Coquitlam-Buntzen Water Use Plan

Reference: COQMON #2

Coquitlam River Rampdown Fish Stranding Monitoring

Implementation Year 11

Study Period: May 1, 2015 – April 1, 2016

Living Resources Environmental Services
#3-108 West 11th Ave., Vancouver B.C. V5Y 1S7
Ph: 604-862-2323 Email:jacemacnair@yahoo.ca

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Executive Summary

This report summarizes rampdown events occurring on the Lower Coquitlam River for the water year May 1, 2015 to April 1, 2016. A total of 10 rampdown events were monitored during the annual survey period: six scheduled rampdowns; May 1, June 1-2, September 1, November 1, 2015and January 15 and April 1, 2016; and four unscheduled rampdowns: November 19 and December 19, 2015 and Feb 1-2 and March 15-16, 2016.

The 2015-2016 water year was the seventh complete year under the Treatment 2 flow regime (only half the year in 2008-2009 was under Treatment 2). 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 requirement of 149m maximum allowable reservoir operating level in 2008, following commissioning of the new dam, has increased reservoir storage. The higher reservoir operating level has not lead to a reduction in the frequency of large scale flow releases and their subsequent full river rampdown fisheries impact surveys. Under Treatment 2 total rampdowns per year have increased from an average of 2.7 to 8.5 per year and unscheduled rampdowns have increased to an average of 3.3 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 were captured and relocated to the river mainstem by dip netting, seine netting or by using gee-type minnow traps. The six scheduled rampdowns stranded a total of 3857 fish, 3455 of which were salvaged alive. The four unscheduled rampdown events produced a total of 465 stranded fish. The total number of fish stranded for all rampdowns, 4322, has been the largest number observed since surveys were initiated in 2001. The dominant species observed during fish salvage operations were juvenile Coho Salmon (85.5.% of all fish sampled).

Modifications to the June rampdown were initiated in 2013 in order to reduce the increasing number of mortalities and stranded individuals observed during previous June events. Rampdowns during this month have 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 2.9 m^3/s to 1.1 m^3/s (a 64% reduction in flow). Since 2013 the modified rampdown method has been 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%.

Acknowledgements

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

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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 can 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 the 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 inthe 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 the 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 3.00 m^3/s and 0.60 m^3/s) in the total volume of water released from the Coquitlam Dam (Table 1), but can represent a sizeable decrease in the total volume of water entering the Coquitlam River. For example, rampdowns scheduled for the dates January 15 and June 1 constitute a drop in the total flow release into the 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 the 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 the 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 the 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 the 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.

