and Sculpin sp. for the assessment. In addition, it was assumed that all life stages (larvae/alevin, fry, juvenile, and adult) could be present in the Nechako Reservoir, although some may have limited presence due to preferential use of the tributaries. Table 3 provides a summary of habitat use information for the fish species of interest along with a summary of the likelihood that the species would utilize the habitat adjacent to the Skins Lake Spillway entrance.

3.1.1.2 Species-Life Stage Rating

Table 4 provides the Species-Life Stage Hazard Screening for the retained fish species and associated life stages in each season based on a professional interpretation of available fish habitat use information (Table 3), the depth contours in the spillway area (Map 2), and the volume of water leaving the Nechako Reservoir at the Skins Lake Spillway (Figure 2, Table 1). This last criterion was determined by the expected reservoir water level and discharge at the Skins Lake Spillway (which is based on gate opening area) in each season (see detail in Section 3.1.2.3). In general, a low rating was given when the water level within the reservoir was "low" with a corresponding "moderate" discharge through the Skins Lake Spillway, or the Nechako Reservoir water level was "moderate" with a "low" discharge through the spillway. A high rating was more likely when the water level in the reservoir was "high" with a "high" discharge from the Skins Lake Spillway because the risk of entrainment increases with the volume of water entrained (as noted by Martins *et al.* (2013), many entrainment events recorded for adult Bull Trout through Mica dam in BC, occurred when the reservoir was at high pool and drafting).

Table 3. Summary of habitat use information for the relevant fish species and likelihood of using the area near the Skins Lake Spillway.

Fish Species	Spawning	Habitat Use			Movement Behaviour	Life Stage Potentially Present in Spillway Area	Likely Presence near the Skins Lake Spillway	Potential Entrainment Hazard
		Spawning	Rearing	Adult				
Brassy Minnow	Mid-May to early June	Spawns usually over sand or gravel	Uses soft mud substrate and vegetation, rarely observed in water >1.5 m deep	Uses soft mud substrate and vegetation, rarely observed in water >1.5 m deep	Schooling behaviour. No downstream movement propensity.	None	This area likely provides minimal habitat for this species, which uses shallow waters for spawning, rearing, and feeding.	Low for all life stages present and seasons.
Bridgelip Sucker	Mid-April to mid-June	Riffle habitat in streams	Shallow, quiet water	Streams with colder, swifter water and rocky substrate. Habitat in lakes unstudied.	Mostly found in rivers. Lake behaviour understudied.	None	The spillway area is likely to provide minimal habitat for this species as it mostly uses streams for spawning, rearing, and feeding.	Low for all life stages present and seasons.
Burbot	December to March	In one to ten feet of water over sand/gravel bottom or five to ten feet over gravel shoals	Limnetic and littoral zones of lakes.	Limnetic habitat. Prefers cool water, restricted to hypolimnion in summer.	May move to nearshore areas to feed at night. Spawn in shallower waters. No downstream movement propensity.	All life stages	There is potential for this species to use the spillway area throughout the year.	Low for most life stages present and seasons but moderate in summer when discharge from the spillway is high and for adults in winter during spawning migrations.
Kokanee	Mid-September to Late October	Streams and littoral zones of lakes over gravel and cobble substrate	Limnetic and littoral zones of lakes	Limnetic zones of lakes	Seasonal movements for spawning, diel feeders in presence of thermocline. Schooling behaviour, and have positive rheotactic (flow) response. Some juveniles may choose to migrate to the ocean.	Fry, Juveniles, Adult	The area is likely to provide only marginal habitat for spawning. Larvae are not at risk as they are not in the water column. Juvenile and adult rearing and feeding during the growing season could occur in this area. In the winter, this habitat may be used for foraging opportunity.	Low for fry in spring and summer. High in summer for juveniles and adults when discharge from spillway is high and for adults in the fall during spawning migrations. Moderate in fall for fry and juveniles and in the winter for juveniles and adults due to potential foraging opportunity in the area.

Table 3. Continued (2 of 3).

Fish Species	Spawning	Habitat Use			Movement Behaviour	Life Stage Potentially Present in Spillway Area	Likely Presence near the Skins Lake Spillway	Potential Entrainment Hazard
		Spawning	Rearing	Adult				
Lake Chub	May to August	Flowing or standing water, substrate unimportant, shallow water and generally in streams	Close to bottom in littoral zone in spring, move closer to the shoreline in summer	Close to bottom in littoral zone in spring, move closer to the shoreline in summer	Adults move from nearshore habitat in the day to deeper habitat at night (up to 50 m). Move in schools to spawning habitats. No downstream movement propensity.	Juvenile, Adult	Low likelihood of presence near the spillway as the species spawns in streams and demonstrates limited movement. The closest tributary to the spillway is at least 2.5 km away.	Low for all life stages present and seasons.
Largescale Sucker	April to mid-July	Fine to coarse gravel lake shoals or sandy areas of tributary streams	Benthic lake habitat when reach 16 to 18 mm in length	Benthic lake habitat up to 25 m depth	Species is relatively sedentary. No downstream movement propensity.	Juvenile, Adult	Low likelihood of presence near the spillway as the species spawns in streams and demonstrates limited movement. The closest tributary to the spillway is at least 2.5 km away.	Low for all life stages present and seasons.
Longnose Sucker	Early spring to mid-June	Streams over gravel substrate in moderate current	Limnetic and littoral zones of lakes	Limnetic and littoral zones of lakes	Adults move from nearshore habitat in the day to deeper habitat at night. Spawning migration in spring. No downstream movement propensity.	Juvenile, Adult	There is potential for some use of the spillway area in the summer, fall, and winter but not for spawning and early life stages. Relative abundance appears low, which reduces risk. May move into area during spawning migration.	Low for all life stages present and seasons except moderate for adults in spring during spawning migrations.
Whitefish sp.	November to Late December	Streams and littoral zones of lakes over gravel and cobble substrate	Littoral zones of lakes in shallow water <2 m	Limnetic or littoral zones of lakes	Consistent seasonal movement for spawning and summer feeding, schooling behaviour, positive rheotactic (flow) response, no downstream movement propensity.	Juvenile, Adult	The spillway area likely provides limited spawning or rearing habitat. Adults may use this habitat in the spring, summer, fall and winter for foraging and spawning. However, they are present in low relative abundance, which reduces the risk.	Low for all life stages present and seasons except moderate for adults in summer when discharge from spillway is high and fall during spawning migrations.
Northern Pikeminnow	Late May to early July	Gravel shallows on lake shores or short distance up tributary streams	Forage in shallower, nearshore areas of lakes in loose schools in summer	Move into deeper benthic offshore lake habitat	Adults tend not to make large migrations. No downstream movement propensity.	Juvenile, Adult	Eggs and larvae are not expected in the spillway area. There is potential for use by juveniles and adults, particularly in the summer, fall and winter, although movements are limited in the winter. Risk is increased by the large relative abundance of this species.	Low for all life stages present in most seasons except high for juveniles and adults in the summer due to high discharge from spillway and moderate for juveniles and adults in the fall due to potential use of area for foraging.

Table 3. Continued (3 of 3).

