Coquitlam-Buntzen Water Use Plan

Coquitlam Dam Flow Release Interim Ramping Rate Monitoring

Implementation Year 12

Reference: COQMON-2

Study Period: May 1, 2016 – April 30, 2017

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Executive Summary

This report summarizes rampdown events occurring on Lower Coquitlam River for the water year May 1, 2016 to April 30, 2017. A total of 7 rampdown events were monitored during the annual survey period: six scheduled rampdowns (May 1, June 1, June 8, and June 15, 2016; and January 15 and April 1 2017) and one unscheduled rampdown (November 11-14, 2016). The scheduled flow adjustments on September 1 and November 1, 2016 took place during spill events so no fish salvages were required. In addition to the 2016-2017 water year results, data from rampdown fish salvages in May and June 2017 are also included in this document.

The 2016-2017 water year was the eighth complete year under the Treatment 2 flow regime. Under Treatment 2, rampdowns are more frequent, but of a much smaller scale in terms of total reduction in flow volume. Additionally, they are predictable due to their scheduled operational dates. The removal of the temporary dam safety 149m maximum allowable reservoir operating level in 2008, following commissioning of the new dam, increased reservoir storage but has not lead to a reduction in the frequency of large scale flow releases and subsequent full river rampdown fisheries impact surveys. Under Treatment 2 total rampdowns per year have increased from an average of 2.7 to 8.0 per year and unscheduled rampdowns have increased to an average of 3.0 per year from 2.7.

Areas previously identified as susceptible to de-watering and fish stranding were visually inspected by survey crews during each rampdown event. Stranded fish are captured and relocated to the river mainstem by dip netting, seine netting or gee-type minnow traps. The four scheduled rampdowns stranded a total of 2127 fish, 1854 of which were salvaged alive. The one unscheduled rampdown event produced a total of 84 stranded fish of which 65 were salvaged alive, in addition to approximately 250 stranded Chum redds. In summary the total number of fish stranded for all rampdowns, was 2211 with a mortality rate of 13.2%. The majority of stranded fish (90.6%) observed during fish salvage operations were juvenile Coho salmon.

Modifications to the June rampdown were initiated in 2013 in order to reduce the increasing number of mortalities and stranding observed during this event. This rampdown alone has been responsible for over 70% of all stranding over the past 6 years due to its timing at the height of Coho fry emergence and having the largest decrease in discharge; dropping from $2.9m^3$sec to $1.1m^3$sec (a 64% reduction in flow). The modified rampdown method was successful in reducing mortalities from 24.4% and 36.7% in 2011 and 2012 to 4.7% in 2013 and 2.5% in 2014. However, in 2015 mortalities rose to 10.3% and increased again in 2016 to 13.0%. The 2017 June rampdown fish salvage saw mortality drop to a low of 1.1%.

Acknowledgements

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BC Hydro operations staff for access to the gate house and updates.

Table of Contents

List of Tables

List of Figures

1.0 Introduction and Site Description

The Coquitlam River watershed located in the Greater Vancouver area in southwestern British Columbia is a typical southwest pacific coastal watershed. Natural river flows are dominated by snowmelt during the spring months, with lower flows through dry summer months prior to elevated precipitation driven flows October through March. The Coquitlam Lake Reservoir portion of the watershed is utilized by two facilities. The Coquitlam facility, with origins dating back to 1892, provides a reservoir for domestic water supply by the Greater Vancouver Water District (GVWD) for the Greater Vancouver area. The Lake Buntzen-1 Powerhouse uses the water diverted from Coquitlam Reservoir to Buntzen Lake Reservoir through the 3.9km Buntzen tunnel. BC Hydro's Coquitlam-Buntzen generation project dates to 1903 when there were two Lake Buntzen powerhouses for electricity generation located on the shore of Indian Arm, Burrard Inlet (Figure 1) (BC Hydro 2005).

The Lower Coquitlam River watershed covers an area of approximately 80 km^2 and has its source at the Coquitlam Dam located within the GVWD watershed boundary. The Lower Coquitlam River flows though the municipality of Port Coquitlam before its confluence with the Fraser River. At present the lower watershed is impacted by gravel extraction, urbanization and the variable controlled discharges from the dam.

Controlled flow releases from the Coquitlam Dam have potential impacts on downstream aquatic communities. Fish can be affected by the ramping rate (rate at which flow is released or decreased from the dam outlets) at all life-history stages. Impacts can include stranding of redds, fry, juveniles or adults depending on the time of year. Rampdown monitoring serves to minimize the potential impacts by identifying areas known to be susceptible to stranding during rampdown events.

Investigations into the impact of rampdowns on fish in Lower Coquitlam River have been ongoing since 2001. Field methods have been developed and refined over the past six years with additional opportunistic surveys Rampdown assessments undertaken since 2001 have focused on developing survey methods that will enable BC Hydro to evaluate the performance of the interim ramping rate (Table 2), and its influence on the potential for stranding of mitigating fish stranding in the Coquitlam River. With respect to this, the management questions outlined by the WUP Consultative Committee (CC) and addressed during monitoring in 2003-2005 (BC Hydro CQD WUP TOR 2006) are:

> *a) What is the most appropriate ramping rate protocol that should be developed for the Coquitlam Dam that best reduces fish stranding risk while being operationally feasible?*
>
> *b) What are the ongoing fish stranding risks and/or impacts of the revised ramping rate protocol?*

The result of management question (a) being addressed, was the implementation of the interim ramping rate protocol in 2005. The following hypothesis will be tested over the remainder of the review period to continue to evaluate the performance of the interim ramp rate protocol:

H1: *The LB1 WUP interim ramping rate protocol does not strand fish at index sites in the lower Coquitlam River.*

The ramping rate established under Treatments 1 and 2 has the goal of minimizing the impact of stranding during rampdowns, while maintaining operational flexibility (BC Hydro 2005) (See Table 2). Following completion of the seismic upgrade on Coquitlam Dam in October 2008, a new flow release schedule (Treatment 2) was initiated. Under this new flow regime a series of scheduled rampdowns will occur at pre-determined times throughout the year. These rampdowns amount to small scale reductions (between 3.00m^3/s and 0.60m^3/s) in the total volume of water released from Coquitlam Dam (Table 1), but can represent a sizeable decrease in the total volume of water entering Coquitlam River. For example, rampdowns scheduled for the dates January 15 and June 1 constitute a drop in the total flow release into Coquitlam River of 51% and 62% respectively (Table 1).

The introduction of the Treatment 2 regime is tied to Lower Coquitlam Fish Productivity Index (COQMON-7) as part of the Coquitlam River Water Use Plan (LB1 WUP). It is central to a long-term adaptive management study being conducted in Coquitlam River to compare anadromous fish production under two experimental flow regimes. Fish population monitoring under the first flow regime (Treatment 1) occurred from 2000 until the completion of the Coquitlam Dam seismic upgrade in October 2008. Fish production under Treatment 2 will be monitored for up to 9 years; 2009 was the first complete year of monitoring under Treatment 2.

The low level outlet (LLO) knife-gate installed at Coquitlam Dam in 2008 will maintain the flow reduction at the same rate as the Treatment 1 rampdown schedule (Table 2 for revised gate adjustment schedule). With the seismic upgrade to Coquitlam Dam complete, BC Hydro dam safety constraints no longer stipulate a maximum reservoir elevation of 149m, beyond which spill releases must be initiated to ensure dam integrity. The Normal Maximum Reservoir Operating Level (MROL) depends on the time of year. It is was anticipated that the increased reservoir capacity would reduce the frequency of unscheduled spills from Coquitlam Dam but this has not been the case to date.

Since 2001, stranding risk has been assessed on the Coquitlam River at several locations from the base of the dam to the confluence with Maple Creek (Macnair et. al 2004-2009). The total survey area incorporates approximately 14 river kilometers. Maps of the area in Appendix 3 identify all stranding index sites and discrete stranding locations.

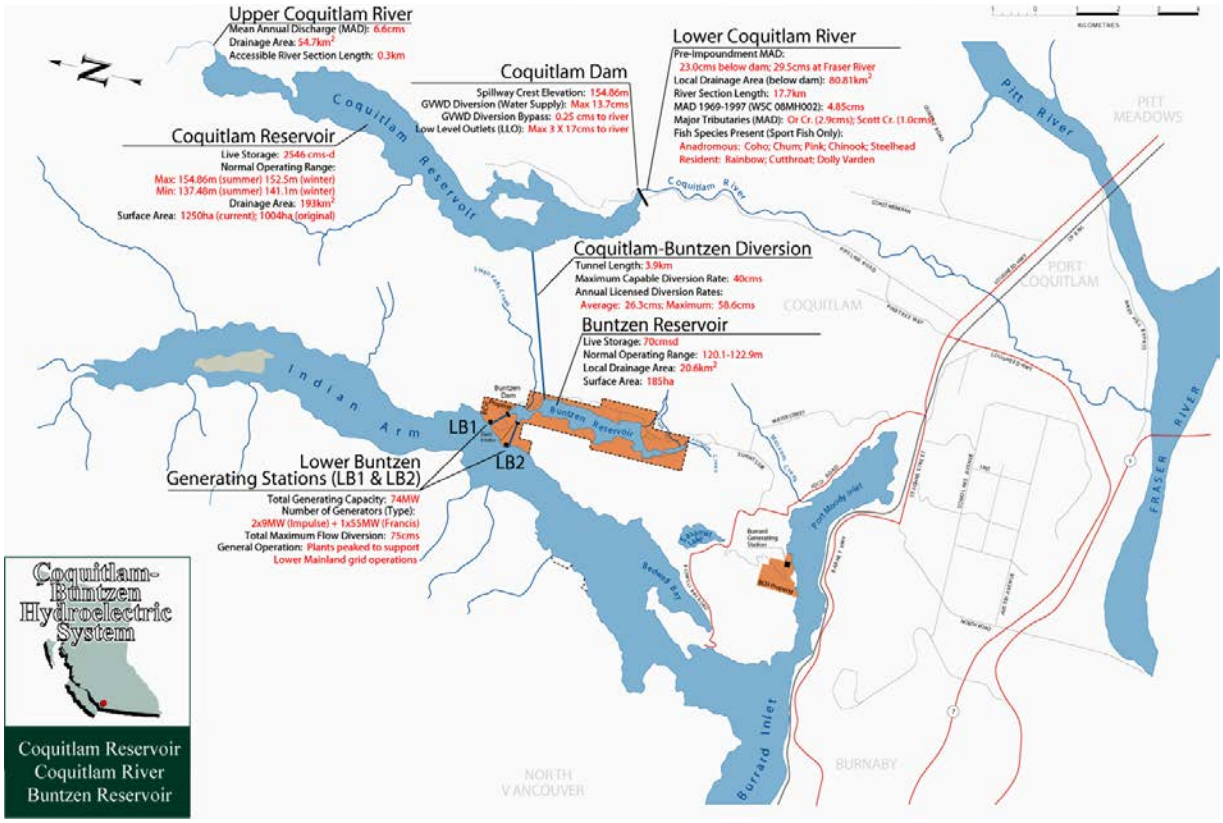

Figure 1 Coquitlam-Buntzen Reservoir, Diversion and Generating System. Map adapted from BC Hydro. Coquitlam-Buntzen Water Use Plan Monitoring Program Terms of Reference Revision 1: December 14, 2006.

Due to the size of the study area, some sections of the river have received little annual investigation. Areas that are not highlighted on the maps in Appendix 3 are generally free of any characteristics that would indicate susceptibility to stranding. All areas not highlighted have been surveyed at least once over the past several years and have been determined by survey crews to have minimal or no stranding risk due to the complete absence of any observed stranding and the stream morphology of the area, therefore, they are not regularly included in any rampdown assessments.

Stranding is identified by three categories:

1. Adult stranding of spawning salmon, which is confined to the active spawning period (Oct.- Jan. depending on species), or other resident adult species.
2. Redd stranding during active spawning and incubation period for pacific salmon, autumn and winter and steelhead in the spring (March-June).
3. Juvenile stranding (fry, parr and smolt), potential risk exists year round.

These categories are used to distinguish stranding by the life stage of salmonids using the Coquitlam River. A single adult female stranded or redd stranded may represent the possible loss of thousands of eggs and the resulting loss of fry, whereas the loss of one

fry among potential millions (Chum Salmon and Pink Salmon for example) would not have the same impact on fish productivity. Redd and adult stranding, however, is much less frequent than stranding of juvenile fish.

Mortalities of adults and juveniles during rampdown events can result from fish being caught in pools or ephemeral channels which dewater during release reductions. This leaves fish isolated in pools that eventually completely drain. In addition, fry are vulnerable to increased predation risk and oxygen depletion when trapped in highly visible, shallow pools (Bradford 1997). Elevated dam releases during the fall or spring may temporarily give access to spawning areas which dewater during subsequent flow reduction. This can impact redds by leaving them stranded, and rendering incubated eggs or alevin unviable.

Table 1 Coquitlam River flow release schedule 2016-17. *Estimated flow is based on monthly flow transects performed to confirm flow target compliance. Table adapted from BC Hydro. COQ-BUN Water Use Plan terms of reference. Revision 1: December, 2016

		Reservoir Diversion Schedule (m^3/sec)					
		Domestic Water		Coquitlam Dam Releases			
				Treatment 1	Treatment 2		
Month	Year	Target	Min	Target	Target	Estimated*	Min
April	2016	12.0	10.8	0.8	3.5	3.77	1.1
May	2016	12.0	11	1.0	2.9	3.21	1.1
June	2016	12.0	10.9	1.4	1.1	1.35	1.1
July	2016	18.0	15.8	1.4	1.2	1.36	1.1
August	2016	23.0	20.2	1.1	2.7	2.86	1.1
September	2016	23.0	20.9	0.8	2.2	2.42	1.1
October	2016	12.0	10.8	0.8	6.1	6.25	3.6
November	2016	12.0	10.8	1.1	4.0	4.04	1.5
December	2016	11.9	10.7	1.1	5.0	5.15	2.5
Jan 1-15	2017	11.9	10.7	1.0	5.9	5.98	3.6
Jan 15-31	2017	11.9	10.7	1.0	2.9	3.21	2.9
March	2017	11.9	10.7	1.0	4.3	4.38	1.1
April	2017	12.0	10.8	0.8	3.5	3.69	1.1

2.0 Methods

During spill reductions, locations susceptible to stranding risk are assessed during daylight hours by crews of between two and four people. Crew size varies depending on the stranding risk associated with a particular rampdown. Due to the short duration of most rampdown events and the large amount of habitat potentially affected, only locations that are most susceptible or have been previously identified as high risk are assessed. Therefore, fish stranding numbers presented in this report represent only what is observed in the index sites, not the entire Coquitlam River area. Areas susceptible to stranding are generally directly adjacent to the river mainstem and have a flat, un-sloped topography containing numerous potholes and depressions where isolated pools can form (Figure 8). Ephemeral side channels that fill during flow releases and drain completely following gate closures are also highly susceptible to stranding (Figure 9). Areas judged to have no stranding risk are usually steeply sloped river banks that drain rapidly and do not retain any standing water, or areas that have been surveyed repeatedly with no stranding having ever been observed.