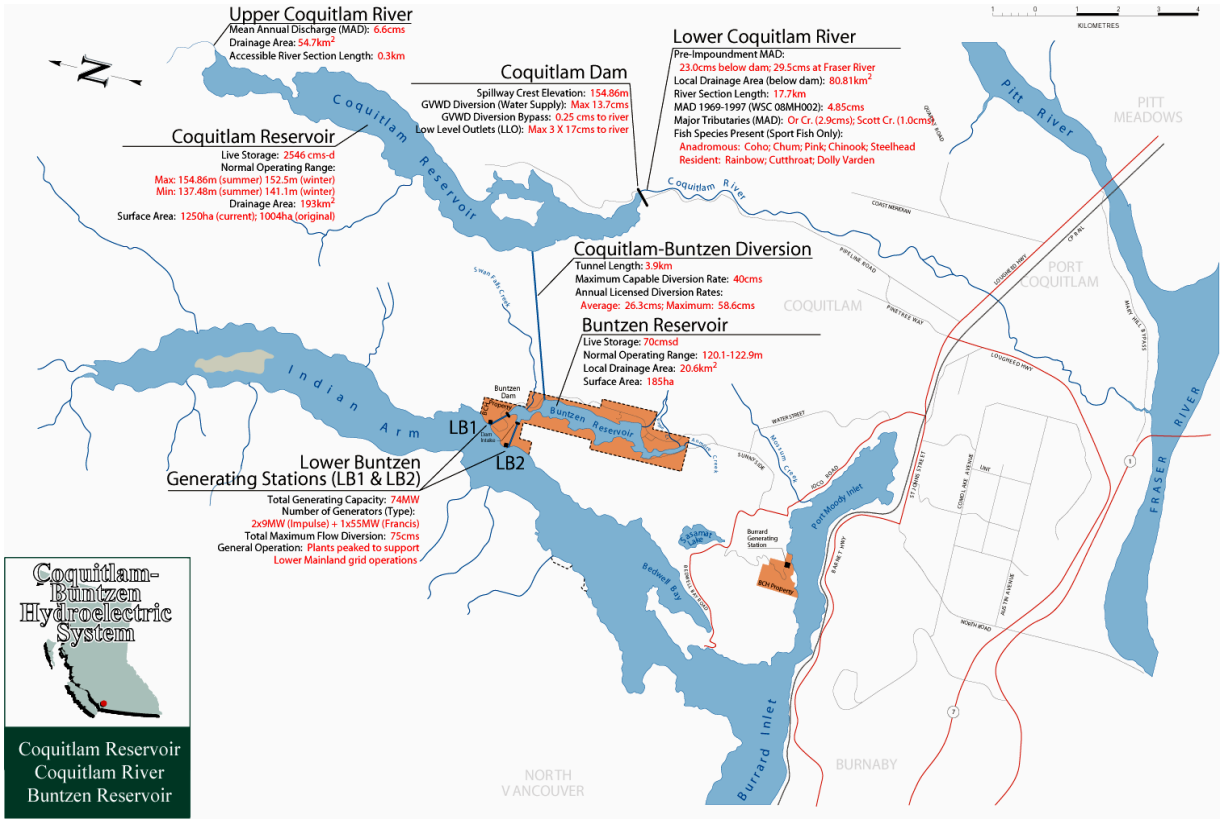

Figure 1 Coquitlam-Buntzen Reservoir, Diversion and Generating System. Map adapted from BC Hydro. Coquitlam-Buntzen Water Use Plan Monitoring Program Terms of Reference Revision 1: December 14, 2006

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 flow 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 under 2014-2015. *Estimated flow is based on monthly flow transects performed to confirm flow target compliance. Scheduled gate changes normally occur on the first of each month with the exception of the January 15 flow reduction. Table adapted from BC Hydro. Coquitlam-Buntzen Water Use Plan Monitoring Program Terms of Reference Coquitlam Dam Flow Release Interim Ramping Rate Monitoring. Revision 1: December 14, 2006

		Reservoir Diversion Schedule (m^3/sec)					
		Domestic Water		Coquitlam Dam Releases			
				Treatment 1	Treatment 2		
Month	Year	Target	Min	Target	Target	Estimated*	Min
April	2015	12.0	10.8	0.8	3.5	3.19	1.1
May	2015	12.0	11	1.0	2.9	2.55	1.1
June	2015	12.0	10.9	1.4	1.1	1.33	1.1
July	2015	18.0	15.8	1.4	1.2	0.86	1.1
August	2015	23.0	20.2	1.1	2.7	1.11	1.1
September	2015	23.0	20.9	0.8	2.2	1.22	1.1
October	2015	12.0	10.8	0.8	6.1	6.49	3.6
November	2015	12.0	10.8	1.1	4.0	4.40	1.5
December	2015	11.9	10.7	1.1	5.0	5.98	2.5
Jan 1-15	2016	11.9	10.7	1.0	5.9	5.98	3.6
Jan 15-31	2016	11.9	10.7	1.0	2.9	2.94	2.9
March	2016	11.9	10.7	1.0	4.3	4.59	1.1
April	2016	12.0	10.8	0.8	3.5	3.63	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 a using 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

Coquitlam Rampdown May 1, 2015

On May 1, 2015 as scheduled under the current flow regime (Treatment 2), the Low Level Outlet (LLO) release from Coquitlam Dam was scheduled to be reduced from 3.5 m^3/s to 2.9 m^3/s. The scheduled rampdown began at approximately 0900hr and was completed by 1030hr.

Upstream of Or Creek (Reach 4), river stage dropped a total of 3.0 cm following completion of the flow reduction and had a maximum hourly decrease of 1.0 cm/hr (Table 3). Downstream of Or Creek river stage dropped between 2.0 and 3.0 cm. Stranding was observed in three locations in Reach 3, one location in Reach 2b and one location in Reach 2a (Table 3). A total of 116 fish were observed to be stranded, with a total mortality of 21 (Table 3). Coho fry represented all fish stranded.