Fish Species	Spawning	Habitat Use			Movement Behaviour	Life Stage Potentially Present in Spillway Area	Likely Presence near the Skins Lake Spillway	Potential Entrainment Hazard
		Spawning	Rearing	Adult				
Sculpin *sp.*	Mid-March to late June	Streams in rocky or littoral zones in lakes	Forage over the substrate in deep water, may school along steep, rocky shoreline	Associated with cover during the day, forage in the open at night in deep water or littoral habitat	Limited movements expected. May move into streams to spawn. No downstream movement propensity.	None	Spawning occurs primarily in streams; thus, eggs and larvae (or adults in spring) are not expected near the spillway area. Juvenile and adult movements are limited. Presence near the spillway is likely limited.	Low for all life stages present and seasons.
Rainbow Trout[1]	Mid-April to Late June	Primarily in streams and lake outlets. Rarely in littoral zones of lakes	Streams and littoral zones of lakes	Streams and littoral or limnetic zones of lakes	Spring movement for spawning, no schooling, opportunistic feeding, and show a positive rheotactic (flow) response. No downstream movement propensity.	Juvenile, Adult	Spawning in the area is unlikely, but there is potential for rearing and feeding in the summer and fall. Larvae are not at risk as they are not in the water column. Adults may move into the spillway area during spawning migrations in the spring. May also use the area during the winter months, although movements are expected to be limited.	Low for all life stages present in most seasons except moderate for adults in the spring during spawning migrations, high for adults in the summer due to high discharge from spillway, and moderate for adults and juveniles in the fall due to potential use of the area for foraging.
White Sucker	Mid-May to mid-June	Streams and littoral zones of lakes over gravel substrate	Shallow warm water in the summer	littoral zone and benthic foragers	Seasonal migration for spawning. No downstream movement propensity.	Adult	Spawning in the spillway area is unlikely, but there is potential for rearing of older individuals in the spillway area in the summer and fall. Spawning movements in the spring may bring fish to pass in the spillway area. They may use the area during the winter months, although movements are expected to be limited.	Low for all life stages present in most seasons except moderate for adults in the summer and fall due to potential use of the area for foraging and due to high discharge from the spillway in the summer, and in the spring during spawning migrations.

[1]Reference information for all species was taken from McPhail (2007), except for Northern Pikeminnow that included information from Beamesderfer (1992) and Rainbow Trout that included information from Mellina *et al*. (2005) and Winsby *et al.* (1998).

Table 4. Species–life stage hazard screening for the Skins Lake Spillway.

Season	Reservoir Water Level vs Discharge[1]	Life Stage	Fish Species[2,3]											
			Brassy Minnow	Bridgelip Sucker	Burbot	Kokanee	Lake Chub	Largescale Sucker	Longnose Sucker	Whitefish sp.	Northern Pikeminnow	Sculpin *sp.*	Rainbow Trout	White Sucker
Spring	Minimum water level with a moderate discharge	Larvae	Low	Low	Low	n/a	Low	Low	n/a	Low	n/a	n/a	n/a	n/a
		Fry	Low	Low	Low	Low	Low	Low	n/a	Low	Low	n/a	n/a	n/a
		Juvenile	Low	Low	Low	Moderate	Low	Low	Low	Low	Low	Low	Low	Low
		Adult	Low	Low	Low	Moderate	Low	Low	Moderate	Low	Low	n/a	Moderate	Low
Summer	High water level with a high discharge	Larvae	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Fry	Low	Low	Moderate	Low	Low	Low	n/a	Low	Low	n/a	n/a	n/a
		Juvenile	Low	Low	Moderate	High	Low	Low	Low	Low	High	Low	Low	Low
		Adult	Low	Low	Moderate	High	Low	Low	Low	Moderate	High	Low	High	Moderate
Fall	High water level with a low discharge	Larvae	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Fry	n/a	n/a	n/a	Moderate	Low	n/a	n/a	Low	n/a	n/a	n/a	n/a
		Juvenile	Low	Low	Low	Moderate	Low	Low	Low	Low	Moderate	Low	Moderate	Low
		Adult	Low	Low	Low	High	Low	Low	Low	Moderate	Moderate	Low	Moderate	Moderate
Winter	Moderate water level with a low discharge	Larvae	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Fry	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Juvenile	Low	Low	Low	Moderate	Low	Low	Low	Low	Low	Low	Low	Low
		Adult	Low	Low	Moderate	Moderate	Low	Low	Low	Low	Low	Low	Low	Low

Green=Low risk, Yellow=Moderate risk, Red=High risk

[1]Entrainment risk is also based on a combination of reservoir water level and discharge at the Skins Lake Spillway.

[2]n/a=non applicable because the life stage is not expected to be present in the spillway area.

[3]Apart from salmonids and Lake Chub (which is a late spawner), fish species are considered juveniles by the fall.

3.1.1.3 Conclusion for Entrainment Assessment

In conclusion, 13 fish species have been identified as potentially using the Nechako Reservoir. In the absence of evidence to the contrary, we assumed that all of these fish species could potentially be present in the reservoir and subject to entrainment. However, to conduct the entrainment risk assessment following the BC Hydro guidelines (BC Hydro 2006), only the species most likely to be entrained (i.e., with at least one life stage per season rated at high hazard for entrainment) were retained for the remaining steps of the assessment (i.e., Kokanee, Northern Pikeminnow, and Rainbow Trout; Table 4). These species are particularly relevant because they are also some of the most abundant species captured in fish studies in Ootsa Lake (Section 3.2.1).

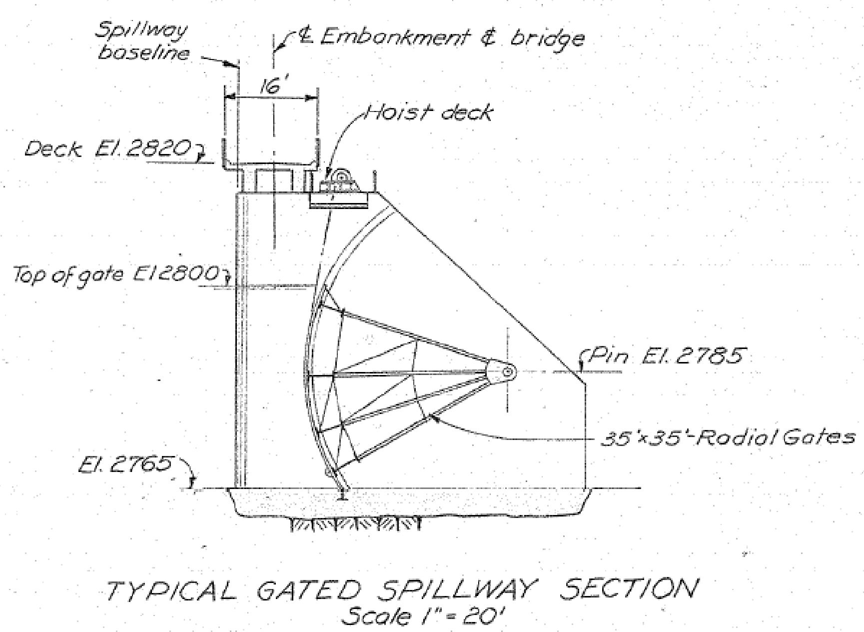
3.1.2 Physical Hazard Screening

The next step in identifying the likelihood of entrainment consisted in determining whether the type, structure and operational characteristics of the Skins Lake Spillway poses an entrainment hazard. The predisposition of fish to be entrained through a spillway is dependent on the physical characteristics of the spillway (type, size, and location), the behavioural and physiological characteristics of the relevant fish species and life-stage (e.g., reaction to flow, swimming ability), and the operational characteristics (i.e., gate operation). The following sub-sections provides an assessment of these factors.