Susceptible areas are visually surveyed several times over the course of the rampdown event to assess at what point stranding becomes evident. All isolated pools are assessed for fish and initial attempts at salvaging are conducted with dip nets or seine nets. Fish that are observed to be in danger of stranding, but are not yet stranded can be “pushed” or “chased” out of high risk areas by survey crews. Another technique employed is the use of shovels to dig out escape channels that then provide access to the river mainstem, allowing fish a safe passage out of stranding areas. Areas that are difficult to net by hand or are known to strand large numbers of fish are fished overnight with baited minnow traps if warranted.

Rampdown site assessments are also linked to dam operations through the three LLO gates and their release stages (Table 2). Timing of site assessments can be correlated with the specific LLO gate flow release stage. For example, during the closure of the second LLO gate, survey crews know to respond to specific index sites which dewater during this stage of the rampdown. LLO gates are classed; LLO1 starting gate = first gate to close, LLO2 second gate = second gate to close, LLO3 = third and last gate to close (Table 2). LLO gate flow reductions can be influenced by rainfall and tributary inputs to varying degrees. For example, the stranding risk at rampdown sites located downstream of Or Creek, (Coquitlam Rivers main tributary) is sometimes minimized due to high flows from this tributary which moderates or even eliminates the stage reduction below the confluence. Survey crews keep in constant contact with BC Hydro gate operators during rampdown events to ensure proper survey timing during dewatering. Prior to initiation of gate changes the rampdown survey crew rendezvous with BC Hydro operating staff to determine rampdown start and finish time. Contact is maintained throughout the gate changes via cell phone and through direct contact at the LLO gatehouse. Remote gate operation was added to the Coquitlam Dam Low Level Outlet Gates in September 2013. The gate movements are now controlled remotely

from BC Hydro's Real Time Operations Center at Fraser Valley Operations (FVO). Fish stranding assessment and salvage crews co-ordinate activities through the operations center and remain in contact during all ramp down operations. The first remotely controlled rampdown was performed on November 1, 2013.

Table 2. Revised gate adjustment schedule for Coquitlam Dam Low level outlets gates during release reductions. Release varies depending on reservoir elevation; discharge data shown is assuming a reservoir elevation of 150.0m above sea level. Steps are implemented at 0.5hr intervals. Adapted from BC Hydro. Generation operating order COQ/LBD 4G-24v5. August 30, 2013.

		Gate Change		
Gate	Step	From	To	Q m^3sec
LLOG1	1	100%	55%	
LLOG1	2	55%	28%	
LLOG1	3	28%	11%	
LLOG1	4	10%	0%	
LLOG2	5	100%	77%	
LLOG2	6	77%	60%	
LLOG2	7	60%	40%	
LLOG2	8	40%	27%	
LLOG2	9	27%	15%	
LLOG2	10	15%	5%	
LLOG2	11	5%	0%	
LLOG3 (Knife Gate Valve)	12	100%	85%	9.5
LLOG3 (Knife Gate Valve)	13	85%	83%	8.8
LLOG3 (Knife Gate Valve)	14	83%	81%	8.5
LLOG3 (Knife Gate Valve)	15	81%	79%	8.3
LLOG3 (Knife Gate Valve)	16	79%	76%	8.1
LLOG3 (Knife Gate Valve)	17	76%	71%	7.9
LLOG3 (Knife Gate Valve)	18	71%	66%	7.7
LLOG3 (Knife Gate Valve)	19	66%	62%	7.3
LLOG3 (Knife Gate Valve)	20	62%	60%	7.0
LLOG3 (Knife Gate Valve)	21	60%	56%	6.6
LLOG3 (Knife Gate Valve)	22	56%	53%	6.2
LLOG3 (Knife Gate Valve)	23	53%	48%	5.9
LLOG3 (Knife Gate Valve)	24	48%	45%	5.5
LLOG3 (Knife Gate Valve)	25	45%	41%	5.1
LLOG3 (Knife Gate Valve)	26	41%	34%	4.8
LLOG3 (Knife Gate Valve)	27	34%	31%	4.1
LLOG3 (Knife Gate Valve)	28	31%	28%	3.5
LLOG3 (Knife Gate Valve)	29	28%	26%	3.2
LLOG3 (Knife Gate Valve)	30	26%	24%	2.8
LLOG3 (Knife Gate Valve)	31	24%	22%	2.6
LLOG3 (Knife Gate Valve)	32	22%	20%	2.4
LLOG3 (Knife Gate Valve)	33	20%	18%	2.2
LLOG3 (Knife Gate Valve)	34	18%	16%	2.0
LLOG3 (Knife Gate Valve)	35	16%	14%	1.8
LLOG3 (Knife Gate Valve)	36	14%	12%	1.6
LLOG3 (Knife Gate Valve)	37	12%	10%	1.4
LLOG3 (Knife Gate Valve)	38	10%	8%	1.2
LLOG3 (Knife Gate Valve)	39	8%	6%	1.0
LLOG3 (Knife Gate Valve)	40	6%	4%	0.6
LLOG3 (Knife Gate Valve)	41	4%	2%	0.5
LLOG3 (Knife Gate Valve)	42	2%	0%	0.3

Dewatered areas are classified by Reach with index sites lettered A-E, including two to three specific rampdown sub-areas in each index site (Appendix 2 & 3). Rampdown survey areas within each index site are not always contiguous, and may represent a large area of discontinuous but comparable fluvial and river edge characteristics (see Appendix 3 for site maps and descriptions). All sites surveyed typically contain many small depressions and areas where fish and spawning habitat are susceptible to stranding. Isolated pools are examined and their location recorded using a GPS so that they can be located during future rampdown assessments if they are determined to pose a stranding risk. All salvaged fish, both live and dead are enumerated, identified to species and live fish are returned to areas of the river mainstem not affected by the flow reduction.

When evaluating whether fish are stranded or not, a distinction is made between fish stranded in an area that will eventually become effectively dry (resulting in mortalities), and fish that are in temporarily isolated areas. Isolated areas will remain continually wetted and capable of supporting fish until higher flows return whether by an increase in flow from the dam, seasonal rainfall or freshet conditions. These isolated areas may be supported by a number of sources, such as: interstitial flows, bank seepage, tributaries or ground water which help to ensure a supply of oxygen and a degree of temperature regulation. Fish in these areas are not considered “stranded” and are therefore not included in stranding data.

River stage elevation changes are monitored at several staff gauge sites during the course of rampdown events (Appendix 1). Stage reductions are determined by survey crews at approximately hourly visual inspections of staff gauges located in Reach 1, Reach 4 and Reach 2b (Appendix 3). In February 2013 a staff gauge and transect site was installed in Or Creek. This will allow the survey crew to monitor the discharge in Or Creek during fish salvage operations. Or Creek is the main tributary to the Lower Coquitlam River and its flow can greatly influence fish stranding downstream of it, affecting reaches 3, 2b, 2a, and 1. These gauges are monitored from the onset of flow reductions to the end of daily salvage operations. Target flow release from Coquitlam Dam is monitored during each rampdown at a transect site established in Reach 4 (Appendix 3, Figure A). River stage elevation is also monitored using hourly flow data from the Water Survey of Canada (WSC) gauge located in Port Coquitlam (08MH002).

The area of each rampdown site was calculated by estimating the extent of inundation during a full 3 LLO gate release. The full extent of each site is included in the area calculation, therefore, areas within the stranding site that do not pose a stranding risk are represented in the area calculation. The total extent of each stranding site is represented as dewatered area in square metres (see Appendix 2 for ramp site descriptions). Survey crews perform area measurements using a hip chain and tape measure, measuring the length and width of each site to determine its areal extent. For scheduled rampdown events, the area of inundation is not quantified due to the fact that these are base flows and do not inundate areas of the river which are not normally wetted.

3.0 Results

3.1 Scheduled Rampdown Summaries May 2016-April 2017

Coquitlam Rampdown May 1, 2016

On May 1, 2016 a rampdown fish salvage was undertaken on Coquitlam River in response to the current flow regime (Treatment 2), the Low Level Outlet (LLO) release from Coquitlam Dam was scheduled to be reduced from 3.5m^3s to 2.9m^3s. The scheduled rampdown began at approximately 0900hr and was completed by 1100hr.

In total 231 stranded fish were observed over the rampdown period. Fish stranding was dominated by juvenile Coho Salmon with a total of 210 or 92% represented by this species (Table 3). Other key species salvaged were Rainbow Trout and Chum Salmon. The total of 231 stranded fish is the highest to date for this rampdown, the previous high was May 1, 2015 with 116.

Following completion of the flow reduction a flow estimate was performed at the Reach 4 transect site. The flow was estimated to be 3.0m^3s which is within the acceptable range of the 2.9m^3s flow target for the month of May.

Coquitlam Rampdown June 1, 8, 15, 2016

In response to the current flow regime (Treatment 2), the Low Level Outlet (LLO) release from Coquitlam Dam is scheduled to be reduced from 2.9m^3sec to 1.1m^3sec in the month of June. In light of high numbers of stranded fish and mortalities during past scheduled flow reductions on this date (Table 6, Figure 2), a decision was made in 2013 to extend the flow reduction over two to three days instead of performing the entire flow reduction over a single day. It was hoped that a more gradual flow reduction would potentially result in fewer stranded fish, and fewer mortalities due to stranding. This extended flow reduction period was first attempted in 2013 and has been successful in reducing stranding mortality when compared to single day rampdowns, however it has not led to a reduction in the number of fish being stranded (which can be influenced by several others factors unrelated to the ramping rate) (Figure 1).

The scheduled flow reductions in 2016 were performed over 3 days, each beginning at approximately 0900hr. June 1 saw the flow decrease from 2.9-2.2m^3/s, flow on June 8 decreased from 2.2 – 1.8m^3/s and flow decreased from 1.8m^3/s to 1.35m^3/s on June 15, 2016. This staggered flow reduction reduced the maximum daily stage elevation drop in Reach 4 dramatically. Flow reductions in 2011 and 2012 for this gate change dropped flow in Reach 4 approximately 16.0cm in 2-3 hours. The maximum decrease this year was 7cm over 3.0 hours on June 15, 2016 (Appendix 1).

Fish stranding over the course of the 3 days was the lowest in 3 years with a total of 1671. Of this total there were: 1601 Coho fry, 19 Coho smolts, 41 Steelhead fry and 9 Steelhead parr (Table 3). The mortality rate was 13.0%, an increase compared to the past three years and the highest yet for all multi-day rampdowns (Table 6).

The act of spreading the flow reduction out over two weeks appears to have had mixed success as the mortality rate was higher than the previous three years, but total stranding was down (Figure 2).

Coquitlam Rampdown January 16 2017

On January 16, 2017 in response to the current flow regime, the Low Level Outlet (LLO) release from Coquitlam Dam was reduced from 5.9m^3/s to 2.9m^3/s. The scheduled rampdown began at approximately 0800hr and was completed by 1300hr.

Upstream of Or Creek (Reach 4), river stage dropped a total of fourteen centimetres following completion of the flow reduction and had a maximum hourly decrease of 4.5cm/hr (Appendix 1). Stranding was observed in one location in Reach 3 (Table 3). In Reach 3, 22 Coho smolts were salvaged using minnow traps. Of concern was the near dewatering of a side channel in Section D3. This channel typically holds many fry and smolts as well as providing water for the Coquiltam River Hatchery. The channel did not dewater but came close to doing so. Fortunately, heavy rain began to fall late in the evening and Coquitlam River stage increased by nearly a metre over the following 24 hour period. DFO staff were notified of the potential problem and took the necessary steps to provide water for incubation should the channel dewater.

Following the completion of gate changes, a flow transect was taken at the Reach 4 site established 300m downstream of Coquitlam Dam. A discharge estimate of 3.21m^3/s was recorded, which is within the target range of 10% for the Treatment 2 flow release of 2.9m^3/s.

Coquitlam Rampdown April 1, 2017

On April 1, 2017 in response to the current flow regime (Treatment 2), the Low Level Outlet (LLO) release from Coquitlam Dam was reduced from 4.3m^3s to 3.5m^3s. The scheduled rampdown began at approximately 0900hr and was completed by 1100hr. Fish salvage activities continued until 1500hr.

Upstream of Or Creek (Reach 4), river stage dropped a total of 4.0 centimetres following completion of the flow reduction and had a maximum hourly decrease of 2.0cm/hr. Downstream of Or creek river stage dropped between 2.0 and 3.0 centimetres. Stranding was observed in one location in Reach 2B (Table 3). A total of 68 Chum fry

were observed to be stranded in a small ephemeral channel, all fry were salvaged and returned to the river mainstem.

Following the completion of gate changes, a flow transect was taken, at the Reach 4 site established 300m d/s of Coquitlam Dam. This transect produced a flow estimate of 3.77m^3s; which is within the targeted range for the Treatment 2 flow release of 3.5m^3s.

Table 3 Fish stranding by species, age class and Reach during scheduled rampdowns 2016-2017. Co 0 = Coho fry. Cm 0 = Chum fry. Pk 0 = Pink fry. St 1 = Steelhead parr/smolt.