The number of fish stranded during this salvage is the largest number yet observed for the May 1 rampdown. This was also the case with the April 1, 2015 rampdown. This is likely due to the fact that there has yet to be any sign of a freshet in the Coquitlam River. The low snow pack had left the Coquitlam River discharge and stage elevation much lower than normal, which may explain why the risk of fish stranding was greater than normal for this time of year.

Following the completion of gate changes, a flow transects was taken, at the Reach 4 site established 300m D/S of the Coquitlam Dam, This transect produced a flow estimates of 2.98 m^3/s, this estimate is within the targeted range for the Treatment 2 flow release of 2.9 m^3/s.

Coquitlam Rampdown June 1-2, 2015

From June 1-2, 2015 in response to the current flow regime, the Low Level Outlet (LLO) release from the Coquitlam Dam was scheduled to be reduced from 2.9 m^3/s to 1.1 m^3/s The scheduled flow reductions in 2015 were performed over 2 days, each beginning at approximately 0900hr. June 1 saw the flow decrease from 2.55-1.97 m^3/s, flow on June 2decreased from 2.12 – 1.09 m^3/s. 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 16.0 cm in 2-3 hours. The maximum decrease this year was 7 cm over 3.0 hours on June 1, 2015 (Table 3).

Fish stranding during the June 1-2 rampdown reached an all-time high of 3679 fish. Of this total 3468 were Coho fry, 210 Steelhead fry and 1 Steelhead parr (in addition to 23

Coastal Tailed Frogs and 2 Lamprey). The mortality rate was 10.3%, an increase compared to the past two years (Figure 1). The fact that the Coquitlam River was experiencing unusually low flow for this time of year likely played a role in the increase in stranding and mortality. In 2015 there was minimal to no freshet emanating from Or Creek, which means that all areas downstream of Reach 4 were experiencing minimal inflow outside of the dam release.

Coquitlam Rampdown September 1, 2015

On September 1, 2015 LLO releases from Coquitlam Dam were scheduled to be reduced from 2.7 m^3/s to 2.2 m^3/s. The scheduled rampdown began at approximately 00830hr and was completed by 1030hr. Total flow river stage reduction was 2 cm in Reach 4 and between 1-2 cm downstream of Reach 4 (Table 3). No stranding was observed throughout the course of the rampdown.

Coquitlam Rampdown November 1, 2015

On November 1, 2015 the LLO release from the Coquitlam Dam was scheduled to be reduced from 6.1 m^3/s to 4.0 m^3/s. The scheduled rampdown began at approximately 0945hr and was completed by 1200hr. River stage elevation downstream of Or Creek dropped approximately 4.0cm following completion of the flow reduction (Figure 2). No stranding was observed and no stranding risk was evident as the detectable decrease in river stage elevation was too small downstream of Or Creek. Upstream of Or Creek, river stage elevation dropped a total of 7.0 cm over the course of the rampdown with an average decrease of 3.0 cm/hr no stranding was observed.

Coquitlam Rampdown January 16, 2016

On January 15, 2016 in response to the current flow regime, the Low Level Outlet (LLO) release from the Coquitlam Dam was scheduled to be reduced from 5.9 m^3/s to 2.9 m^3/s. The scheduled rampdown began at approximately 0845hr and was completed by 1300hr.

Upstream of Or Creek (Reach 4), river stage dropped a total of 16 cm following completion of the flow reduction and had a maximum hourly decrease of 5.5 cm/hr (Table 3). Stranding was observed in one location in Reach 3 (Table 3). In Reach 3, 13 Steelhead smolts and 19 Coho smolts were salvaged (Figure 1). 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. 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 D/S of the Coquitlam Dam. Discharge was estimated at 2.94 m^3/s which is within the target range for the Treatment 2 flow release of 2.9 m^3/s.

Coquitlam Rampdown April 1, 2016

On April 1, 2016 in response to the current flow regime, the Low Level Outlet (LLO) release from the Coquitlam Dam was scheduled to be reduced from 4.3 m^3/s to 3.5 m^3/s. The scheduled rampdown began at approximately 0900hr and was completed by 1030hr.