3.1.2.1 Physical Characteristics of the Spillway

The Skins Lake Spillway is composed of two bays with radial gates measuring10.7 m by 10.7 m each (Mercier, pers. comm. 2021, KCB 2020) that can be controlled by RTA. The gates are perpendicular to the reservoir water column and open from the bottom, conveying water at depth to the surface of the spillway. A cross section of the spillway showing one of the radial gates is shown in Figure 3. Spillway discharge increases as the gates open, as does entrainment hazard. The hazard to benthic species (e.g., Burbot) is ever present because the gates open from the bottom, but the hazard increases for midwater and surface-oriented species (e.g., Rainbow Trout) as the gate opens, drawing water from further up the water column.

Figure 3. **A cross-section of the Skins Lake Spillway showing one of the radial gates (Mercier, pers. comm. 2021).**



3.1.2.2 Behavioural and Physiological Characteristics of the Fish

The propensity of the focal species to be entrained is primarily based on their conspecific behavior (e.g., schooling behavior), propensity to be attracted to and use habitat near the spillway, their use of the water column, and their migratory behavior, as well as their ability to swim away once in the current to avoid entrainment (discussed in the next sub-sections).

Conspecific Behaviour

Conspecific behaviour such as schooling will increase entrainment hazard. Of the focal species, only Kokanee are expected to school at both the juvenile and adult life stages, increasing their likelihood for entrainment. This entrainment risk was observed by Triton (1992) for Kokanee in Revelstoke Reservoir.

Attraction to Spillway

Attraction to and use of the spillway area is unlikely considering the size of the reservoir and the large amount of available habitat elsewhere (with more suitable habitats such as stream outlets). However, Kokanee may be at greater risk of being attracted to the spillway as they have been observed congregating near hydroelectric intakes in winter due to the attraction to flow and ice-free zones

(Martins *et al.* 2014). While Rainbow Trout are not abundant in the nearshore area of the Nechako Reservoir (Winsby *et al.* 1998), they are attracted to current and accordingly may orient to the spillway flows.

Use of the Water Column

Position in the water column will affect entrainment likelihood, because the Skins Lake Spillway opens from the bottom; thus, current velocity and the likelihood of entraining fish will be higher for benthic fish species that use the lower portion of the water column. Thus, hypolimnetic infrastructure entrances are expected to increase entrainment exposure for species like Northern Pikeminnow (McPhail 2007). Fish species that utilize more pelagic habitat like Kokanee would be more likely to be entrained only if the gates at the spillway are opened more fully and draw water from higher in the water column (see Section 3.1.2.1).

Migratory Behaviour

Migratory Behaviour will increase the entrainment likelihood for Kokanee and Rainbow Trout. These species are typically migratory within lakes/reservoirs and connecting river systems, migrating for feeding and spawning (McPhail 2007). Although their adult migratory orientation will be upstream into reservoir tributaries, their migrations will increase the likelihood of encountering the spillway. Kokanee are the most susceptible to entrainment due to downstream movements from natal areas as juveniles (e.g., Stober *et al.* 1983, Skaar *et al.* 1996) and entrainment studies have shown large numbers of Kokanee entrained on an annual basis at some hydroelectric facilities (e.g., Triton 1992)[1]. Movement behaviours of juvenile Kokanee in the Elsie Lake Reservoir led to a medium to high entrainment risk rating for juvenile Kokanee in a BC Hydro entrainment study (BC Hydro 2007). Also, entrainment studies at Libby Dam in Montana showed that migratory species such as Mountain Whitefish, Rainbow Trout, Burbot, Largescale Sucker, Longnose Sucker, and Northern Pikeminnow were entrained more often than nonmigratory fish (Skaar *et al.* 1996).

Swimming Ability

Once fish are within the current in front of the Skins Lake Spillway entrance, their likelihood of entrainment will depend on their swimming capabilities, which vary among fish species and life stages. Several studies have shown that the swimming ability of fish is positively correlated with their size and that smaller fish (<100 mm) are unlikely to escape entrainment within hydroelectric infrastructures (e.g., Bainbridge 1958). However, if adult fish, which have a higher swimming capability than other

[1] Juvenile Kokanee can revert to an anadromous life history (Foerster 1947, Fulton and Pearson 1981, Kaeriyama *et al.* 1992, Godbout *et al.* 2011), thus some proportion of juvenile Kokanee may choose to move downstream over the structures to try and migrate to the ocean. In the Alouette Reservoir, flows are released to allow Kokanee to migrate downstream to re-introduce anadromy to the population (Baxter and Bocking 2006, BC Hydro 2009).

life stages, are unable to escape the currents, then all fish of these species are expected to be entrained. Investigation of juvenile swimming speeds was thus only warranted herein if adults could escape the Skins Lake Spillway current.

The swimming capabilities of Kokanee, Rainbow Trout, and Northern Pikeminnow adults are presented in Table 5. The burst values are the swimming speeds that can be sustained for a period of 20 to 60 seconds. Generally, burst speed may only be encountered to avoid a predator, capture prey, or avoid entrainment in intakes (Katapodis and Gervais 2016). It should be noted that values in this table are based on laboratory experiments and that swimming speed is proportional to the length of a fish with larger fish generally exhibiting faster swimming capabilities.

Based on the available literature, Kokanee have the lowest range of burst speed and are expected to be the most susceptible of the three fish species to entrainment within the Skins Lake Spillway, while Rainbow Trout adults have the highest burst speed and are expected to be the least susceptible to entrainment (Table 5). These findings were compared to expected velocities at the Spins Lake Spillway gates (see next section) to determine the ability for fish to escape entrainment.

Table 5. Adult fish swimming speeds of species that may be susceptible to entrainment at the Skins Lake Spillway.

Fish Species	Life Stage	Burst Speed (m/s)	Average Fork Length (m)	Average Prolonged Swimming Speed (m/s)	References
Kokanee	Adult	0.8 - 1.0	0.58	n/a	Katapodis 1991, Lee *et al.* 2003
Rainbow Trout	Adult	1.8 - 4.3	0.38	0.63	Jones et al. 1974, Katapodis 1991, Jain *et al.* 1997, Burgetz *et al.* 1999
Northern Pikeminnow	Adult	n/a	0.31	1.07	Mesa and Olson 1993, Kolok and Farrell 1994

n/a = not available in literature

3.1.2.3 Operational Characteristics of the Spillway

The flow velocities at the Skins Lake Spillway gates, as well as the reservoir discharge proportion, which is a measure of the proportion of the reservoir volume that is entrained (as per BC Hydro methodology; BC Hydro 2006), were used as general indicators of the physical potential for fish entrainment and are discussed in the following sub-sections.

Flow Velocities

KCB (2020) modelled the current velocity approaching the Skins Lake Spillway with both gates fully open to simulate the probable maximum flood of 2030 m^3/s at a reservoir level of 856.3 m. The modelling predicted that velocity was 1 m/s at a distance of 100 m upstream of the spillway gates. Although not indicative of normal operating conditions, this model illustrates the extreme upper bound of velocities at the entrance to the spillway. Under normal operating conditions when the gates are only partially opened the spillway discharges an average of 113.3 m^3/s (Mercier, pers. comm. 2021) and velocities will be lower.

Long-term Skins Lake Spillway gate discharge data over a period of 12 years (between 2010 and 2021) was provided by RT and analysed (Mercier, pers. comm. 2021). Of note, the spillway discharge is not measured directly, but derived from the reservoir level and the gate opening. During that period, the 10^{th} percentile, median and 90^{th} percentile velocities varied little by month, suggesting that the flow at the gates remains relatively constant (Table 1). Overall, monthly velocity at the gates generally varied between 7.8 m/s (10^{th} percentile) and 11.4 m/s (90^{th} percentile; Table 1).