			Reach					
Date	**Species**	**Salv/Mort**	**1**	**2a**	**2b**	**3**	**4**	**Total**
1-May-16	Co 0	s	26	51	38	78	98	291
1-May-16	St 1+	s		10		6		16
1-May-16	Co 1+	s				3		3
1-May-16	cm 0	s						0
1-May-16	Co 0	m	15	21	12	4	2	54
1-May-16	Cm 0	m					2	2
1-Jun-16	Co 0	s		250	160	80	310	800
1-Jun-16	St 0	s		2	2			4
1-Jun-16	Co 1+	s				19		19
1-Jun-16	St 1+	s				9		9
1-Jun-16	Co 0	m			24	41		65
8-Jun-16	Co 0	s	97		93	89	95	374
8-Jun-16	St 0	s			18	6		24
8-Jun-16	Co 0	m	2		49	53	3	107
8-Jun-16	St 0	m			11	2		13
8-Jun-16	dace	m	1					1
15-Jun-16	Co 0	s		112	17	6	89	224
15-Jun-16	Co 0	m			4	16	11	31
16-Jan-17	Co 1+	s				22		22
1-Apr-17	Cm 0	s			68			68
			141	**446**	**496**	**434**	**610**	**2127**

3.2 Unscheduled Rampdowns Summaries May 2016-April 2017

One unscheduled rampdown occurred on Coquitlam River during the 2016-2017 monitoring program.

Coquitlam Rampdown November 11, 14, 2016

On November 11, 2016 a rampdown fish salvage was undertaken on Coquitlam River following a full 3 Low Level Outlet LLO gate spill that been ongoing since November 4 2016. The first gate closure was initiated on Friday November 11 at 0830hr when the first of two LLO gates were shut at the prescribed rate. The third and final gate was ramped down on November 14 2016.

The spill and subsequent rampdown occurred at the peak of adult Chum spawning in Coquitlam River which meant that redd stranding was a likely outcome of the flow reduction. In addition, the 2016 Chum salmon run experienced record numbers of adult Chum which in turn led to a record number of adults and redds stranded. High numbers of returning adults may also have pushed fish into marginal habitats due to increased pressure on ideal spawning areas.

In total 84 stranded fish were observed over the two day period. Fish stranding was dominated by adult Chum salmon and juvenile Steelhead and Coho with a total of 79 or 93% represented by these two species (Table 4). In addition to the stranded fish a total of 193 stranded redds were also observed. These redds were classified as stranded and unviable due to the fact that they will not be wetted for the remainder of the incubation period. No efforts were made to ascertain if any redds had eggs deposited within them.

All stranding occurred on the first day of the rampdown. No stranding occurred on the second day due to heavy rainfall which kept the river elevated above normal flow despite the gate closure. See Appendix 1 for river stage change during the rampdown.

Table 4 Fish stranding by species, age class and Reach during unscheduled rampdowns 2016-2017. Co 0 = Coho fry. Cm 0 = Chum fry. Pk 0 = Pink fry. St 1 = Steelhead parr/smolt

			Reach					
Date	**Species**	**Salv/Mort**	**1**	**2a**	**2b**	**3**	**4**	**Total**
11-Nov-16	Co 0	s		2		7	4	13
11-Nov-16	Rt 1+	s		1		1	1	3
11-Nov-16	Cm Adult	s	9	31	6	3		49
11-Nov-16	Co 0	m					2	2
11-Nov-16	Rt 1+	m					3	3
11-Nov-16	Cm Adult	m	3	4		2		9
11-Nov-16	Lmp	m	1					1
11-Nov-16	Dace	m	1				3	4
11-Nov-16	*Redds*	*m*	*143*	*47*	*18*	*42*		*250*
14-Nov-16	n/a							0
		Total	**14**	**38**	**6**	**13**	**13**	**84**

3.3 Rampdown Summaries to date May-June 2017

Coquitlam Unscheduled Rampdown May 3, 2017

On May 3, 2017 a rampdown fish salvage was undertaken on Coquitlam River following an experimental Sockeye Salmon smolt attraction release flow that had been ongoing since April 25, 2017. The experimental flow had temporarily increased the Coquitlam dam release flow from 3.5m^3/s to 8.5m^3/s The gate closure was initiated on Friday, May 3 at 0830hr and was complete by 1530hr.

Heavy rainfall meant that the river downstream of Or Creek rose in elevation for most of the day so stranding was not an issue in the majority of the river's length. A total of 48 stranded fish were observed stranded by survey crews. Of the total, 35 were salvaged and there were 13 mortalities.

Coquitlam Unscheduled Rampdown May 13, 2017

On May 13, 2017 a rampdown fish salvage was undertaken on Coquitlam River following an experimental Sockeye smolt attraction release flow that had been ongoing since May 5 2017. The experimental flow had temporarily increase the Coquitlam dam release flow from 3.5m^3/s to 8.5m^3/s The gate closure was initiated on Friday May 13 at 0830hr and was complete by 1530hr.

There was a total of 940 stranded fish observed, 893 of which were returned safely to the river for a mortality rate of 4.9%. Coho fry represented virtually all of the stranded fish with a total of 932; there were also 7 Chum fry and one Lamprey salvaged (Table 5). This represents the largest single day stranding event yet observed during an unscheduled rampdown. The total of 940 stranded fish is more than double the previous high of 411 on June 30, 2010. The fact that this rampdown occurred at the peak of Coho emergence made it a very high risk

Coquitlam Scheduled Rampdown June 1, 8, 15, 2017

In response to the current flow regime (Treatment 2), the Low Level Outlet (LLO) release from Coquitlam Dam was reduced from 2.9m^3sec to 1.1m^3sec for the month of June. In light of high numbers of stranded fish and mortalities during past scheduled flow reductions on this date (Table 5, Figure 2), a decision was made in 2013 to extend the flow reduction over two to three days instead of performing the entire flow reduction over a single day. It was hoped that a more gradual flow reduction would potentially result in fewer stranded fish, and fewer mortalities due to stranding.

The scheduled flow reductions in 2017 were performed over 3 days, each separated by one week. On June 1 the flow was to be reduced from 2.9-2.2m^3/s, flow on June 8 decreased from 2.2 – 1.8m^3/s and flow decreased from 1.8m^3/s to 1.35m^3/s on June 15 2017. This staggered flow reduction reduced the maximum daily stage elevation drop in Reach 4 dramatically. Flow reductions in 2011 and 2012 for this gate change dropped flow in Reach 4 approximately 16.0cm in 2-3 hours. The maximum decrease this year was 5cm over 3.0 hours on June 15 2017 (Appendix 1).

Table 5 Fish stranding by species, age class and Reach during rampdowns to date for 2017-2018. Co 0 = Coho fry. Cm 0 = Chum fry. Pk 0 = Pink fry. St 1 = Steelhead parr/smolt. LMP = Lamprey(sp). TSS = Three Spine Stickleback.

			Reach					
Date	**Species**	**Salv/Mort**	**1**	**2a**	**2b**	**3**	**4**	**Total**
3-May-17	Co 0	s					35	35
3-May-17	Co 0	m				13		13
13-May-17	Co 0	s		197	570	63	56	886
13-May-17	Co 0	m		14	6	23	3	46
13-May-17	Cm 0	s			7			7
13-May-17	Lmp	s			1			1
		Total	**0**	**211**	**584**	**99**	**94**	**988**
		s	**0**	**197**	**578**	**63**	**91**	**929**
		m	**0**	**14**	**6**	**36**	**3**	**59**

			Reach					
Date	**Species**	**Salv/Mort**	**1**	**2a**	**2b**	**3**	**4**	**Total**
1-Jun-17	Co 0	s					84	84
1-Jun-17	Co 1+	s				4		4
1-Jun-17	TSS	s					11	11
1-Jun-17	Co 0	m					2	2
8-Jun-17	Co 0	s					37	37
8-Jun-17	TSS	s					1	1
15-Jun-17	Co 0	s					47	47
		Total	**0**	**0**	**0**	**4**	**182**	**186**
		s	**0**	**0**	**0**	**4**	**180**	**184**
		m	**0**	**0**	**0**	**0**	**2**	**2**

Fish stranding over the course of the 3 days was by far the lowest observed since 2011 with a total of only 186. Figure 2 shows the dramatic difference in stranding observed during the June scheduled rampdown in 2017, the previous low for this rampdown was 977 fish and the mean from 2011-2016 is 1959 stranded fish. Of the 186 fish observed there were in total: 170 Coho fry, 4 Coho smolts, and 12 Three Spine Stickleback (Table 5). The mortality rate was 1.1%, also the lowest yet observed and far lower than the 2011-2016 mean of 13.3%. The explanation for this dramatic reduction in stranding is entirely due to river conditions during the flow reductions. As shown in Appendix 1,

heavy rain combined with freshet conditions during the rampdowns meant that river stage over the majority of the Coquitlam River was rising and not falling at the time of the flow reduction. This was certainly the case on the June 8 and June 15 rampdowns, though less evident during the June 1 rampdown. The result of these high flows meant that there was no fish salvage activities required for the majority of the river, hence the seemingly large reduction in fish stranding (Table 7).

4.0 Discussion

4.1 Stranding Risk

As has been the case since Treatment 2 was initiated, the majority of stranding in the Coquitlam River is the result of fish salvages occurring in the month of May and June (including scheduled and unscheduled events). The eighth full year of rampdown monitoring under Treatment 2, 2016-2017, saw a total of 2211 stranded fish observed, which is near the average for Treatment 2 of 1950 (Figure 5 & Table 6). Of these events, the scheduled June 1 flow reduction has been by far the main contributor to fish stranding. This one rampdown has been responsible for 70.3% of all stranding observed on the Coquitlam River since Treatment 2 was initiated, and in 2016-2017 was responsible for 75.7% of all stranding (Table 7).

The June flow adjustment of 2.9m^3/s to 1.1m^3/s represents a significant loss of flow volume and river stage in the uppermost reach of the Coquitlam River. While areas downstream of Reach 4 may or may not be significantly impacted at this time of year from a scheduled flow reduction (depending on freshet and local rainfall), Reach 4 is always very vulnerable. The June flow reduction in Reach 4 is equivalent to 62% of the total flow volume in this section of the Coquitlam River. Reach 4 is above the buffering influence of Or Creek, and has virtually no natural inflow. In addition, its entire length is composed of shallow pools and small channels that attract juvenile fish. Reach 4 is also narrow and confined by berms and roadways along its length, which results in the river stage elevation decreasing more rapidly and to a greater degree than areas downstream of Or Creek (See Figure 4). Scheduled rampdowns typically see only a small decrease (or an increase depending on rainfall or freshet conditions) in river stage in the areas below Or Creek.

Adult Coho escapement in the Coquitlam River is also concentrated in Reach 4. Typically between 65-75% of all Coho spawning occurs in this Reach (Shick et al. 2014). This heavy spawning concentration, combined with the fact that May and June represent peak emergence for Coho fry, creates a heightened risk of stranding during rampdowns at this time of year.

Figure 2 illustrates the increase in the past several monitoring years in the amount of fish stranded on the Coquitlam River under Treatment 2. This increase is influenced by a number of factors, including: the number of rampdown events, seasonal timing of rampdown events, total flow volume decrease, minimum target flow release, as well as survey crews finding more stranding areas and increased efficiency in fish salvage. In the first year under Treatment 2 (2009-2010) fish stranding was limited, but the results have swung far in the other direction the past several monitoring years (Figure 2). In addition, during the first year under Treatment 2, the flow releases from the LLO gate at the Coquitlam Dam were approximately 20-40% over the target due to a miscalculation in the stage discharge curve at the LLO gate. Therefore, there was consistently more

water and a higher river stage in the Coquitlam River, as a result of this there was likely less of a stranding risk.

In years 3 & 4 of Treatment 2 the ratio of salvaged fish to mortalities was the second and third worst on record (Table 6), with a 30.6% and 24.3% mortality rate for all stranded fish observed. This is well above average compared to the mean mortality rate of 14.5% for all rampdowns (using 2004-2017 data, (Table 6). The high mortality rate in years 3 and 4 was primarily a result of the scheduled June rampdown. The ramping rate established for the June flow reduction called for the entire LLO gate operation to be done in 2 hours which results in a rapid decrease of river stage, approximately 15.0-16.0cm in this short period of time.

In light of these high numbers of stranded fish and mortalities during past scheduled flow reductions in June, a decision was made to modify the rampdown by extending the flow reduction over two to three consecutive days or three days over a two week period. It was anticipated that a more gradual flow reduction would result in fewer stranded fish, and more importantly, fewer mortalities due to stranding.

Table 6 Yearly site by site comparison of stranded fish during all rampdown events, 2001-2017. T1 = Treatment 1 2004-2008, T2 = Treatment 2 2009-2017.

	Reach 1		Reach 2a		Reach 2b		Reach 3		Reach 4		Total	Total	Total	%
Year	Salv	Mort	Salv	Mort	Salv	Mort	Salv	Mort	Salv	Mort	Strand	Salv	Mort	Morts
2017-18	0	0	197	14	578	6	67	36	271	5	1174	1113	61	5.2%
2016-17	132	23	459	25	402	100	329	118	597	26	2211	1919	292	13.2%
2015-16	278	172	521	65	147	64	2288	227	461	99	4322	3695	627	14.5%
2014-15	895	36	314	30	663	29	375	20	575	52	2989	2822	167	5.6%
2013-14	0	0	318	12	0	0	428	5	300	32	1095	1046	49	4.5%
2012-13	65	9	143	79	85	24	322	28	847	504	2106	1462	644	30.6%
2011-12	154	9	164	21	3	11	65	88	1071	338	1924	1457	467	24.3%
2010-11	103	6	389	21	39	25	78	13	134	26	834	743	91	10.9%
2009-10	21	0	40	2	0	0	5	0	45	13	126	111	15	11.9%
2008-09	31	5	33	9	49	12	12	0	13	0	164	138	26	15.9%
2007-08	67	6	32	11	199	17	20	1	65	1	419	383	36	8.6%
2006-07	39	14	3	4	47	80	36	4	0	0	227	125	102	44.9%
2005-06	95	0	0	0	1	9	0	7	85	6	203	181	22	10.8%
2004-05	75	2	10	0	13	9	0	0	48	0	157	146	11	7.0%
2001-04	36	4	0	2	0	0	6	1	0	16	65	42	23	35.4%
Total	**1991**	**286**	**2623**	**295**	**2226**	**386**	**4031**	**548**	**4512**	**1118**	**18016**	**15383**	**2633**	**14.6%**
T1	343	31	78	26	309	127	74	13	211	23	1235	1015	220	17.8%
T2	1648	255	2545	269	1917	259	3957	535	4301	1095	16781	14368	2413	14.4%

The reduction in mortality illustrated in Figure 2 and Table 6 shows the impact of the past five scheduled flow reductions on this date. The mortality rate dropped from 24.4% and 36.7% in 2011 and 2012 to only 4.5% in 2013 and 5.6% in 2014. In 2015 it rose to 10.3% and then to 13.0% in 2016 before dropping to 1.1% in 2017. However, the number of fish stranded during the June rampdowns has not decreased over the same period and in fact, the years 2014-2016 had peak amounts of stranded fish (Table 7). Though it is important to note that this increase may be independent of the ramp

rate and may also be correlated with – for example – the amount of Coho fry present in the Coquitlam River during ramp events.