Upstream of Or Creek (Reach 4), river stage dropped a total of 5.0 centimetres following completion of the flow reduction and had a maximum hourly decrease of 2.0 cm/hr (Table 3). Downstream of Or creek river stage dropped between 2.0 and 3.0 cm. Stranding was observed in two locations in Reach 4 and a total of 6 Chum fry were observed to be stranded. Of the stranded fry, 5 were salvaged and returned to the river. (Table 3).

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 estimates of 3.58 m^3/s, this estimate is within the targeted range for the Treatment 2 flow release of 3.5 m^3/s.

Table 3 Fish stranding by species, age class and Reach during scheduled rampdowns 2015-2016. Co 0 = Coho fry. Cm 0 = Chum fry. Pk 0 = Pink fry. St 1 = Steelhead parr/smolt. LMP = Lamprey. CTF = Coastal tailed frog.

			Reach						Stage Decrease cm		
Date	**Sp.**	**Salv/Mort**	**1**	**2a**	**2b**	**3**	**4**	**Total**	**R4**	**R2b**	**R1**
1-May-15	Co 0	s		29	43	23		95			
1-May-15	Co 0	m			17	4		21			
1-Jun-15	Co 0	s		327	12	457	209	1005	7	4	4
1-Jun-15	Co 0	m		16		61	20	97			
1-Jun-15	St 0	s		7		103	10	120			
1-Jun-15	St 0	m		2		15	1	18			
1-Jun-15	St 1+	s					1	1			
1-Jun-15	CTF	s					18	18			
2-Jun-15	Co 0	s	205	121	64	1606	118	2114	5	3	4
2-Jun-15	Co 0	m	87		26	118	21	252			
2-Jun-15	St 0	s	23	16	11		8	58			
2-Jun-15	St 0	m	7		3	4		14			
2-Jun-15	Lmp	s				1	1	2			
2-Jun-15	CTF	s					5	5			
1-Sep-15	n/a	n/a						0			
2-Nov-15	n/a	n/a						0			
15-Jan-16	Co 1+	s				18		18	16	11	12
15-Jan-16	Rt 1+	s				13		13			
1-Apr-16	Cm 0						5	5	4	3	3
1-Apr-16	Cm 0						1	1			
			322	**518**	**176**	**2423**	**418**	**3857**			

3.2 Unscheduled Rampdowns

Four unscheduled rampdown occurred on the Coquitlam River during the 2015-2016 monitoring program.

Coquitlam Rampdown Summary November 19, 2015

On November 19, 2015 a rampdown fish salvage was undertaken on the Coquitlam River following a full 3 LLO gate spill that been ongoing since November 12, 2015. Due to extremely high inflow and the accompanying risk of downstream flooding, the gate closure occurred on the evening of November 17, 2015 when salvage crews could not be on site. This situation was unavoidable due to the flood risk and community safety issues taking precedence over fish salvage surveys. The fish salvage was therefore carried out the day after the gate closure.

Fish stranding was dominated by juvenile Steelhead and Coho; a total of 35 were observed stranded with 22 salvaged live and returned to the river (Table 4). In total 37 stranded fish were observed over the two day period. Due to the fact that the fish salvage took place the day after the rampdown, recovery of live stranded fish was hampered. In addition, stranded fish remains were likely preyed upon prior to the fish salvage survey and therefore were not able to be enumerated.

Coquitlam Rampdown Summary December 18-19, 2015

On December 18, 2015 a rampdown fish salvage was undertaken on the Coquitlam River following a full 3 Low Level Outlet (LLO) gate spill that been ongoing since December 9, 2015. The gate closure was initiated on Friday, December 18 at 0830hr when the first of two LLO gates were shut at the prescribed rate. Due to a miscommunication between staff at Fraser Valley Operation Centre (FVO), the third and final gate was ramped down on the evening of December 18, 2015 and not the following day as planned. This error meant that salvage crews could not be on site during the final gate closure. This situation lead to a greater than normal amount of stranding and fish mortality as a result of the rampdown.