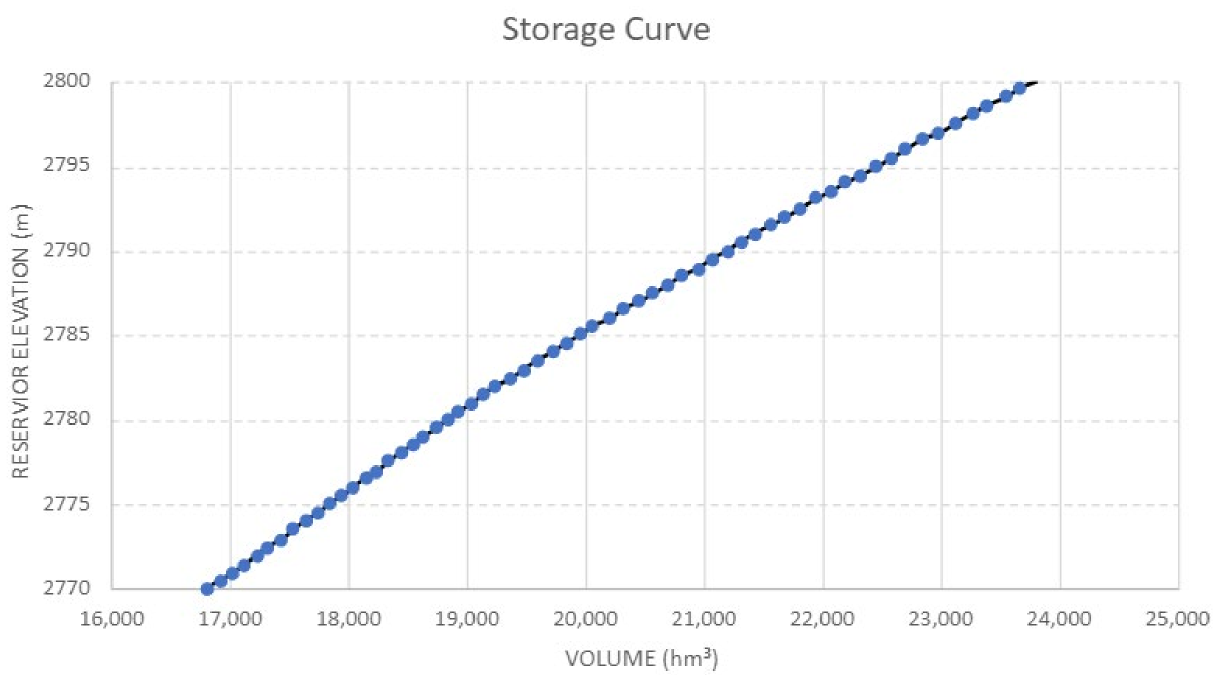
Based on this evidence, velocities directly in front of the spillway can greatly exceed the swimming speeds of all the retained fish species and life stages during high flow discharges (Table 5). However, it is expected that the velocity field will diminish greatly over a short distance from the spillway under normal operating conditions, as has been shown at other facilities. For example, at the Mica Dam in BC, modeling of current in the forebay of the dam showed that beyond 15 m, the velocity profile becomes uniform and reduced, minimizing the potential for fish entrainment. Another studied at this location marked Bull Trout and showed that they were holding steadily at only 23 m from the intake where flows were <0.2 m/s (Martins *et al.* 2014). Thus, under normal operating conditions the entrainment risk zone is relatively small representing only the area immediately adjacent to the intakes (Langford *et al.* 2020).

Discharge Proportion

The proportion of the reservoir discharged per day can act as an indicator of the propensity of fish to be drawn towards intakes and be entrained (BC Hydro 2006). The total proportion of the reservoir discharged over a period of time (e.g., event) may be more significant than the proportion discharged each day (BC Hydro 2006). However, as the volume discharged through the Skins Lake Spillway is relatively constant for each season (Table 1), the proportion per day was used to assess the hazard rating.

The reservoir storage curve for elevations between 2,770 feet (844 m) and 2,800 feet (853 m) was calculated and presented in RTA (2013) and is provided below (Figure 4). This reservoir storage curve is still accurate today (Mercier, pers. comm. 2021) and shows that the reservoir volume usually varies between ~16,900,000,000 m^3 and ~23,900,000,000 m^3. The daily volume that are spilled out of the Skins Lake Spillway by season based on the average discharge are 3,114,298 m^3 (winter, November 1 to February 28), 9,304,681 m^3 (spring, March 1 to May 15), 15,888,708 m^3 (summer, May 15 to August 30), and 2,891,419 m^3 (fall, September 1 to October 31). These values represent between 0.01% to 0.09% daily of the minimum and maximum reservoir volumes and would lead to a low discharge proportion rating as less than 2% of the total reservoir volume is discharged per day (as proposed by the BC Hydro methodology, i.e., Percent total reservoir volume per day: <2% = low, 2%-10%= moderate, >10% =high; BC Hydro 2006).

Figure 4. Elevation versus storage volume relationship for the Nechako Reservoir (modified from RTA 2013).



3.1.2.4 Conclusion for Entrainment Assessment

The velocities identified in Section 3.1.2.3 greatly exceed the swimming speeds of all the retained fish species and life stages (Table 5). However, the velocities gradually increase as one approaches the spillway, which is expected to lower the likelihood of entrainment by providing fish with a graduated, accelerating, velocity field and vertical and horizontal velocity gradients that will provide hydraulic cues of the approaching spillway, and thus an opportunity for some of the fish to avoid the spillway gates, by swimming away. In addition, at least one gate is open throughout the year and provides at least partial flow throughout the year; thus, fish would experience a sudden and notable increase in flow at only one gate for only part of the year. The potential for entrainment for these species is also reduced by the low proportion of the reservoir waters that are being entrained through the Skins Lake Spillway (<2% total reservoir volume per day; Section 3.1.2.3).

However, Kokanee is at risk of entrainment based on its migratory and conspecific behaviour, swimming ability, and potential attraction to the spillway area (Section 3.1.2.2). Northern Pikeminnow may also be at risk because the species is known to use the lower portion of the water column and the spillway gates open from the bottom (the velocities lower in the water column will be higher with the gates partially open; Section 3.1.2.2).

3.1.3 Entrainment Likelihood Rating Conclusion

The Entrainment Likelihood Rating was derived using the combination of results from the Species Life Stage Hazard Screening (Section 3.1.1; Table 4) and the Physical Hazard Screening (Section 3.1.2). The Species Life Stage Hazard Screening was summarized for each fish species and life stage by retaining the most conservative rating for each life stage and season (i.e., the highest). In turn, the Physical Hazard Screening was determined based on the conclusions of the physical hazard screening provided above (Section 3.1.2.4). The final entrainment rating was then determined based on the BC Hydro methodology provided in Table 6. In this methodology, the discharge proportion rating has a stronger influence on the entrainment likelihood than the species life stage and physical hazard screenings. This evaluation led to a low Likelihood of Entrainment Rating for Rainbow Trout, and a moderate rating for Northern Pikeminnow and Kokanee; Table 7).

Table 6. Hydraulic entrainment likelihood rating guideline from BC Hydro (2006).