In addition, river conditions can dramatically impact stranding during the June rampdown. For example, when comparing the results of the June 2017 rampdowns which had the lowest amount of stranding (184) for Treatment 2 vs 2015 which has the most to date (3704). The 2015 June rampdown had the lowest discharge recorded during monitoring. In June 2015 the Coquitlam River was at 2.5m^3/s when the rampdown began and fell to 1.1m^3/s following the flow reduction, while during the 2017 June rampdown the discharge ranged from 5.5m^3/s to 20m^3/s. This demonstrates how the lack of, or abundance of, water downstream of Reach 4 can influence stranding. In the example of the 2017 June rampdown, the Coquitlam River was so high due to rainfall that no stranding assessments took place below Reach 4, which translates into 80-90% of the potential stranding area going unsurveyed. Hence the seemingly large drop in fish stranding.

The act of spreading the flow reduction out over multiple days appears to have had mixed success as the mortality rate has dropped over the past five years, but the amount of fish stranded has not changed (Table 6 & Table 7). Yearly, the number of stranded fish continues to fluctuate based on a number of factors, but the risk of stranding has not been addressed through this operational approach.

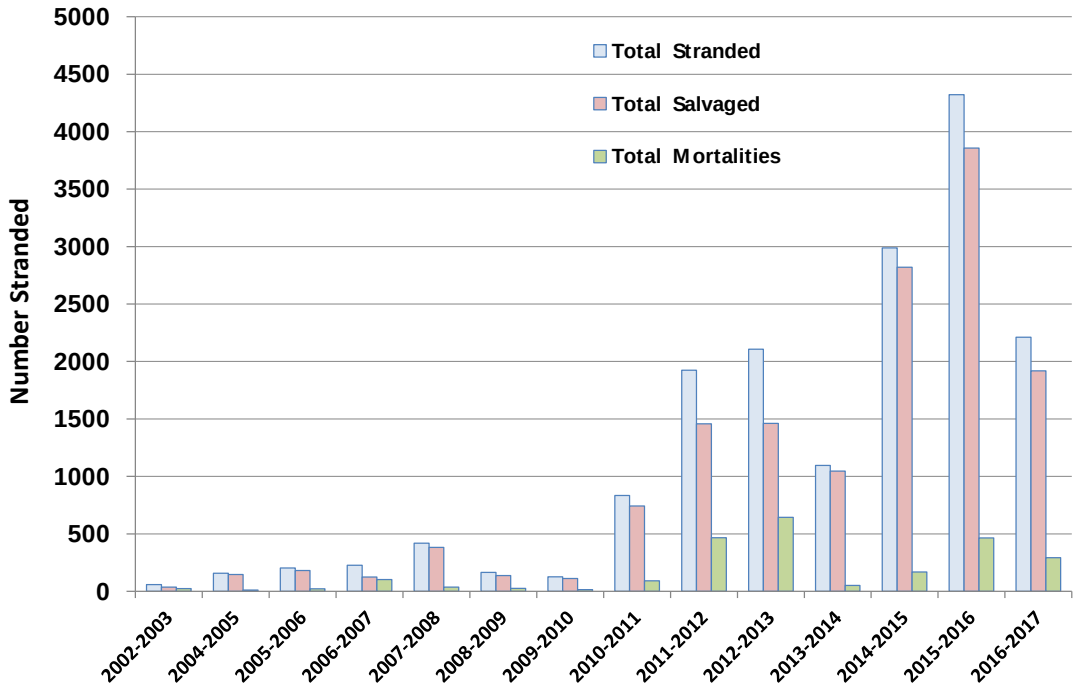

Figure 2 Number of fish salvaged and mortalities for all rampdowns 2002-2017.

As discussed, the fact that the June rampdown reduces the flow release to the Coquitlam River by 62% at a sensitive time appears to be the central cause of stranding. In addition, the fact that the flow reduction reduces the discharge to a yearly low of 1.1m^3/s is likely problematic. Salmon fry depend on spring freshet conditions to provide an increase in flow to accommodate migration within and from their natal grounds (Hartman 1982). At this time of year the natural flow pattern for streams and rivers in the South Coast region is typically an increase in discharge, not a severe and rapid reduction. Therefore, the June rampdown represents the opposite of the conditions that migrating Salmon fry depend on for survival.

The total decrease in river volume in Reach 4 is also high during the January 15, and November 1 scheduled rampdowns, with a loss of 50%, and 33% of total flow volume respectively (Table 1). Compare this to the March 31, April 30 and August 31 scheduled rampdowns which have flow volume decreases of 19%, 17% and 19% respectively. However, during periods of low flow in the Coquitlam River (mid-late summer) even small reductions in release can have impacts. For example the September 1, 2011 rampdown which had a minimal elevation decrease of 0.04-0.03 metres depending on the reach, stranded 98 fish primarily due to below average flow in the Coquitlam River at the time of the flow reduction. Stranding during this rampdown has only been witnessed on one other occasion, with 7 stranded fish observed in 2014 (Table 7).

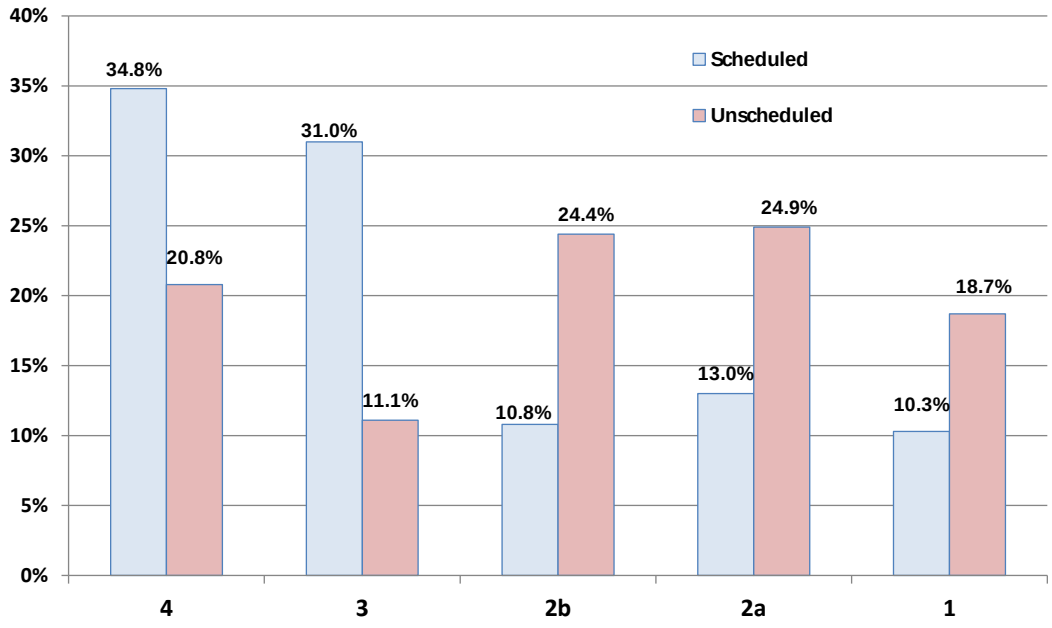

Figure 3 Stranding distribution by Reach, 2004 - June 2017; highlighting the difference in stranding distribution by Reach between scheduled and unscheduled rampdowns.

Table 7 Stranding results of scheduled rampdowns since the introduction of Treatment 2.

Scheduled Rampdowns												
Date	**Status**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**Total**
15-Jan	Salvaged	-	0	0	0	5	10	0	0	31	22	**46**
	Mortality	-	0	0	0	2	10	0	0	0	0	**12**
1-Apr	Salvaged	-	0	0	0	1	129	28	48	5	68	**211**
	Mortality	-	0	0	0	0	15	0	14	1	0	**30**
1-May	Salvaged	-	0	0	-	0	100	0	95	310	-	**505**
	Mortality	-	0	0	-	0	3	0	21	56	-	**80**
1-Jun	Salvaged	-	20	55	1355	1377	967	2600	3327	1454	184	**11339**
	Mortality	-	0	19	331	506	46	67	381	217	2	**1569**
1-Sep	Salvaged	-	0	0	98	0	0	7	0	0		**105**
	Mortality	-	0	0	82	0	0	0	0	0		**82**
1-Nov	Salvaged	0	0	11	0	0	0	0	0	0		**11**
	Mortality	0	0	2	0	0	0	0	0	0		**2**

Other flow reductions where widespread stranding has been observed was the May 1, 2016 rampdown and the May 13, 2017 rampdown (Table 3 & Table 5). The May 13 rampdown was significant in that it represented the highest number of fish stranded during an unscheduled rampdown that has been observed with 940, more than double the previous high of 411 on June 30, 2010. The decrease in discharge was quite high, from 8.5m^3/s to 3.5m^3/s, representing a decrease of 59%. Coho fry were the dominant species observed, with 932 of the 940 total stranded.

May rampdowns also occur at the peak of Chum and Pink fry emergence when millions of Salmon fry are in the river, with many congregating in shallow margins along the river banks which elevates the stranding risk. However, despite the presence of large numbers of fry during these two flow reductions, stranding is nowhere near as problematic as the June 1 flow reduction. Typically Pink and Chum fry migrate almost immediately from the Coquitlam River following emergence, whereas Coho fry remain in the river looking for rearing space. This fact likely plays a significant role in reducing the risk of stranding for Chum and Pink fry.

As the results of the spring and summer rampdowns demonstrate, a strong determiner of stranding risk on Coquitlam River is the time of year at which a rampdown occurs. Rampdowns that occur in the fall and winter months (September 21 – March 21) are the least likely to strand fish. Data on stranding by season and life stage (Table 9) shows that fall and winter rampdowns strand an average of 31 and 35 fish per rampdown respectively, while the average for spring and summer is 452 and 71 fish per rampdown. This seasonal difference is likely due to the reduction of juvenile fish in the system during the fall and winter (compared to spring and summer when millions of fry may be present) and possibly colder water conditions in winter which can minimize fish movement (Bustard 2011).

Final river stage elevation is also an important contributing factor as rampdowns occurring from October 1 - January 15 (under Treatment 2) typically occur at a higher minimum stage elevation than spring and summer rampdowns due to higher flow release. For example, rampdowns in the spring and summer months return to a stage elevation of between 0.17cm and 0.10cm (based on the Reach 4 staff gauge), while those in the fall and winter return to a stage elevation of between 0.40cm and 0.25cm. The higher minimum discharge results in an elevated river stage which can keep areas vulnerable to stranding continuously wetted.

Table 8 Stranding and mortality scheduled vs. unscheduled rampdowns 2001-2017.

2001-2017	Stranded	Per Ramp	Salvaged	Mortality	Per Ramp	Rate
Unscheduled	4962	115	4085	877	20	**17.7%**
Scheduled	13064	284	11300	1764	38	**13.5%**
Total	**16784**	**336**	**14210**	**2574**	**51**	**15.3%**

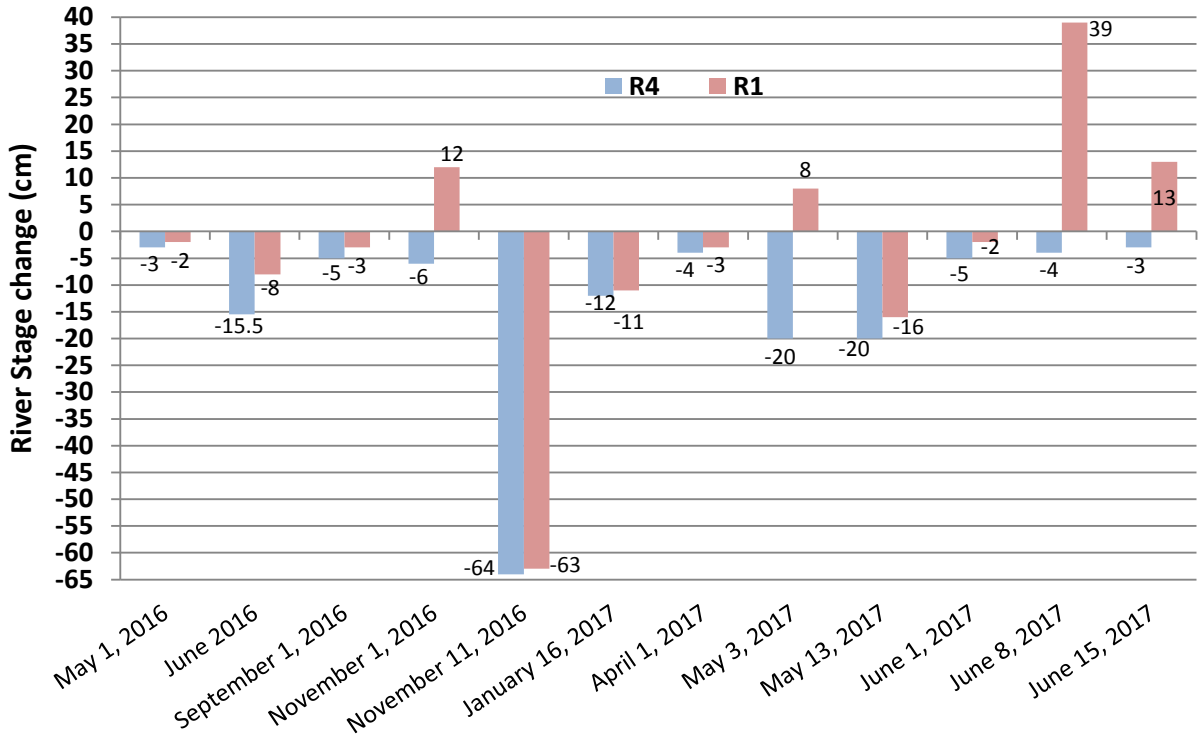

Figure 4 Comparison of Reach 4 with Reach 1 river stage change. Total river stage change during all rampdowns May 2015- June 2017.