In total 101 stranded fish were observed over the two day period. Fish stranding was dominated by juvenile Steelhead and Coho with a total of 59 or 60% represented by these two species (Table 4). Due to the fact that the fish salvage took place the day after the rampdown, recovery of live stranded fish was severely hampered. Stranded fish remains were likely preyed upon prior to the fish salvage survey and therefore were not able to be enumerated. Of the 101 fish stranded, all but one was recovered on December 19, the second day of the rampdown.

Since 2007 eight full 3 LLO rampdowns have occurred in the winter months and have averaged 59 stranded fish and a mortality rate of 26%. This compares to the 101 stranded during the December 18-19, which had a mortality rate of 82%. This high incidence of mortality is likely a direct result of the rampdown occurring when no fish salvage crew was on site.

Coquitlam Rampdown Summary February 1-2, 2016

On February 1 and 2 , 2016 a rampdown fish salvage was scheduled to be undertaken on the Coquitlam River following a full 3 Low Level Outlet LLO gate spill that had been initiated on January 27, 2016. The flow reduction on both days was initiated at 0830hr when the first of two LLO gates were designated to be shut at the prescribed rate.

Upstream of Or Creek (Reach 4), river stage dropped a total of 5.0 centimetres following completion of the flow reduction and had a maximum hourly decrease of 2.0 cm/hr (Table 4). Downstream of Or creek river stage dropped between 2.0 and 3.0 centimetres. Stranding was not observed in any area of Coquitlam River during the fish stranding survey.

Coquitlam Rampdown Summary March 15-16, 2016

On March 14, 2016 a rampdown fish salvage was scheduled to be undertaken on the Coquitlam River following a full 3 Low Level Outlet LLO gate spill that had been initiated on March 10, 2016. The flow reduction was initiated 0830hr when the first of two LLO gates were designated to be shut at the prescribed rate. However, due to a technical problem with the remote gate operation, the scheduled gate closure and fish salvage had to be postponed until March 15-16, 2016. The flow reduction went ahead as planned on the following two days.

In total 343 stranded fish were observed over the two day period. Fish stranding was dominated by juvenile Chum Salmon and Coho Salmon with a total of 313, or 91.3%, represented by these two species with Chum representing 77.0% of the entire number observed stranded (Table 4). This is the largest number of Chum observed stranded during any rampdown to date.

Since 2007, eight full 3 LLO rampdowns have occurred in the winter months and have averaged 59 stranded fish and a mortality rate of 26%. This compares to the 343 stranded during the March 15-16 rampdown, which had a mortality rate of 41%. This high incidence of mortality is likely a direct result of the rampdown occurring when Chum fry were migrating out of the system in large numbers.

Table 4 Fish stranding by species, age class and Reach during unscheduled rampdowns 2015-2016. Co 0 = Coho fry. Cm 0 = Chum fry. Pk 0 = Pink fry. St 1 = Steelhead parr/smolt

			Reach					
Date	**Sp.**	**Slav/Mort**	**1**	**2a**	**2b**	**3**	**4**	**Total**
19-Nov-15	Co 0	s					22	22
19-Nov-15	St 0	m		2			4	6
19-Nov-15	St 1+	m					7	7
19-Nov-15	Dace	m					2	2
18-Dec-15	Cray	s			1			1
19-Dec-15	TSS	s	2					2
19-Dec-15	Cot	s	5					5
19-Dec-15	Lmp	s	3					3
19-Dec-15	Co 0	s					6	6
19-Dec-15	St 0	s		2				2
19-Dec-15	TSS	m	25					25
19-Dec-15	Cot	m	2	3				5
19-Dec-15	Co 0	m	8	2			9	19
19-Dec-15	St 0	m	6	2	11			19
19-Dec-15	St 1+	m	3		7		3	13
19-Dec-15	Dace	m					1	1
1-Feb-16	n/a							
2-Feb-16	n/a							
15-Mar-16	Cm 0	s	17		16			33
15-Mar-16	Rt 1+	s		2		3		5
15-Mar-16	Lmp	s	1					1
15-Mar-16	Cray	s		2				2
15-Mar-16	Cm 0	m	15	16			21	52
15-Mar-16	Rt 1+	m	1	1		1		3
15-Mar-16	Pk 0	m		1				1
16-Mar-16	Cm 0	s	22	15		67	4	108
16-Mar-16	Rt 1+	s					6	6
16-Mar-16	Co 1+	s					47	47
16-Mar-16	Cm 0	m	13	20		24	7	64
16-Mar-16	Rt 1+	m	3				3	6
16-Mar-16	Pk 0	m	2					2
			128	**68**	**35**	**95**	**142**	**468**