Discharge Proportion Rating	Species-Life History/ Habitat Hazard	Likelihood of Entrainment Rating
High	High or Moderate	High
	Low	Moderate
Moderate	High or Moderate	Moderate
	Low	Low
Low	High or Moderate	Moderate
	Low	Low

Table 7. **Entrainment likelihood rating for the Skins Lake Spillway.**

Fish Species	Discharge Proportion Rating	Species-Life History Hazard	Habitat Hazard	Likelihood of Entrainment Rating
Kokanee	Low	High	Moderate	Moderate
Northern Pikeminnow		High	Moderate	Moderate
Rainbow Trout		High	Low	Low

3.2 Ecological Significance of Fish Entrainment on Fish Community

The second goal of the ORS consisted in determining the potential consequences of fish entrainment on the fish community, which is based on the value and relative abundance of the affected fish species, and the likely proportion of the population that is likely to be affected by entrainment. The following sub-sections provide an overview of the available fish abundance information for the study area (i.e., Ootsa Lake), and the known fish value, which were then used to evaluate the value-abundance rating, the proportion of the population impacted rating and the Ecological Significance Rating.

3.2.1 Relative Fish Abundance

The relative abundance of fish in the study area is based on the results of two studies in Ootsa Lake area, and fish salvage data obtained in the plunge pool of the Skins Lake Spillway, which are detailed below. These data were collected some years ago and are limited; however, they are still expected to provide a reasonable indication of relative abundance by species in the study area.

Firstly, a fish and fish habitat study was conducted in Ootsa Lake as part of submerged timber salvage operation (Map 1; Winsby *et al.* 1998). Fish sampling in three locations in Ootsa Lake during the late summer (August and September 1997) was conducted using gillnets, minnow traps, and electrofishing (Table 8). Sampling was conducted in both inner embayments close to stream mouths and in outer bay sites away from stream mouths. Northern Pikeminnow were the dominate species captured (n=900; Table 8), followed by Rainbow Trout (n=76), and Largescale Sucker (n=73). All other species were captured in marginal abundance, suggesting that the abundance of these species is low in Ootsa Lake (Table 8).

Table 8. **Total capture and percent capture for fish species captured in Ootsa Lake in August/September 1997 (Winsby *et al.* 1998).**

Fish Species	Andrews Bay		Wells Creek Bay		Whiting Creek Bay		Total # Fish	Total Proportion (%)
	# Fish	Proportion (%)	# Fish	Proportion (%)	# Fish	Proportion (%)		
Burbot	0	0	0	0	1	5	1	0.1
Kokanee	13	2	9	3	9	8	31	2.7
Lake Chub	0	0	0	0	3	3	3	0.3
Largescale Sucker	52	8	21	6	0	0	73	6.4
Longnose Sucker	17	2	8	2	2	2	27	2.4
Mountain Whitefish	7	1	6	2	19	18	32	2.8
Northern Pikeminnow	561	82	284	80	55	51	900	78.5
Prickly Sculpin	0	0	3	1	0	0	3	0.3
Rainbow Trout	33	5	25	7	18	17	76	6.6
Total							**1146**	**100**

Secondly, fish sampling was conducted in Ootsa Lake in summer and fall (September and November 1997, July through October 1998) in the general area near the Skins Lake Spillway (within 15 km) as part of another timber salvage study (Brooks 2000). Sampling was conducted with gillnets and live traps in areas 100 to 200 m from shore in water 8 to 15 m deep. Rainbow Trout (n=101, 11% of the net catches), Kokanee (n=298, 31% of the net catches), and Northern Pikeminnow (n=548, 57% of net catches) were the most abundance species captured (Table 9). Species caught during surface net sampling also included Longnose Sucker (n=12), Largescale Sucker (n=2), and Whitefish *sp.* (n=1), which represented one percent or less of the total catch, while a few individuals were caught during bottom trap sampling (Burbot =2, Sculpin =2), which also represented less than one percent of the total catch (Table 9).

Table 9. Total capture and percent capture for fish species captured in Ootsa Lake between September 4 and November 2, 1997, and July 9 and October 22, 1998 (Brooks 2000).

Fish Species	# of Fish	Proportion (%)
Burbot	2	0.2
Kokanee	298	30.8
Largescale Sucker	2	0.2
Longnose Sucker	12	1.2
Northern Pikeminnow	548	56.7
Rainbow Trout	101	10.5
Sculpin *sp.*	2	0.2
Whitefish *sp.*	1	0.1
Total	**966**	**100**

Finally, fish salvages were conducted in 2011, 2018, and 2019 within the plunge pool of the Skins Lake Spillway to conduct works/maintenance on this infrastructure. Kokanee, sculpin *sp.* and Rainbow Trout were the most abundant fish (juveniles and adults) found on these occasions and represented 57% (n=1747), 12% (n=376) and 18% (n=572) of the total captures, respectively (Table 10). It is unclear if these fish were entrained over the spillway from the Nechako Reservoir or if they came from downstream. However, it appears clear that at least some Kokanee came from downstream. For example, most adults (all greater than 150 mm) found in October 2018 were concurrent with the upstream spawning migration period for Kokanee at a time when the volume of flow entrained into the spillway was lower (average of 94 m^3/s) than August (173 m^3/s; Table 1).

Table 10. Fish salvage data for the Skins Lake Spillway plunge pool in 2011, 2018, and 2019 (Avison 2018, 2019, Tolton 2011).

Date	Rationale for Fish Salvage	Sampling Method	Fish Species	Number of individuals	Size Range (mm)	Life Stage
August 2011	Relocated isolated fish from several small pools of water along the Skins Lake Spillway	Minnow Trap x4	Burbot	1	540	Adult
			Rainbow Trout	1	n/a	Juvenile
			Sculpin sp.	145	15 to 50	Juvenile
			Whitefish sp.	8	30 to 90	Juvenile
Total				**155**		
October 2018	Fish salvage directly downstream of the Skins Lake Spillway within the plunge pool for inspection and repairs required in the plunge pool and spillway apron	Seine x5	Burbot	13	50 to 780	Juvenile, adult
			Kokanee	1622	150 to 200	Adult
			Mountain Whitefish	77	90 to 360	Juvenile, adult
			Rainbow Trout	110	150 to 500	Adult
Total				**1822**		
August 2019	Routine Maintenance and Repairs required at the Skins Lake Spillway. Spillway plunge pool drained and fish salvaged.	Seine x15, dip net, electrofishing, minnow trap x1	Brassy Minnow	3	60 to 70	Adult
			Burbot	46	30 to 780	Juvenile, adult
			Kokanee	125	60 to 250	Juvenile, adult
			Largescale Sucker	25	250 to 500	Adult
			Longnose Sucker	18	90 to 450	Juvenile, adult
			Mountain Whitefish	192	50 to 400	Juvenile, adult
			Northern Pikeminnow	5	250 to 400	Adult
			Rainbow Trout	265	150 to 570	Adult
			Prickly Sculpin	427	30 to 120	Adult
Total				**1106**		

3.2.2 Fish Value

The value of species to recreational and aboriginal (Indigenous) fisheries was considered in the assessment. Sportfishing is an important activity in the Nechako region (Ableson and Slaney 1990). Furthermore, Indigenous Groups, including the Cheslatta Carrier Nation, rely on fisheries resources in the reservoir and broader watershed. In particular, Burbot, Kokanee, Mountain Whitefish, and Rainbow Trout are important in Aboriginal (Indigenous) and recreational fisheries in the Nechako Reservoir (Envirocon 1989).

In recent years, Tahtsa locals have expressed concern that there are fewer Kokanee and Rainbow Trout in Tahtsa Lake, but also the reservoir in general (Kurtz 2021). However, none of the retained fish species have status of concern in the province (Table 1), nor are subject to commercial fishing.

3.2.3 Value-Abundance Rating

A Value-Abundance rating was determined for each relevant fish species based on their value abundance, and conservation status, as per the BC Hydro methodology (BC Hydro 2006). Based on the ratings definitions provided in the BC Hydro methodology (Table 11), Kokanee and Rainbow Trout fall into the second species category (Native species; aboriginal fishery, commercial fishery or Sport fish fishery) while Northern Pikeminnow fall into the third species category (Native species; non-sport fish). Subsequently, the relative abundance was highest for Northern Pikeminnow and Kokanee while Rainbow Trout are rare but of high value to Indigenous Groups (Section 3.2.1). Thus, all three species were given a high rating (Table 12).