Coho fry have the highest stranding risk due to their year round residence, abundance at emergence and habit of congregating in shallow river margins, ephemeral channels and shallow pools (Dunn 2002, Macnair 2008). All of these factors make them heavily susceptible to stranding. This contrasts with Chum and Pink fry which are the most

numerous species when emergence is underway (March-May), but almost immediately migrate out of the river and are absent from the water column from June to February. Coho salmon juveniles are the most likely fish to be stranded over the entire study period, representing 87.0% of all stranded fish between 2004-2017 (Figure 7). In Year 8 Coho fry and smolts represented 88.7% of all stranding observations. Overall, salmonids accounted for 98.6% of all stranded fish for the 2004-2017 period (Figure 8).

Table 9 Showing the relationship between seasonal timing and stranding risk all rampdowns, 2001-2017. Totals represent stranded salmonids only.

2001-June 2017		Life Stage When Stranded				
Season	**# Rampdowns**	**Adult**	**Fry**	**Smolt/Parr**	**Total**	**Average**
Spring (Mar 23-June 22)	34	17	15218	141	15376	452
Summer (June 23-Sept 22)	14	4	925	64	993	71
Fall (Sept 23 - Dec 22)	25	141	416	223	780	31
Winter (Dec 23 - Mar 22)	16	1	325	241	567	35
	89	**163**	**16884**	**669**	**17716**	**199**

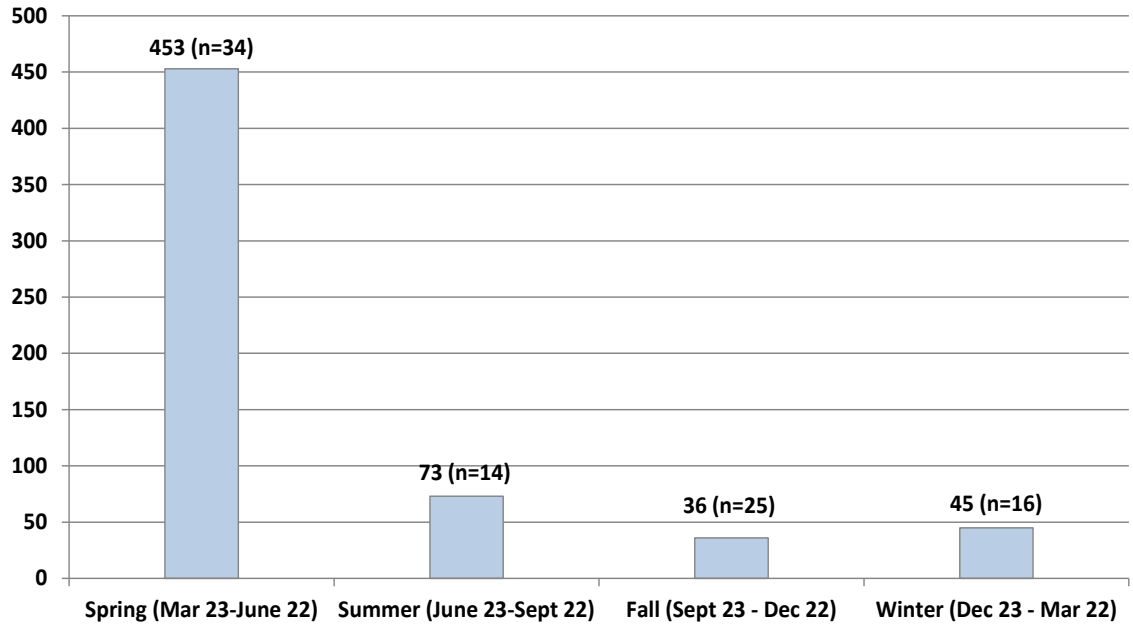

Figure 5 Stranding by season all fish species 2001-2017.

In Year 8 stranding was concentrated in the upper reaches of the Coquitlam River with Reach 3 and 4 accounting for 48.3% of all stranding. This trend is the norm under Treatment 2 as Reach 3 and 4 normally see 45-75% of all stranding and have averaged 56.5% over the Treatment 2 period (Figure 3). Reach 4 is also upstream of the influence of Or Creek which means that any flow reduction, regardless of scale, will be guaranteed to reduce the river stage. Therefore, a stranding risk always exists in contrast to the other Reaches.

The majority of unscheduled rampdowns involve large flow releases, often seeing flow reductions of all 3 LLO gates on the Coquitlam River which can release up to 40-45m^3/s of water per second, therefore the stranding impact tends to extend to the entire river length and be more evenly distributed by Reach (Figure 3).

4.2 Redd Stranding

Redd stranding on the Coquitlam River as a result of flow reductions is a risk only during fall Salmon spawning, and Steelhead spawning in the spring. Widespread stranding of redds in the fall only occurs if there is an extended spill event that coincides with peak or near peak spawning period. This has happened on 5 occasions on the Coquitlam River since 2001, stranding an estimated 897 pink and chum redds over the 2001-2017 period (Table 10). Steelhead redd stranding is limited to one problematic area on the Coquitlam River that surveyors have observed redd stranding in the same location in seven consecutive years (Table 10).

The relatively low number of redds stranded, and the low frequency of stranding events, points to the fact that redd stranding is not a major concern on the Coquitlam River. The yearly loss of 1-3 steelhead redds compares to a yearly average of 234 steelhead redds observed (steelhead redd data from 2005-2017). Chum and pink redds are not enumerated, but as average escapement ranges from 10,000-60,000 (Schick 2018, see Appendix 3 for Coquitlam River escapement estimates 2002-2017), it is certain that a minimum of several thousand redds are created each fall. The loss of a few hundred redds in infrequent intervals over 17 years of study would likely have very little to no bearing on population levels of Chum Salmon and Pink Salmon.

Table 10 Redd stranding on Coquitlam River 2001-2017. Steelhead spawning timing March-May, Pink and Chum, September-November.

Year	Steelhead	Pink	Chum	Total
2001				
2002				
2003			300	300
2004-2010				
2011	1	30		31
2012	1		300	301
2013	1			1
2014	3		17	20
2015	1			1
2016	2		250	252
2017	2			2
Total	**11**	**30**	**867**	**908**

4.2 Rampdowns and Flow Release Targets

Since the introduction of Treatment 2 there has been no reduction in the total number of unscheduled rampdowns (Table 11). It was anticipated that removal of the temporary dam safety 149m maximum allowable reservoir operating level (in place during Treatment 1 2001-2009) would reduce the number of unscheduled spill events. Under Treatment 1, the Coquitlam River averaged 2.7 unscheduled rampdowns per year, under Treatment 2 the average has risen slightly to 3.0 unscheduled rampdowns per year. With respect to the number of full 3 Low Level Outlet (LLO) Gate spills, again, no reduction has been evident in the past eight years of monitoring. Under Treatment 1, the Coquitlam River had 14 full LLO spills in seven years (2002-2009), under Treatment 2 there have been 13 (as of August 2017) in the past eight years of monitoring. Of the 25 unscheduled rampdowns since the initiation of Treatment 2, 12 have been full 3 LLO gate release rampdowns, the remainder have been due to dam maintenance and for experimental flows designed to attract Sockeye smolt migration.

Flow transects performed throughout the 2016-2017 monitoring year indicated that flow releases from the Coquiltam Dam have been consistently within the targeted range (estimated flows must be within 10% for the targeted value).

Table 11 Number of rampdown per year 2001-2017. 2017-2018 year to date May-July 2017.

Monitoring Year	Scheduled	Unscheduled	Total
2017-2018*	3	2	5
2016-2017	4	1	5
2015-2016	6	4	10
2014-2015	6	3	9
2013-2014	6	1	7
2012-2013	5	4	9
2011-2012	5	3	8
2010-2011	6	5	11
2009-2010	4	5	9
2008-2009	3	1	4
2007-2008	n/a	5	5
2006-2007	n/a	4	4
2005-2006	n/a	2	2
2004-2005	n/a	3	3
2003-2004	n/a	3	3
2002-2003	n/a	1	1
2001-2002	n/a	1	1
Total	**45**	**46**	**91**
Treatment 2 Average	**5.0**	**3.0**	**8.0**
Treatment 1 Average		**2.7**	**2.7**

4.3 Fish Productivity Impacts

Stranding influence on fish production in the Coquitlam River is likely to be minimal for all species with the exception of Coho and possibly Steelhead juveniles. For Pink and chum fry the impact is negligible. Schick et al. (2014) reports the estimated average annual outmigrating population for chum and pink fry for the 2003-2013 period is 2,248,900 and 958,000 respectively. Contrast this with a total of 79 Chum mortalities and zero pink mortalities observed during rampdowns for the same period. Coho and Steelhead smolt population estimates for the same period average 14,479 and 4,242 per year respectively (Schick et al. 2014). The estimated average number of Coho and Steelhead smolt/parr stranded per year due to rampdowns is 17 and 15 respectively, or less than 0.4% of the estimated population. However, in light of the impacts on Coho fry, and to a lesser extent Steelhead fry in the past four monitoring years, there may be cause for concern.

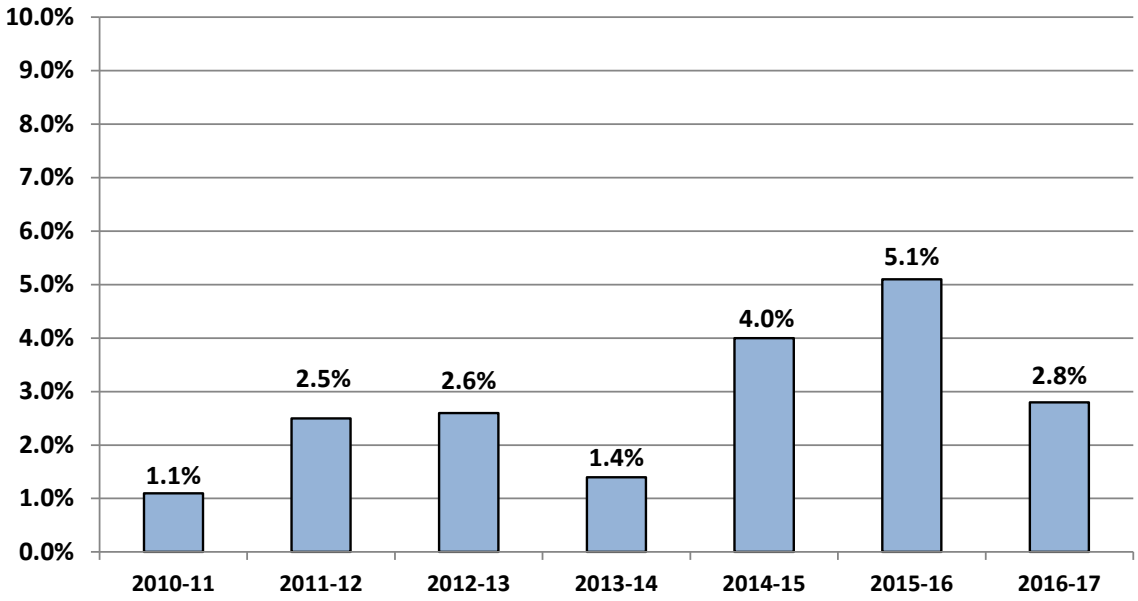

Figure 6 Estimated potential impact of rampdowns on Coho fry population in the Coquitlam River. Values represent the estimated proportion of the total population of coho fry that could be eliminated due to rampdowns each year.

Coho fry populations are typically the hardest hit with respect to stranding, estimates of total fry productivity (based on fall standing stock estimates 2003-2015) range from 21000 to 105000 with a mean of approximately 56101 (Schick 2016). Using available data it is possible to give a rough idea of the impact of stranding on the Coho fry population in the Coquitlam River. For example: using the average number of Coho fry observed stranded from 2011-2016, (2727) and comparing it to the average Treatment 2 Coho fry standing stock estimate of 70760 (a yearly estimate of the total number of fry in the system in late summer) would represent a loss of approximately 2.8% of the Coho fry population for 2016-17 (Figure 6). This estimate is roughly average (Figure 6), with the highest estimate of loss at 5.1% in 2015-16 and the lowest 1.1% in 2010-11.

This level of loss could have the potential to have an impact on the Coho fry population. Bearing in mind that freshwater mortality can be highly variable and often substantial for juvenile Coho salmon under natural conditions (Bradford 1995' Nickelson and Lawson 1998). For comparison, summer mortality rates - covering the period June to September - for juvenile Coho ranged from 26% - 56% in a study of three unregulated streams in the Pacific Northwest (Au 1972, Spalding 1995).

This is a rough estimate using the only available data but does provide a useful illustration and is comparable between years. The impact on Steelhead fry is not quite as dramatic; using the total number observed stranded (248) in the 2015-2016 monitoring year and comparing it to the average Treatment 2 standing stock estimate (32746), gives a potential loss of 0.8% of the population due to stranding. This is the highest estimate yet for Steelhead fry loss and is still well below potential Coho fry losses.