4.0 Discussion

4.1 Stranding Risk

In this, the seventh full year of rampdown monitoring under Treatment 2 (2015-2016), the total of 4322 stranded fish observed was the largest amount since surveys were initiated in 2001 (Table 5). 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 or early June (including scheduled and unscheduled events). 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 81.8% of all stranding observed on the Coquitlam River in the past five years and in 2015-2016 was responsible for 86% of all stranding.

The June flow adjustment of 2.9 m^3/s to 1.1 m^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 2). 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.

Exacerbating this problem in the late spring of 2015 was the fact that there was only minimal rainfall and a low snowpack which meant that there was virtually no freshet emanating from Or Creek. This lead to a situation where all areas downstream of Reach 4 experienced minimal inflow outside of the dam release. By comparison, during the rampdown in June 2014, the flow in the Coquitlam River was 5.0m^3/s at the start and fell to 2.9 m^3/s when the flow reduction was complete. In 2015 the Coquitlam River was at 2.5 m^3/s when the rampdown *began* and fell to 1.1 m^3/s following the flow reduction. The impact of the lack of additional water from Or Creek meant that several side channels containing potentially thousands of fry dried up completely, or came close to doing so.

Of particular concern was the near complete dewatering of a side channel in Reach 3. This channel typically holds thousands of fry and hundreds of smolts as well as providing water for the Coquiltam River Hatchery. As the channels dewatered, rampdown crews on site notified DFO staff of the potential problem. Fortunately, they were able to

quickly take the necessary steps to ensure that this situation did not result in the loss of water for incubating eggs in the hatchery.

Adult Coho spawning 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.

In years 3 & 4 of Treatment 2 the ratio of salvaged fish to mortalities was the second and third worst on record (Table 5), 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 15.4% for all rampdowns (using 2004-2016 data, Table 5). 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-three days. It was anticipated that a more gradual flow reduction would result in fewer stranded fish, and more importantly, fewer mortalities due to stranding.

The reduction in mortality indicated in Figure 3 shows the impact of the past three 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 slightly to 10.3% (Table 5). However, the number of fish stranded during the June rampdowns has risen over the same period. Table 6 shows the increase in stranding since 2012 for the June rampdown, though it is important to note that this increase may be completely independent of the ramp rate and may be more closely correlated to – for example – the amount of Coho fry present in the Coquitlam River. Nevertheless, this does illustrate that regardless of the ramp rate, stranding of Coho fry during the June rampdown will continue to be an issue under the current flow regime.

The act of spreading the flow reduction out over multiple days appears to have been successful with respect to lowering the amount of mortality during flow reductions. However, the low flow river conditions meant that despite the caution taken in the flow reduction, the number of stranded fish was high. Table 6 shows the results of the past five scheduled flow reductions on this date. Based on the results of this third attempt at a modified ramping operation, we can conclude that it continues to be successful in reducing fish mortality related to stranding. It is recommended that this operational approach to the June scheduled rampdown be repeated in the future.

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 1.1 m^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 an increase in discharge, not a severe and rapid reduction. Therefore, the June rampdown represents the opposite of the conditions that migrating fry depend on for survival.

The total decrease in river volume in Reach 4 is high during the January 15, June 1 and November 1 scheduled rampdowns, with a loss of 50%, 63% and 33% of total flow volume respectively (Table 1). This compared 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 Sept 1, 2011 rampdown which had a minimal elevation decrease of 0.04-0.03 metres depending on Reach, but 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 5).