Table 11. Value-Abundance Categories, and ratings methodology, as per BC Hydro (2006).

Species Category	Abundance	Value
Endangered, threatened, or species of special concern	Listed species in federal or provincial registry at any level, including threatened populations.	High
Native species; Aboriginal Fishery, Commercial Fishery or Sport fish species	High to moderate use/abundance. Or low abundance and considered moderate to high value.	High
	Low use/ abundance.	Moderate
Native species; non-sport fish, or aboriginal fishery of low traditional use and value, or commercial fishery of low to	High abundance or deemed an important forage fish species for other fish.	High
	Moderate abundance or deemed a moderately important forage fish species for other fish.	Moderate
	Low abundance or not known to be significant forage species for other fish.	Low
Exotic and Introduced species	Non-native species (anthropocentrically introduced) species considered very highly by sport fishermen, commercial fishery, or by regulatory agencies.	High
	Introduced sport or commercial fish of high to moderate social importance.	Moderate
	Non-native exotic that is either a nuisance species or has moderate or negligible social, ecological or economic value.	Low

Table 12. Value-Abundance Rating for the Nechako Reservoir fish species.

Fish Species	Value-Abundance Rating	Rating Rationale
Kokanee	High	Native species part of aboriginal and sport fishery that is in moderate abundance
Northern Pikeminnow	High	Native non-sport fish species in high abundance
Rainbow Trout	High	Native species part of aboriginal and sport fishery that is in low abundance but considered moderate to high importance value

3.2.4 Proportion of the Population Impacted Rating

The rating for the proportion of the population impacted is relevant to the assessment of the overall ecological effect within the reservoir, and was rated by assessing the following factors:

- *Likelihood of entrainment* - rated as moderate for Kokanee and Northern Pikeminnow and low for Rainbow Trout due to fish habitat use, swimming abilities and behaviour (Section 3.1.3).
- *Proportion of the population expected to be entrained* - low discharge proportion rating as less than 2% of the total reservoir volume is discharged per day (Section 3.1.2.3).

The hazard rating for this component was estimated using the BC Hydro guidelines (BC Hydro 2006), where the rating was defined as:

- *Low* – Effect not measurable with standard assessment methods, possibly <5% of the total species population in the reservoir.
- *Moderate* – Effect potentially detectable with standard methods but not necessarily significant, possibly 5% to 25% total species population in the reservoir.
- *High* – Effect measurable and "*significant*" portion of annual mortality rate, possibly >25% total species population in the reservoir.

Using this information, we rated the entrainment risk for all species as low at the Skins Lake Spillway given the large size and complex habitat withing the Nechako Reservoir that can be utilized by the different fish species (Table 13). Although it is likely that some fish are being entrained through the spillway, it is unlikely that more than 5% of the population of any species is being entrained. Rationale for each species is further detailed below.

- *Kokanee* – This species has a moderate risk of entrainment through the Skins Lake Spillway (Table 7) but is one of the most abundant species captured in the Ootsa Lake area of the Nechako Reservoir despite decades of spillway operations (based on available data; Section 3.2.1). It is unknown if Kokanee are using habitat directly adjacent to the Skins Lake Spillway entrance; however, they would need to be directly adjacent to the spillway to experience water velocities that could cause entrainment. While numerous Kokanee were found in the plunge of the spillway during fish salvages (1,747; Table 10), it is unclear if these fish were mostly spawning adults that migrated upstream from Skins or Chesletta Lake or fish that were entrained in the spillway. Overall, Kokanee are a pelagic species that are expected to be at low risk of entrainment through the Skins Lake Spillway gates that open from the bottom and are only 28% open throughout the year. Considering this habitat use and the low volume of flow entrained, it is unlikely that more than 5% of the Kokanee population in the Nechako Reservoir are being entrained through the spillway.

- *Northern Pikeminnow* - This species is at moderate risk of entrainment through the Skins Lake Spillway (Table 7) but was captured in high abundance in the Ootsa Lake portion of the Nechako Reservoir despite decades of spillway operations (based on available data; Section 3.2.1). Furthermore, adults utilize deep water habitats that may experience higher velocities through the bottom opening of the spillway gates, increasing their risk for entrainment. However, considering the low volume of flow entrained (<2%) and limited migratory behavior of this species (Section 3.1.2.2), it is unlikely that more than 5% of the Northern Pikeminnow population in the Nechako Reservoir are being entrained through the Skin Lake Spillway.
- *Rainbow Trout* – This species is at low risk of entrainment through the Skins Lake Spillway (Table 7) and is in low abundance in Ootsa Lake (based on available data; Section 3.2.1). Furthermore, Rainbow Trout are mainly distributed through the limnetic zone and adults have the swimming capability to escape entrainment unless they move directly adjacent to the gate opening, which is located at the bottom of the reservoir. In consideration of low volume of flow entrained (<2%), it is unlikely that more than 5% of the Rainbow Trout population in the Nechako Reservoir are entrained.

Table 13. Proportion of population impacted rating for the Skins Lake Spillway.

Fish Species	Proportion of Population Impacted Rating	Rating Rationale
Kokanee	Low	Moderate risk of entrainment and abundant in the reservoir. However, juveniles and adults are able to escape velocities up to a certain distance from the spillway (>50 m). While large numbers of Kokanee (1,747) were found in the spillway plunge pool, it is unclear if they swam up into the spillway or were entrained. Species remains abundant in Ootsa Lake area of the Nechako Reservoir, despite decades of spillway operation. May use the pelagic habitat near the spillway but low likelihood of being entrained through the bottom opening gates. Entrainment may be occurring at low levels but unlikely to cause a population decline on its own.
Northern Pikeminnow	Low	Moderate risk of entrainment and high abundance in the reservoir. Also, adults use deeper waters that may experience higher velocities through the bottom opening of the gates. However, despite three fish salvages only 5 individuals were captured out of 1,106 fish, representing <1% of the catch. Entrainment not likely to be resulting in a population decline given the high abundances captured despite decades of spillway operations.
Rainbow Trout	Low	Moderate risk of entrainment but low abundance in the reservoir. Unlikely to be subject to high velocities at the spillway gate opening at the bottom of the reservoir since the species is usually found higher in the water column. Further, it has the highest swimming speed of the three species to escape entrainment. This, entrainment not likely to be resulting in a notable population decline.

3.2.5 Ecological Significance Rating

The Ecological Significance Rating combines the Value-Abundance Rating with the Proportion of the Population Impacted Rating and is presented in Table 15. Based on the ratings definitions provided in the BC Hydro methodology (Table 14), Kokanee and Rainbow Trout fall into category 2 of fish (Native species: sport fish or aboriginal value), whereas Northern Pikeminnow fall into Category 3 (Native species, non-sport fish). All three species have a high value abundance rating (Table 12), and thus their rating was determined based on their proportion of population impacted rating, which is low for all three species (Table 13). Based on this methodology, the ecological significance rating was determined to be moderate for Kokanee and Rainbow Trout, and low for Northern Pikeminnow (Table 15).

Table 14. Ecological Significance Rating as per the BC Hydro Methodology (BC Hydro 2006).