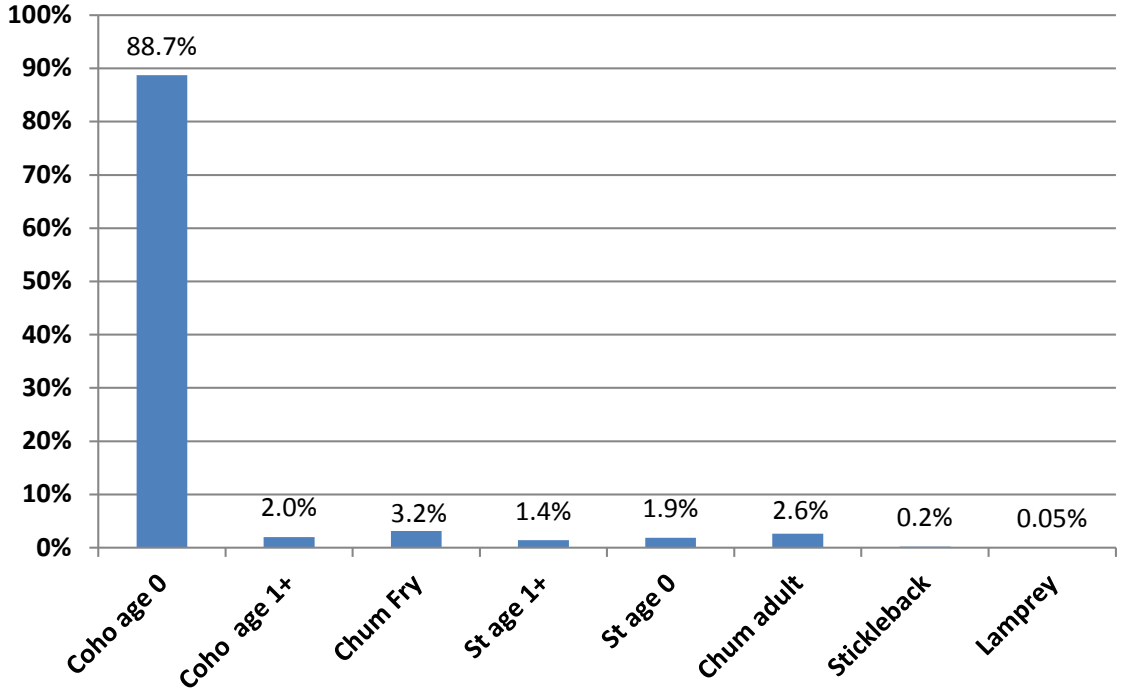

Figure 7 Stranding distribution by species and age class 2016-2017 all rampdowns.

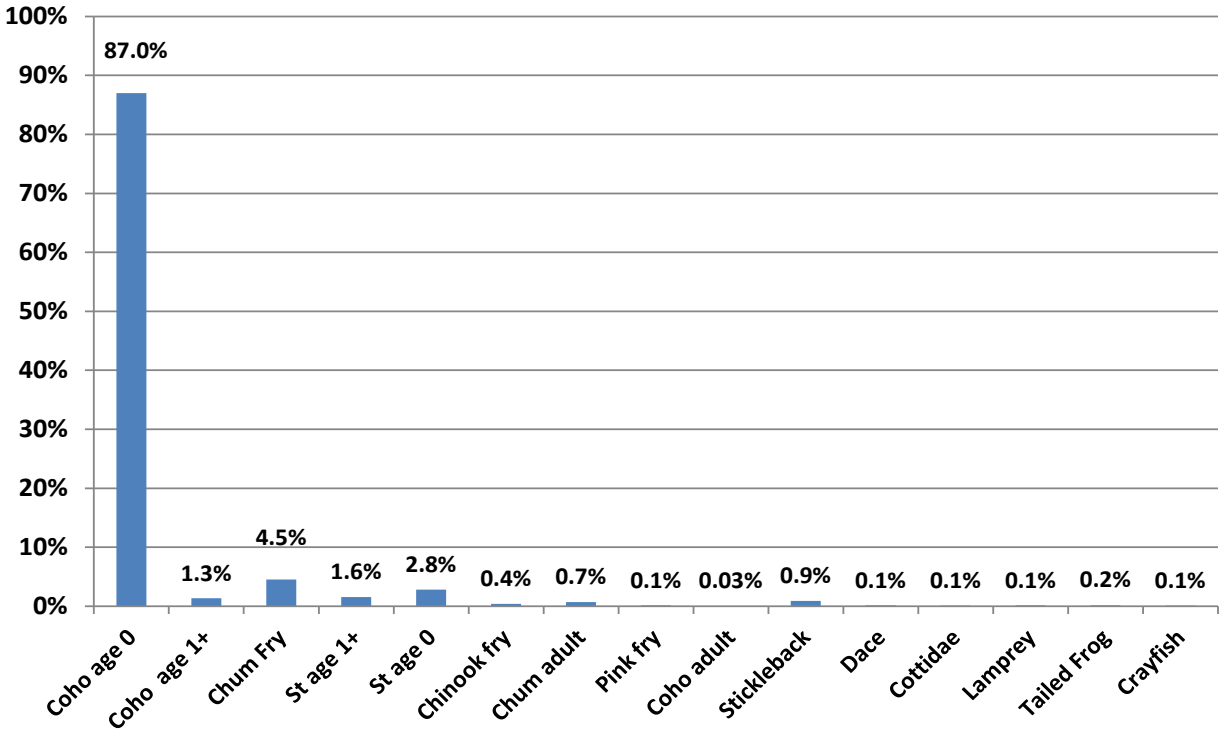

Figure 8 Stranding distribution by species and age class, 2004-July 2017, all rampdowns. In addition one Kokanee, Pink adult and Northern Pike Minnow have been found.

5.0 Conclusions and Recommendations

The results of the past 8 years of rampdown monitoring clearly indicate that fish stranding and mortalities have increased due to operational changes to the flow regime under Treatment 2. An analysis of the results from Table 6 show that under Treatment 1 survey crews observed an average of 205 stranded fish and 37 mortalities per year, while under Treatment 2 this has risen to 1621 stranded fish and 272 mortalities. The cause of this increase is likely related to two main factors:

1. An increase in the number of rampdowns per year due to monthly flow changes at the Coquitlam Dam. Treatment 1 had an average 2.7 rampdowns per year (all unscheduled), while under Treatment 2 the average has risen to 8.0 per year.

2. Increase in rampdowns at critical time period for emerging juvenile fish. Scheduled rampdowns in April, May, and June occur at peak emergence for fry in the Coquitlam River, which results in a consistent, yearly elevation in the risk of stranding. As discussed in Sec. 4.1, the June rampdown alone has been responsible for 76% of all stranding over the past six years.

The ramping rate established under Treatment 2 appears to be effective at minimizing stranding during both scheduled and unscheduled rampdowns with the exception of the June scheduled rampdown. The June rampdown, may need to have its ramp rate and operational procedures reexamined and altered. The first step taken towards this was undertaken in 2013 and has had some promising results as total mortality and the mortality rate have dropped. This alteration is purely an operational one (spreading out the rampdown over two or three days) and the results indicate that the June rampdown may also benefit from a more gradual flow reduction as total stranding has not been reduced despite the drop in mortality.

In addition, this particular rampdown should undergo a reassessment of its minimum target flow. The June reduction does not fit the natural hydrograph for the watershed (according to WSC Gauge 08MH141 Coquitlam River above Coquitlam Lake). Flows are normally high and rising during the months of May and June, but this is not reflected in Reach 4, where flows instead drop significantly. A higher minimum flow target for June would very likely prevent a significant amount of stranding.

Having more water available, whether through Coquitlam Dam release or from tributaries, can certainly reduce stranding. For example, during the rampdown on June 1, 2017 the discharge in the Coquitlam River (at WSC gauge) was 9.0m^3/s at the start and fell to 8.3m^3/s when the flow reduction was complete. During the following two flow reductions on the 8 and 15 discharge never fell below 5.0m^3/s. This is in contrast to the 2015 Coquitlam River rampdown when the discharge was at 2.5m^3/s when the rampdown began and fell to 1.1m^3/s following the flow reduction. The impact of additional water from Or Creek in 2017 meant that many side channels and stranding

areas containing thousands of fry remained wetted and continued to provide adequate habitat. The impact this additional water had on stranding was significant, and is demonstrated by comparing the 2015 similar rampdown which stranded 3708 fish, versus 186 in 2017.

The May 13, 2017 rampdown that led to a record number of stranded fish for an unscheduled rampdown was directly due to the timing of the rampdown (at the height of Coho fry emergence) and the large decrease in flow (for 8 days at 8.5m^3/s down to 2.9m^3/s or 65% of the water in the river). The rampdown on May 3, 2017 was also of the same magnitude and duration but fortunately did not lead to widespread stranding due to the fact that the river was rising from heavy rainfall (Table 5, Appendix 1). Future rampdowns related to Sockeye smolt attraction flows will need to be carefully monitored if they occur in the spring due to the increased stranding risk associated with the timing, duration and magnitude of the event.

As Table 7 clearly demonstrates, fish stranding under scheduled rampdowns in the Coquitlam River is heavily concentrated in the June rampdown, with regular, but far more limited stranding during the April 1 and May 1 rampdowns. Outside of the June flow reduction, the risk of stranding appears to be minimal during most scheduled rampdowns downstream of Reach 4. This is due to the fact that the scheduled releases under Treatment 2 do not inundate large areas of habitat.

Though the majority of stranding each year is observed during only one scheduled rampdown, it is recommended that all rampdowns continue to be monitored by survey crews during the upcoming monitoring year. The potential for stranding definitely exists, and has been documented on all scheduled rampdown dates. In addition, with the gate operations at the Coquitlam Dam now controlled remotely, it is imperative that a crew be on site in case of operator error or equipment failure, which has occurred on a few occasions during the past several years.

Stranding sites examined under the previous flow regime have been reevaluated under the new Treatment 2 conditions. The results of the eighth year under Treatment 2 demonstrate that some formerly susceptible areas may now be considered low risk for stranding. Additionally, new areas have been identified during scheduled rampdowns and those new areas have been categorized and included in all rampdown fish salvage surveys. The fluvial morphological structure of the Coquitlam River will continue to transform as it adapts to the increased annual flow, therefore areas of stranding will shift, and thus should continue to be monitored.

Comparison of rampdown mortality to fish productivity clearly shows the negligible impact that rampdowns appear to have on fish productivity in the Coquitlam River, with the exception of Coho salmon fry. Results from the past few years show that greatly elevated Coho fry stranding during scheduled and unscheduled rampdowns at critical time periods can be cause for concern. Rampdowns that occur in spring and summer

could also potentially require larger rampdown crews and a modified ramp rate to ensure that high numbers of juvenile mortalities do not occur.

With respect to the management questions and hypothesis outlined in the introduction:

H1: *The LB1 WUP interim ramping rate protocol does not strand fish at index sites in the lower Coquitlam River.*

Results to date indicate that fish continue to be stranded under the revised ramping rate protocol. In addition, the risk of fish stranding has increased since the introduction of Treatment 2 flow regime despite careful adherence to the ramping protocol.

Although fish will continue to be stranded regardless of ramp rate, survey crews are well adapted to the conditions of the ramp rate and are able to salvage many of the fish that become stranded. Minimizing impacts with careful adherence to rampdown rates, minimum flow targets and consistent monitoring of potential stranding sites will continue to be the most appropriate means to reduce the fish stranding risk while being operationally feasible. However, at this point there is no accurate data on what portion of stranded fish are actually salvaged, and what portion of fish in the river become stranded. This makes it difficult to assess whether or not stranding has a population level impact on fish in the Coquitlam River.

Summary of Recommendations

- The ramp rate for the June flow reduction could be further modified to be more gradual, possibly taking place over several days for example.

- Stranding of large numbers of Coho fry during the June rampdown will continue to be an issue under the current flow regime. A reexamination of the target flow level of $1.1m^3/s$ should be considered as it falls outside of the natural hydrograph for the Coquitlam River and clearly creates a high stranding risk.

- Examine ways to assess what portion of fish present in the Coquitlam River become stranded during rampdowns. This would help to gain a better understanding of whether or not stranding has a population level impact of fish species in the river

- During scheduled rampdowns fish salvage crews should focus efforts in Reach 4, due to the elevated risk of stranding in this area.

- Monitoring for fish stranding should be continued in order to ensure that flow targets are achieved and all potential stranding is monitored. Continued monitoring will also act to guard against any LLO gate failures or operator errors.

- Future June 1 scheduled rampdowns should continue to use the modified gate closure operation due to the successful implementation in 2013.

- Ensure proper communication with Fraser Valley Operations (FVO) desk during gate closures. This is critical to prevent flow changes happening when crews are not present.

- Pay special attention to the side channel that feeds water into the hatchery during rampdowns in January and June-September when releases are less than $3.0 m^3/s$ as it has the potential to dry up.

- Future rampdowns related to Sockeye smolt attraction flows will need to be carefully monitored if they occur in the spring due to the increased stranding risk associated with the timing, duration and magnitude of these events.

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Appendix 1 Total daily and hourly river stage reductions by staff gauge scheduled rampdowns.

May 1, 2016

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0830	0.33	0930	0.68	1000	7.86	
0900	0.33	1100	0.68	1200	7.85	
1000	0.31	1300	0.66	1400	7.84	
1200	0.30	1430	0.66	1600	7.84	
1330	0.30	1600	0.66	1800	7.84	
	3.0		2.0		2.0	Max Stage Reduction (cm)
	3.0		1.0		0.5	Max Stage Reduction (cm)/hr

1-Jun-16

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	.31	0900	.60	0900	7.85	
1030	.29	1200	.59	1100	7.85	
1200	.28	1300	.57	1200	7.84	
1400	.28	1400	.57	1400	7.82	
1600	.28	1600	.57	1600	7.815	
	3.0		3.0		3.5	Max Stage Reduction (cm)
	1.5		2.0		1.0	Max Stage Reduction (cm)/hr

8-Jun-16

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0830	.27	0900	.57	1000	7.81	
0930	.26	1100	.56	1100	7.80	
1130	.225	1200	.55	1200	7.79	
1300	.225	1400	.55	1400	7.77	
1500	.225	1600	.55	1600	7.77	
	4.5		2.0		4.0	Max Stage Reduction (cm)
	1.9		1.0		1.0	Max Stage Reduction (cm)/hr

15-Jun-16

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	.225	0930	.60	1000	7.85	
1000	.20	1100	.59	1100	7.83	
1100	.17	1200	.58	1200	7.81	
1230	.155	1400	.56	1400	7.80	
1400	.155	1600	.56	1600	7.80	
	7.0		4.0		5.0	Max Stage Reduction (cm)
	3.0		1.0		2.0	Max Stage Reduction (cm)/hr

September 1, 2016

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0800	0.30	0900	0.68	0800	7.76	
0900	0.30	1100	0.70	1000	7.76	
1000	0.28	1300	0.69	1200	7.79	
1200	0.27	1430	0.70	1400	7.74	
1400	0.27	1600	0.70	1600	7.75	
				1800	7.80	
	3.0		1.0		5.0	Max Reduction (cm)
	1.0		0.5		2.5	Max Reduction (cm)/hr

November 1, 2016

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	0.45	0800	0.72	0800	8.07	
1030	0.44	1000	0.70	1000	8.07	
1130	0.42	1130	0.69	1200	8.06	
1230	0.41	1400	0.69	1400	8.05	
1500	0.39	1600	0.69	1600	8.07	
1600	0.39	1700	0.69	1800	8.06	
				2200	8.19	
	5.0		3.0		2.0	Max Daily Stage Reduction (cm)
	2.0		1.0		0.5	Max Stage Reduction (cm)/hr