Table 5 Yearly site by site comparison of stranded fish during all rampdown events, 2004-2016. T1 = Treatment 1 2004-2008, T2 = Treatment 2 2009-2016

	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
2015-2016	278	172	521	65	147	64	2288	227	461	99	4322	3695	627	14.5%
2014-2015	895	36	314	30	663	29	375	20	575	52	2989	2822	167	5.6%
2013-2014	0	0	318	12	0	0	428	5	300	32	1095	1046	49	4.5%
2012-2013	65	9	143	79	85	24	322	28	847	504	2106	1462	644	30.6%
2011-2012	154	9	164	21	3	11	65	88	1071	338	1924	1457	467	24.3%
2010-2011	103	6	389	21	39	25	78	13	134	26	834	743	91	10.9%
2009-2010	21	0	40	2	0	0	5	0	45	13	126	111	15	11.9%
2008-2009	31	5	33	9	49	12	12	0	13	0	164	138	26	15.9%
2007-2008	67	6	32	11	199	17	20	1	65	1	419	383	36	8.6%
2006-2007	39	14	3	4	47	80	36	4	0	0	227	125	102	44.9%
2005-2006	95	0	0	0	1	9	0	7	85	6	203	181	22	10.8%
2004-2005	75	2	10	0	13	9	0	0	48	0	157	146	11	7.0%
Total	**1823**	**259**	**1967**	**254**	**1246**	**280**	**3629**	**393**	**3644**	**1071**	**14566**	**12309**	**2257**	**15.5%**
T1	307	27	78	24	309	127	68	12	211	7	1170	973	197	16.8%
T2	1516	232	1889	230	937	153	3561	381	3433	1064	13396	11336	2060	15.4%

Other flow reductions where widespread stranding was observed was the May 1, 2015 rampdown and all three unscheduled rampdowns (Table 3 & 4) The May 1 scheduled rampdown occurs at the peak of Chum and Pink fry emergence when millions of these fry are in the river, 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. This fact likely plays a significant role in reducing the risk of stranding for Chum and Pink fry.

Table 6 Stranding with daily totals for the June rampdown 2011-2016. *Note, June 2016 data included only for further comparison not included in any other data presented.

Year	Day 1	Day 2	Day 3	Total
2011	1355			1355
2012	1377			1377
2013	171	396	400	967
2014	1051	411	1205	2667
2015	1259	2404		3663
2016*	897	519	255	1671

As the results of the spring and summer rampdowns demonstrate, a strong determiner of stranding risk on the 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 given in Table 9 shows that fall and winter rampdowns strand an average of 30 and 15 fish per rampdown respectively, while the average for spring and summer is 449 and 66 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 literally millions of fry may be present) and possibly colder water conditions in winter which can minimize fish movement (Bustard 2011).

Table 7 Species and age class (salmonids only) stranding composition by Reach 2015-2016

Species stranded	R1	R2a	R2b	R3	R4	Total
Coho (age 0)	881	302	646	395	503	2727
Steelhead (age 0)	15	18	22		2	57
Steelhead (age 1+)		6	1		7	14
Chum (age 0)		12	24		3	39
Chinook (age 0)	5					5
Total Stranded by reach	**901**	**338**	**693**	**395**	**515**	**2842**
Percentage stranded by reach	**31.7%**	**11.9%**	**24.4%**	**13.9%**	**18.1%**	

Table 8 Stranding results of scheduled rampdowns since the introduction of Treatment 2.

		Scheduled Rampdowns									
Date	**Status**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**
15-Jan	Salvaged	-	0	0	0	5	10	0	0	31	**46**
	Mortality	-	0	0	0	2	10	0	0	0	**12**
1-Apr	Salvaged	-	0	0	0	1	129	28	48	5	**211**
	Mortality	-	0	0	0	0	15	0	14	1	**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	**11155**
	Mortality	-	0	19	331	506	46	67	381	217	**1567**
1-Sep	Salvaged	-	0	0	98	0	0	7	0		**105**
	Mortality	-	0	0	82	0	0	0	0		**82**
1-Nov	Salvaged	0	0	11	0	0	0	0	0		**11**
	Mortality	0	0	2	0	0	0	0	0		**2**

Final river stage elevation is also an important contributing factor as rampdowns occurring from October 1 -January 15 (under Treatment 2) have a higher final stage elevation than spring and summer rampdowns. For example, rampdowns in the spring and summer months return to an average discharge of 2.3 m^3/s respectively, while those in the fall and winter return to a discharge flow of 4.7 m^3/s. The higher discharge results in an elevated river stage which can keep areas vulnerable to stranding continuously wetted.