Category	Value Abundance Rating	Proportion of the Population Rating	Ecological Significance Rating
1 "Listed"	High	Any	High
2 Native Species: Sport Fish or Significan Aboriginal Traditional Use or Value	Low	Low	Low
		Moderate	Moderate
		High	High
	Moderate	Low or Moderate	Moderate
		High	High
	High	Low	Moderate
		Moderate or High	High
3 Native Species: Non-Sport Fish or Moderate Aboriginal Traditional Use or Value	Low	Low or Moderate	Low
		High	Moderate
	Moderate	Low	Low
		Moderate or High	Moderate
	High	Low	Low
		Moderate	Moderate
		High	High
4 "Exotics" and Introduced Species: or Low Aborignial Fisheries Use or Value	Low	Any	Low
	Moderate	Low or Moderate	Low
		High	Moderate
	High	Low	Low
		Moderate	Moderate
		High	High

Table 15. Ecological significant rating for the Skins Lake Spillway.

Fish Species	Value-Abundance Rating	Proportion of Population Impacted	Ecological Significance Rating
Kokanee	High	Low	Moderate
Northern Pikeminnow	High	Low	Low
Rainbow Trout	High	Low	Moderate

3.3 Consequences of Entrainment on Fish

The third goal of the ORS is to determine the potential consequences of fish entrainment for those fish entrained in the spillway. This consequence was assessed using available literature, Ecofish experience with other hydroelectric projects, and professional judgement.

Known mechanisms of injury and/or mortality for fish passing through hydroelectric projects consist of (Čada 2001):

- Strike, where fish collide with structures such as runner blades, stay vanes, wicket gates, and draft tube piers, which can cause blunt trauma;
- Supersaturation of dissolved oxygen, which can cause gas bubble disease;
- Rapid, large pressure changes, which can cause barotrauma;
- Hydraulic shear, which can injure fish;
- Turbulence, which can cause a loss of orientation in fish and negatively affect their survival (e.g., leading to further injury or predation);
- Grinding, where fish are squeezed through narrow gaps between fixed and moving structures; and
- Cavitation can occur during turbine passage when bubbles collapse onto and injure fish (note however, that turbines are not employed at Skins Lake).

Considering the water velocity and physical characteristics of the spillway and plunge pool, fish passing through the Skins Lake spillway may experience: 1) blunt trauma from striking the bottom of the plunge pool; 2) gas bubble disease from exposed to supersaturated water below the spillway; and

3) internal damage from barotrauma when fish are entrained. These potential effects are discussed in the following sub-sections.

3.3.1 Blunt Trauma

Modeling of the hydraulic conditions within the Skin Lake Spillway chute and plunge pool was conducted under different spillway discharges, including the extreme discharge of 1,899 m^3/s (KCB 2020). The results of this work show that with both gates fully open, the flow through the spillway chute is expected to be concentrated towards the centreline of the spillway where the velocities are expected to be highest (up to 20 m/s) near the entrance to the plunge pool. Fish entering the spillway at these flows could be subjected to blunt force trauma upon contact with the concrete bottom of the plunge pool (Figure 5). However, this occurrence is expected to be rare as the modelled flows were higher than normal operations (extreme flows) and the plunge pool is up to 13.5 meters deep, which should provide most fish with time to decelerate and swerve away before hitting the bottom.

3.3.2 Gas Bubble Disease

Spillways like dams and natural waterfalls supersaturate water with dissolved gas, which can cause free gas bubbles or emboli to form inside fish blood vessels, creating gas bubble disease and potentially leading to mortality (Weitkamp and Katz 1980). No dissolved gas (Total Gas Pressure; TGP) data are available at the plunge pool; thus, the potential for gas bubble disease and mortality are unknown. However, the plunge pool is deep (up to 13.5 m), and fish can likely avoid the harmful effects of supersaturation by moving into deeper waters. Hydrostatic compensation occurs in deeper waters where additional pressure increases the solubility of dissolved gases sufficiently to compensate for supersaturation (i.e., every additional meter of water can compensate for approximately 10% of saturation; Pleizier *et al.* 2019). Thus, it is expected that TGP is not sufficiently elevated to cause gas bubble disease in the Skins Lake Spillway plunge pool. Of note, the effects of TGP on fish between the spillway and the Nechako River will be assessed separately in the near future and may lead to additional studies that can confirm this conclusion.

3.3.3 Barotrauma

Fish that pass hydro structures either through turbines, deep spills, or other deep pathways can experience rapid decreases in pressure that can result in barotrauma. Barotrauma is a risk for physostomous fishes such as salmonids, whose swim bladders regulate buoyancy by filling with pressurized air at depth. During passage by turbines or though gates or valves, fish rapidly move from high to low pressure environments too quickly for their swim bladders to acclimate to ambient pressure. The expanding gas can form air emboli (in the gills especially), swim bladder rupture, and cause internal hemorrhaging (Stephenson *et al.* 2010), but also affect behaviour, such as decreasing swimming ability, especially for smaller fish (Brown *et al.* 2012). According to Brown *et al.* (2012), the key predictor of mortality rate due to barotrauma is the difference between the pressure state a fish is at when it becomes entrained compared to the minimum pressure it experiences during entrainment. Fish that are entrained at depth experience higher rates of injury and mortality from barotrauma than fish from surface waters because they inflate their swim bladders to maintain buoyancy at depth, creating a body of pressurized air that can expand rapidly when subject to low pressure during turbine passage (Brown *et al.* 2012).

According to long-term reservoir level data (between 2010 and 2021) provided by RT (Mercier, pers. comm. 2021), the elevation of the reservoir varied between 2,789 and 2,800 feet. Based on the design specifications of the Skins Lake Spillway these reservoir levels would represent a water depth of 7.3 m to 10.7 m. As the gates are only opened a small portion from the bottom of the reservoir (average of 0.8 m and 1.0 m for gates 1 and 2; Mercier, pers. comm. 2021), this indicates that the depth water is being entrained from is between 6.3 m and 10.7 m deep. Based on entrainment from a depth of 10.7 m and rapid exposure to the surface, the pressure differential would be ~ 100 kPA and resultant mortality based on equations in Brown *et al.* (2012) would be ~5%. This level of mortality could be experienced by the fish that had acclimated at 10.7 m depth while mortality will be lower for fish entrained at shallower depths. Furthermore, entrained fish will be quickly conveyed into up to 13.5 m of water in the plunge pool, equalizing pressure and avoiding barotrauma. Some fish may be carried to the surface by turbulent flows in the plunge pool; however, the pressure differential at 5 m depth would reduce potential mortality by more than half to 2%. These levels of mortality pose a low hazard for the Kokanee, Rainbow Trout and Northern Pikeminnow populations.

Figure 5. Photo of the plunge pool and Nechako River downstream (JDC 2021).

3.3.4 Fate/Consequence Rating

The Fate/Consequence rating is based on an evaluation of displacement of fish and the risk of mortality when passing through the hydroelectric infrastructure. The generalized Fate/Mortality rating is based on a combination of the impact of displacement and likelihood of mortality (Table 16, BC Hydro 2006). Displacement can be considered of neutral consequence if: (1) fish are passing to an equally suitable habitat, (2) their loss to the upstream population is not detrimental, and (3) their effect on the downstream population is neutral or positive (BC Hydro 2006). In turn, the likelihood of mortality is determined by the consequences assessment described in the previous section (i.e., low for all relevant species and mechanisms of injury/mortality).