January 16, 2017

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	0.44	0800	0.78	0800	7.91	
1030	0.40	1000	0.77	1000	7.91	
1130	0.37	1130	0.76	1200	7.90	
1300	0.34	1300	0.73	1400	7.87	
1500	0.33	1430	0.70	1600	7.85	
1600	0.32	1700	0.69	1800	7.80	
				2000	7.87	
	12.0		9.0		11.0	Max Reduction (cm)
	3.0		2.0		2.5	Max Reduction (cm)/hr

Apirl 1, 2017

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	0.40	0800	0.86	0800	8.07	
1030	0.38	1000	0.86	1000	8.08	
1130	0.37	1130	0.84	1200	8.06	
1300	0.36	1300	0.83	1400	8.06	
1500	0.36	1430	0.83	1600	8.05	
1600	0.36	1700	0.83	1800	8.04	
	4.0		3.0		3.0	Max Reduction (cm)
	1.3		1.3		0.5	Max Reduction (cm)/hr

May 3, 2017

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0830	.54	0900	.74	0600	8.14	
0930	.50	1030	.77	0800	8.19	
1100	.43	1200	.80	1000	8.22	
1200	.39	1400	.79	1200	8.22	
1330	.37	1600	.79	1400	8.20	
1530	.34			1600	8.18	
				1800	8.18	
				2000	8.20	
	4.0		3.0		2.0	Max Reduction (cm)
	2.0		1.0		1.0	Max Reduction (cm)/hr

May 13, 2017

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0800	.52	0900	.74	0600	8.15	
0930	.47	1030	.73	0800	8.13	
1030	.43	1200	.72	1000	8.12	
1200	.40	1400	.72	1200	8.09	
1330	.36	1600	.71	1400	8.05	
1600	.32			1600	8.00	
				1800	7.99	
				2000	8.00	
	4.0		3.0		15.0	Max Reduction (cm)
	2.0		1.0		2.5	Max Reduction (cm)/hr

1-Jun-17

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0700	.33	0730	.75	0700	7.96	
0830	.31	0930	.75	1000	7.97	
0930	.29	1100	.75	1200	7.96	
1000	.28	1400	.74	1400	7.95	
1200	.28	1600	.74	1600	7.94	
1500	.28	1700	.74	1800	7.94	
	5.0		1.0		2.0	Max Reduction (cm)
	2.0		0.3		0.5	Max Reduction (cm)/hr

8-Jun-17

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	.28	0900	.71	1000	7.97	
1000	.27	1100	.71	1200	7.96	
1100	.25	1200	.74	1400	8.08	
1200	.24	1400	.86	1600	8.38	
1400	.24	1600	.87	1800	8.36	
	4.0		0.0		1.0	Max Reduction (cm)
	2.0		0.0		0.5	Max Reduction (cm)/hr

15-Jun-17

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	.24	0930	.64	1000	7.80	
1000	.23	1100	.63	1200	7.80	
1100	.21	1200	.65	1400	7.81	
1230	.21	1400	.68	1600	7.82	
1400	.21	1600	.74	1800	7.93	
	3.0		1.0		0.0	Max Reduction (cm)
	2.0		0.3		0.0	Max Reduction (cm)/hr

Appendix 2 Site descriptions and photographs.

Reach 1

Site A1: This area is characterized by densely treed and shrubby river margins that contain many depressions that form isolated pools. The substrate is mainly soil and vegetated cover, along with some areas of exposed gravel and cobble.
Total Area: 3800m^2

Figure 7 Site A1 showing gravel bar separating river mainstem (left) with isolated pool (right), following rampdown June 1 2012.

Figure 8 Showing trench dug to allow water from river mainstem to flow into isolated pool.

Figure 9 Site A1showing gravel area on fluvial island where fish are regularly stranded

Site A2: These areas are characterized by large expanses of exposed gravel and cobble suitable for spawning adjacent to the river, accompanied by moderately treed areas with numerous depressions that form isolated pools when dewatering. These areas represent a hazard for stranding of both adults, juveniles and redds due to the combination of off channel habitat and spawning gravel that is wetted during flow releases.
Total Area: 19000m^2

Site A3: This area is primarily a large gravel and cobble fan with gently sloping topography. There are several areas where large isolated pools form during rampdowns.
Total Area: 4800m^2

Reach 2A

Site B1: This area is a side channel that is normally wetted except at very low flows (below 3.00cms WSC gauge Port Coquitlam). It is a gravel and cobble substrate, that drains quickly and leaves behind many isolated pools. It rarely completely dewaters, so is only a stranding risks when flow in the river is very low.
Total Area: 270m^2

Site B2: This area is a long narrow partially treed platform with a combined soil, gravel and vegetated substrate. It strands adults, juveniles and redds. This site only becomes

inundated during a full three LLO release, and is one of the earliest sites to begin dewatering.
Total Area: 3000m^2

Figure 10 Site B2, showing isolated pool formed during flow reduction, this site strands juveniles, adults and redds. Substrate is primarily mud and soil.

Site C1: This site is a long side channel composed of gravel and cobble substrate. It drains rapidly and forms many isolated pools that do not retain water well. This site experienced the highest number of stranding during the past two years
Total Area: 690m^2

Figure 11 View of site C1 side channel that is wetted during single gate openings. This site typically has one of the highest incidence of stranding on Coquitlam River.

Site C2: The area is densely covered in shrubs. The substrate is very muddy with vegetated ground cover. Juveniles were regularly stranded in this area until the 2007/2008 rampdown period, which often requires the use of minnow traps for salvage. River Morphology changes may have reduced the risk of stranding at this site.
Total Area: 550m^2

Reach 2B

Site C3: This site is a small side channel composed of gravel and cobble substrate. It drains slowly and forms many isolated pools that do not retain water well. This site experiences only minimal stranding.
Total Area: 60m^2

Site D1: This area is long side channel that completely dewaters during the June flow reduction. It is a gravel cobble substrate combined with some deeper pools
Total Area: 300m^2

Site D2: Parts of this area are densely vegetated with trees and shrubs, though It is primarily a narrow river margin with cobble and boulder substrate.
Total Area: 60m^2

Reach 3

Site D3: This area is a combination of a long, narrow platform densely grown in with trees and shrubs, as well as a small side channel that is permanently wetted. It has a combined soil, gravel and vegetated substrate. Isolated pools form during flow reductions, stranding juveniles which are best removed using minnow traps due to the dense concentration of roots within the pools.
Total Area: 665m^2

Site D4: This area is a small series of pools, with a gravel substrate. Some of the pools are quite deep <30cm and attract coho fry and steelhead fry and smolts.
Total Area: 40m^2

Reach 4

Site E1: This area is adjacent to a rearing pond that overflows during dam releases. Juveniles spill over the pond and can become stranded. Substrate is mainly cobble and gravel intermixed with moderately treed areas.
Total Area: 900m^2

Site E2: This area consists of narrow river margins that are densely treed and shrub covered. Many isolated pools form close to the river mainstem during gate closure.

Observations over the past 3 years indicate that many of these pools remain wetted year round due to their proximity to the river channel.
Total Area: 1800m^2

Site E3: This area, situated near the dam face, is densely covered in trees and shrubs. Isolated pools are minimal, but juveniles are often caught in the area of dense vegetation during dewatering.
Total Area: 340m^2

Summary of best fit escapement estimates and survey peak count for Chum, Pink, Coho and Chinook 2002-2018 (Schick et al 2016)

		Chum		Pink		Coho		Chinook	
Year	**T**	**est.**	**count**	**est.**	**count**	**est.**	**count**	**est.**	**count**
2002	1	15,378	4,874	-		2,648	346	-	
2003	1	18,301	4,953	5,418	2,937	1,562	320	-	87
2004	1	27,992	6,073	-	-	2,562	511	-	21
2005	1	24,559	5,592	4,279	1,115	1,334	164	-	22
2006	1	51,860	11,348	-	-	939	91	-	76
2007	1	11,066	2,287	2,944	1,154	2,401	405	-	182
2008	1	18,224	3,586	-	-	878	177	952	295
2009	2	19,600	7,185	10,698	3,597	3,175	516	1,529	743
2010	2	6,931	1,659	-	-	12,338	1,292	8,018	1798
2011	2	27,410	9,504	10,427	3,706	3,835	899	4,918	1254
2012	2	57,300	4,502	-	-	11,320	1,269	1,632	292
2013	2	42,220	11,498	34,280	10,081	13,290	1,341	2,413	669
2014	2	8,491	2,854	-	-	4,957	1,029	572	130
2015	2	23,410	7,391	9,327	5,311	4,979	881	123	66
2016	2	78,120	15,172			6,867	1,156	511	105
2017	2	n/s		n/s		n/s		n/s	
2018	2		5,369	-	-		928		113
T1 Mean		**23,911**	**5,530**	**4,214**	**1,735**	**1,761**	**288**	**952**	**114**
T2 Mean		**32,935**	**7,237**	**16,183**	**5,674**	**7,595**	**1,035**	**2,465**	**574**

Appendix 3 Coquitlam River rampdown site maps and discreet stranding locations represented by the red dots.

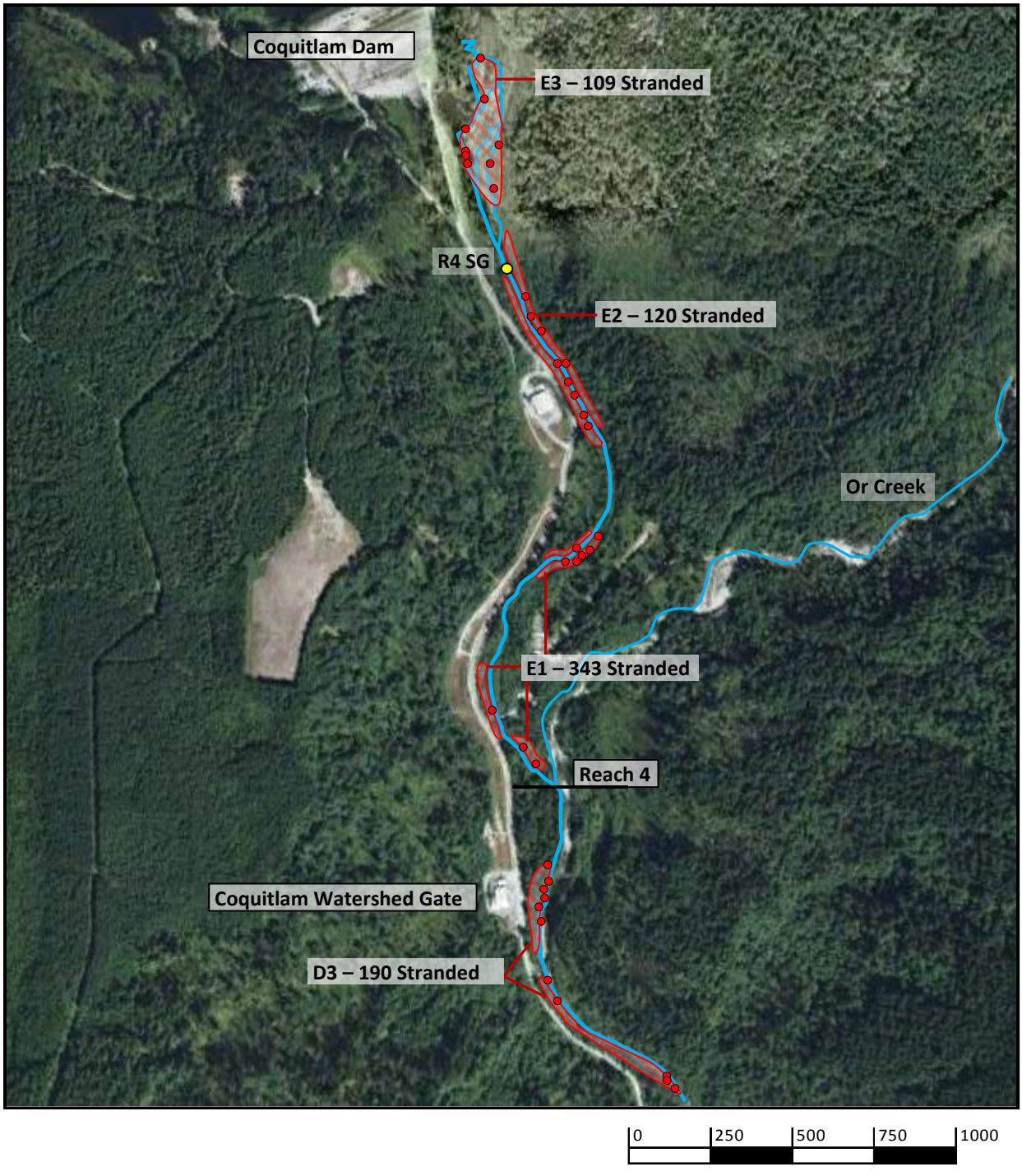

Figure A
Coquitlam River Stranding Reach 4 and 3.