In the case of the Skins Lake Spillway, the fate of fish displaced is expected to be neutral because:

- Kokanee, Rainbow Trout and Northern Pikeminnow are passing to an equally suitable habitat – the fish leaving the Nechako Reservoir (a lentic habitat) also had access to several tributaries (lotic habitat). Downstream of the spillway, fish will (enter the Cheslatta), and have access to multiple tributaries (lotic habitats), as well as to Skins, Cheslatta Lakes (lentic habitats, which are located 1.5 km and 23 km downstream of the spillway, respectively)
- Their loss to the upstream population is not detrimental – the loss of low numbers of fish from the Nechako Reservoir is not expected to have detrimental effects on the reservoir population, as shown in Section 3.2.4 (<5%).
- Their effect on the downstream population is neutral or positive – Rainbow Trout, Northern Pikeminnow and Kokanee have been present downstream for several decades (Section 1.1.3). While entrained fish could cause competition for food and habitat, the number of fish entrained is expected to be small for all three species (Section 3.2.4). Thus, the entrainment of low numbers of new individuals is not expected to negatively affect the downstream fish populations.

Based on this assessment, the overall Fate/Consequence Rating is expected to be low for all three species (Table 17).

Table 16. Fate Consequences Rating as per the BC Hydro Methodology (BC Hydro 2006).

Displacement Impact	Individual Mortality	Fate/Consequences Rating
Neutral or Little Impact	Low Rate (0 - 10%)	Low
Moderately Negative	Moderate Rate (10 - 50%)	Moderate
Significantly Negative	High Rate (>50%)	High

Table 17. Fate/consequence rating for the Skins Lake Spillway.

Fish Species	Infrastructure	Fate/Consequence Rating	Rating Rationale
Kokanee		Low	Kokanee would be passing to equally suitable habitats (Skins and Cheslatta Lakes, which are roughly 1.5 and 23 km downstream of the spillway), their loss to the upstream population would not be detrimental because only a small proportion of the population is expected to be displaced (<5%), and their effect on the downstream population is expected to be neutral since this species has been present downstream for decades and is likely only entrained in low numbers.
Rainbow Trout	Two radial gates, 23 m wide by 20 m long concrete spillway chute spillway and deep plunge pool	Low	Rainbow Trout would be passing to equally suitable habitats (tributaries to Cheslatta River, as well as Skins and Cheslatta Lakes, which are roughly 1.5 and 23 km downstream of the spillway), their loss to the upstream population would not be detrimental because only a small proportion of the population is expected to be displaced (<5%), and their effect on the downstream population is expected to be neutral since this species has been present downstream for decades and is likely only entrained in low numbers.
Northern Pikeminnow		Low	Northern Pikeminnow would be passing to equally suitable habitats (tributaries to Cheslatta River, as well as Skins and Cheslatta Lakes, which are roughly 1.5 and 23 km downstream of the spillway), their loss to the upstream population would not be detrimental because only a small proportion of the population is expected to be displaced (<5%), and their effect on the downstream population is expected to be neutral since this species has been present downstream for decades and is likely only entrained in low numbers.

3.4 Frequency of Occurrence of Fish Entrainment

The frequency of occurrence rating estimates how often fish may be subjected to fish entrainment and depends primarily on the planned (or unplanned) operational conditions during sensitive periods (e.g., potential aggregation of fish in front of the intake for spawning) as well as seasonal changes in operation that may alter the potential for entrainment. If entrainment occurs infrequently, the impact on the overall health of the ecosystem and the population may be low, even if the entrainment effects are expected to be moderate. Depending on the number of individuals of a fish species that get entrained, some population level effects may be observed (BC Hydro 2006).

The frequency of fish entrainment events has previously been classified as follows (RTA 2013):

- *Frequently* – Fish entrainment occurs continuously, (i.e., daily or weekly);
- *Occasionally* – Fish entrainment occurs seasonally or annually; and
- *Rarely* – Fish entrainment occurs rarely (i.e., less than annually).

At the Skins Lake Spillway, the operation is continuous with a mean monthly discharge that varies between 39.9 m^3/s in December and 229.8 m^3/s in July (2010-2021, Mercier, pers. comm. 2021) and at least one of the two gates is releasing flow year-round. Accordingly, some low level of entrainment may be occurring year-round, but the bulk of entrainment would occur seasonally, coincident with fish presence at the spillway (Section 3.1.1.2).

3.5 Final Risk Screening Rating

The Final Risk Screening Rating is estimated based on a professional judgement of the combination of:

- Ecological Significance Rating;
- Fate/Consequence Rating;
- Entrainment Likelihood Rating; and
- Frequency of Occurrence Rating.

The combination of these ratings results in a Final Risk Screening for each species according to the BC Hydro Methodology (Table 18, BC Hydro 2006). The Final Risk Screening Rating is low for all three species (Table 19).

Table 18. Final Risk Screening as per the BC Hydro (2006) Methodology.

Ecological Significance Rating	Fate/ Consequence Rating	Likelihood of Entrainment	Frequency of Use	Final Risk Screening Rating
High	High or Moderate	High or Moderate	Frequent or Occasional	High
			Rare	Moderate
		Low	Any	Moderate
	Low	High	Any	Moderate
		Moderate	Frequent or Occasional	Moderate
			Rare	Low
		Low	Any	Low
Moderate	High	High	Frequent or Occasional	High
			Rare	Moderate
		Moderate	Any	Moderate
		Low	Frequent	Moderate
			Occasional or Rare	Low
	Moderate	High	Frequent or Occasional	Moderate
			Rare	Moderate
		Moderate	Frequent or Occasional	Moderate
			Rare	Low
		Low	Any	Low
	Low	Any	Any	Low
Low	High	High	Frequent	Moderate
			Occasional or Rare	Low
		Low or Moderate	Any	Low
	Moderate	High	Frequent	Moderate
		Moderate or Low	Any	Low
	Low	Any	Any	Low

Table 19. Final Risk Screening Rating for the Skins Lake Spillway.

Fish Species	Ecological Significance Rating	Fate/Consequence Rating	Entrainment Likelihood Rating	Frequency of Occurrence Rating	Final Risk Screening Rating
Kokanee	Moderate	Low	Moderate	Occassionally	Low
Northern Pikeminnow	Low	Low	Moderate	Occasionally	Low
Rainbow Trout	Moderate	Low	Low	Occasionally	Low

4 CONCLUSION

A fish entrainment risk assessment methodology developed by BC Hydro (BC Hydro 2006) was used to conduct a desktop entrainment risk (ORS) for the Skins Lake Spillway in the Nechako Reservoir. The results of this assessment led to a final risk rating of low for all three species that were considered most susceptible to entrainment at this location (i.e., Kokanee, Northern Pikeminnow and Rainbow Trout). However, there is uncertainty in this assessment due to a lack of recent information on the fish distribution and relative abundance near the spillway, the habitat conditions near the spillway entrance, and the presence of salvaged fish in plunge pool (e.g., Kokanee) with no clear evidence regarding their origin (i.e., entrained or from downstream).

The results of this assessment will be shared with the WEI Technical Advisory Group for discussions to address Indigenous Groups' concerns with entrainment of fish at the Skins Lake Spillway and to determine next steps. According to the ORS methodology in BC Hydro (2006) an overall risk rating of low does not require any further evaluation; however, additional evaluation of the fish entrainment at the Skins Lake Spillway may be warranted, based on the interest in this issue by stakeholders.

Yours truly,

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Personal Communications

Mercier, A. Water Resources Engineering Analyst, Operational Excellence & Integrated Operations, Rio Tinto. Conference call with Isabelle Girard, Matt Sparling and Jennifer Carter on April 1, 2021 and subsequent emails with Isabelle Girard and Jennifer Carter in April 2021.

Robertson, M. Senior Policy Advisor at Cheslatta Carrier Nation. Several conversations and communications with Jayson Jurtz in 2019-2021.