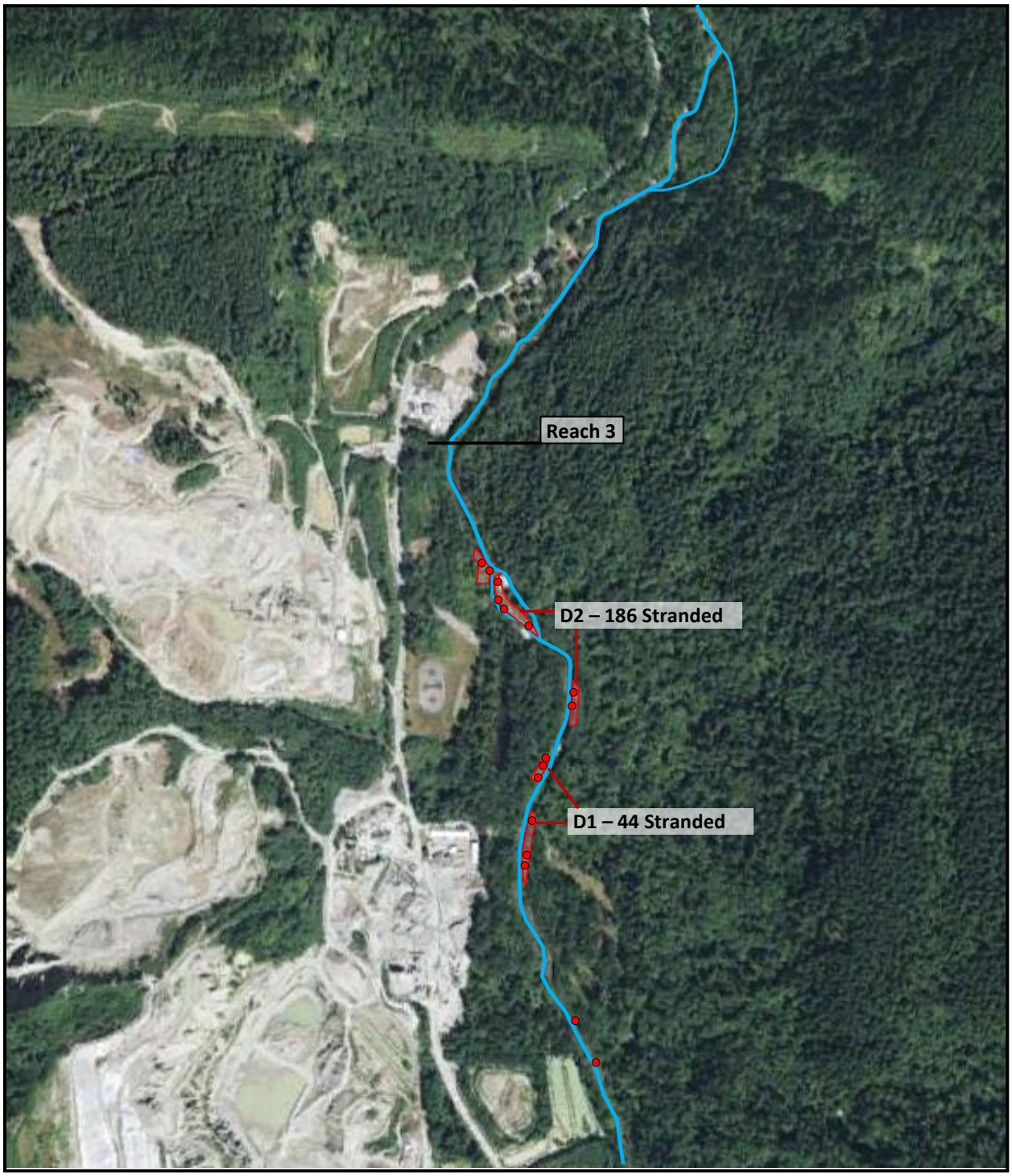

Figure B
Coquitlam River Stranding Reach 3 and 2b

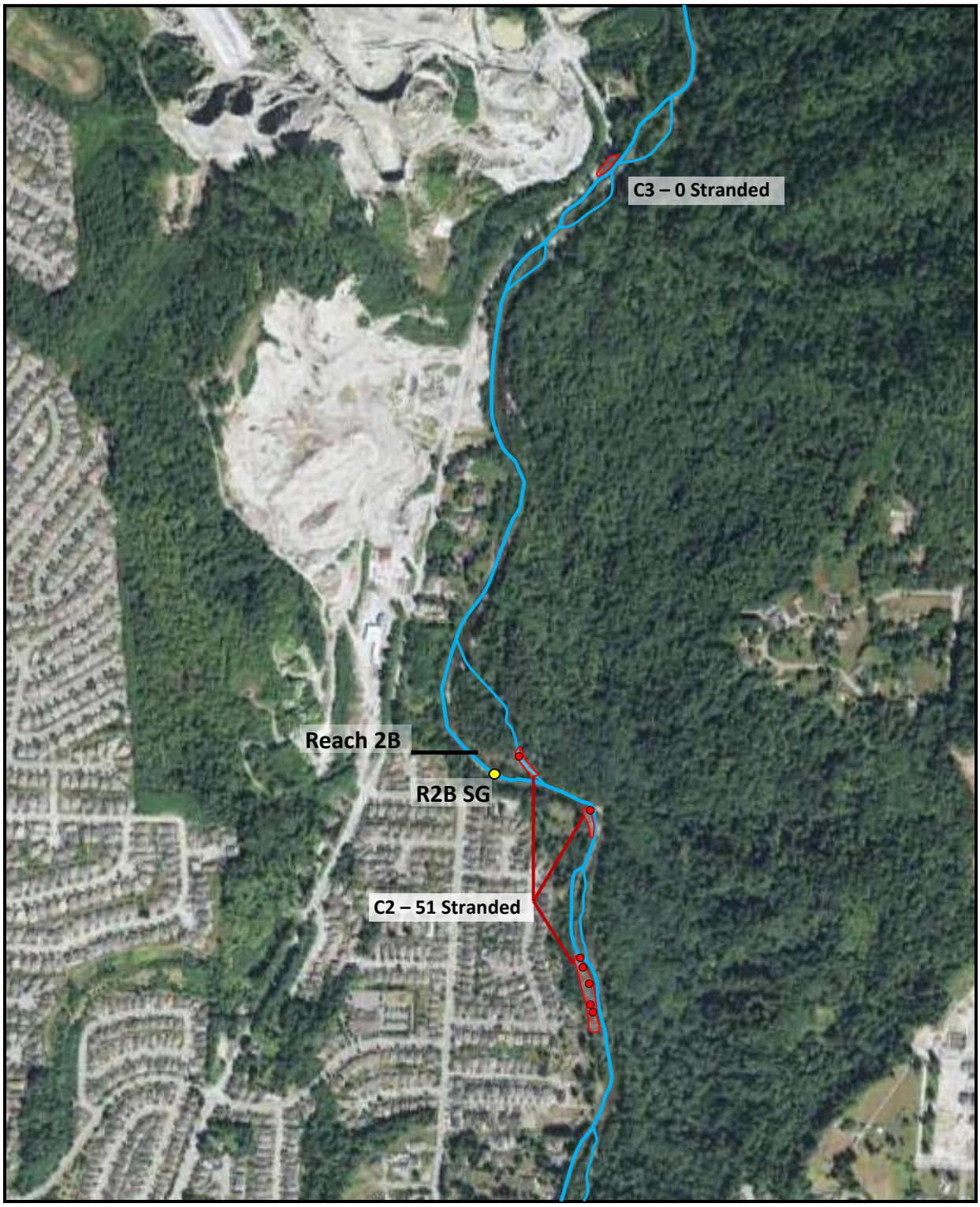

Figure C
Coquitlam River Stranding, Site C, Reach 2a & 2b.

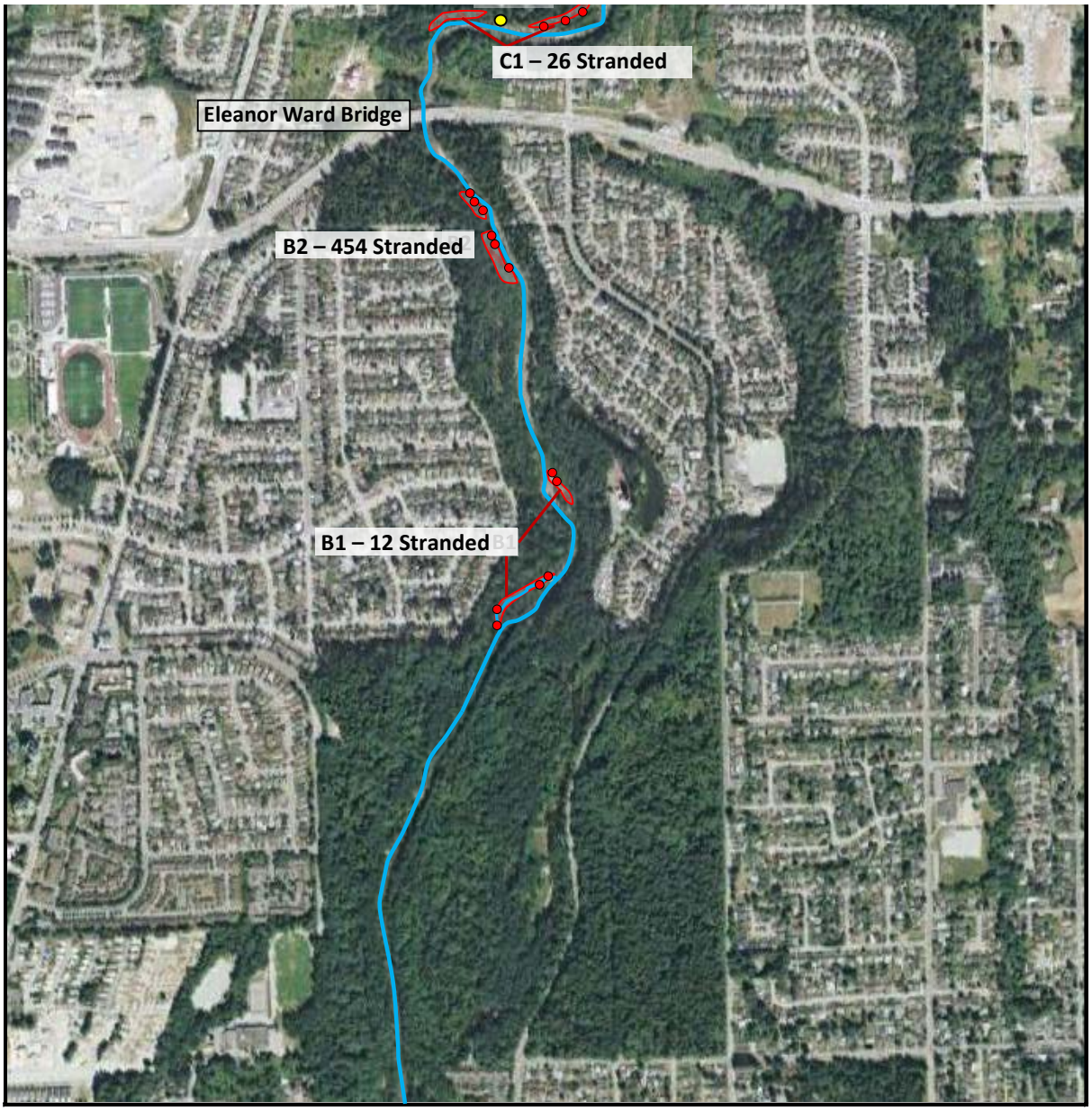

Figure D

Coquitlam River Stranding, Site B & C, Reach 2a.

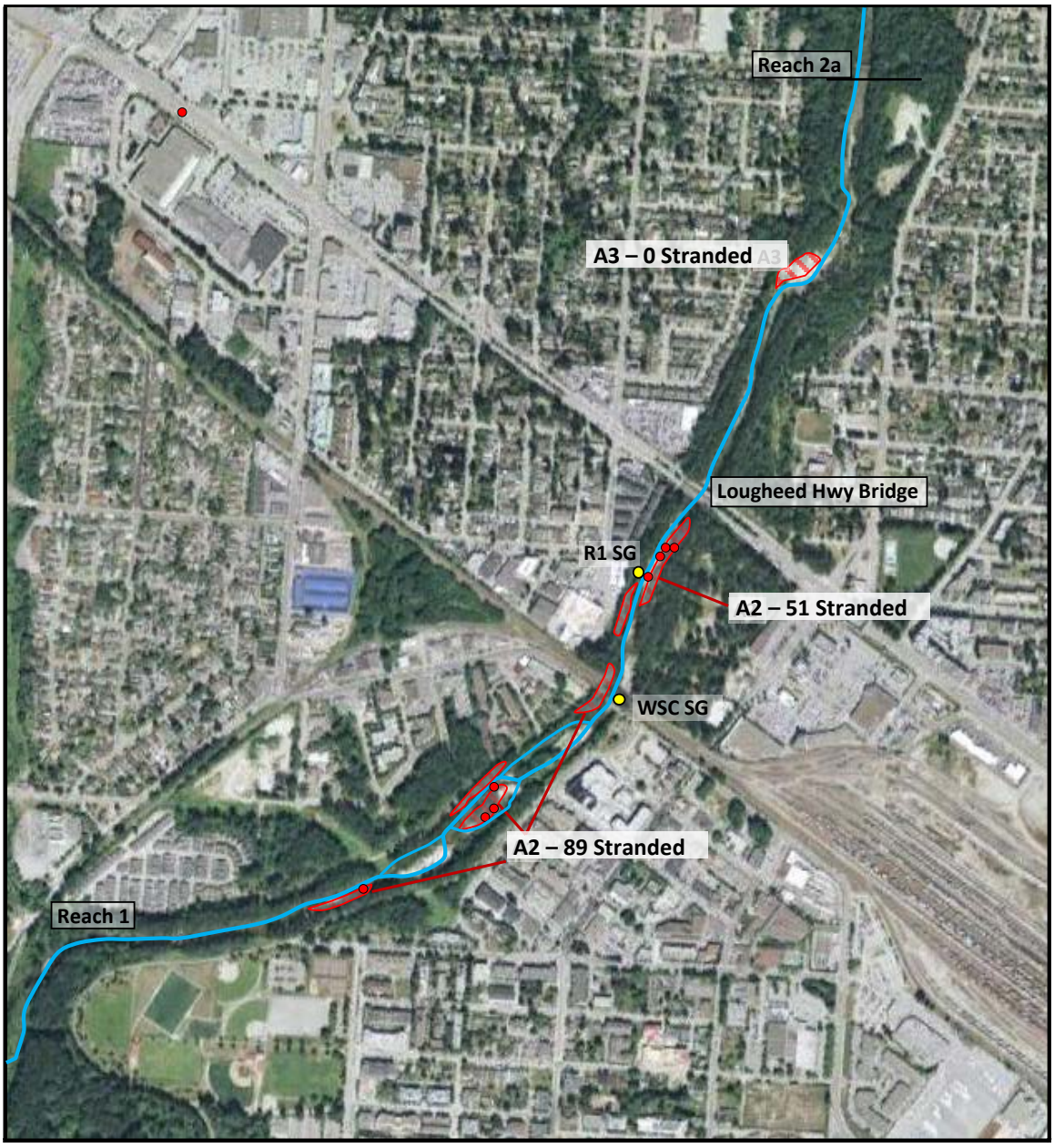

Figure E

Coquitlam River Stranding, Site A, Reach 1.