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 87.4% of all stranded fish between 2004-2016 (Figure 5). In Year 7 Coho fry and smolts represented 86.3% of all stranding observations. Overall, salmonids accounted for 97.6% of all stranded fish for the 2004-2016 period (Figure 5).

Table 9 Showing the relationship between seasonal timing and stranding risk all rampdowns, 2001-2016. Totals represent stranded salmonids only.

2001-April 2016		Life Stage When Stranded				
Season	# Rampdowns	Adult	Fry	Smolt/Parr	Total	Average
Spring (Mar 23-June 22)	27	17	12004	90	12111	449
Summer (June 23-Sept 22)	15	4	925	64	993	66
Fall (Sept 23 - Dec 22)	23	83	401	217	701	30
Winter (Dec 23 - Mar 22)	14	1	53	152	206	15

Figure 3 illustrates the increase in the past few monitoring years in the amount of fish stranded on the Coquitlam River under Treatment 2. This increase has been influenced by a number of factors already outlined, 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 reduced, but the results have swung far in the other direction the past four monitoring years (Figure 3). 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.

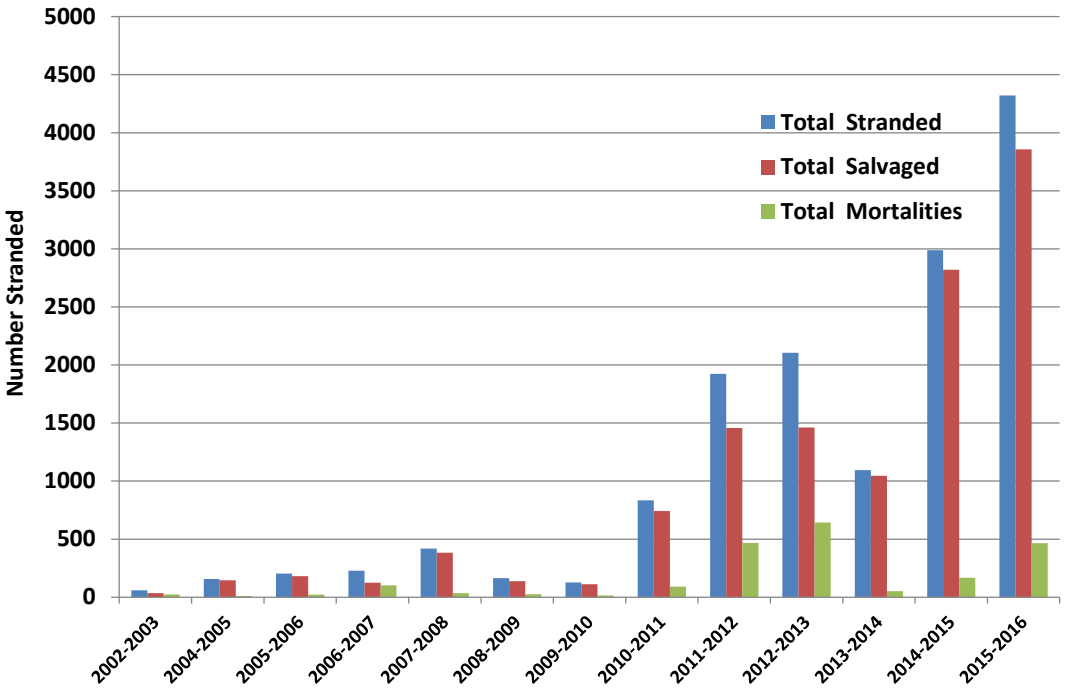

Figure 2 Number of fish salvaged and mortalities for all rampdowns 2002-2016.

In Year 7 stranding was concentrated in the lower reaches of the Coquitlam River for the first time since Treatment 2 was initiated; with Reach 1 accounting for 31.7% of all stranding (Table 7). This trend is the opposite of prior years under Treatment 2 as Reach 3 and 4 normally see 60-80% of all stranding and have averaged 70% over the Treatment 2 period (Figure 4). Prior to 2014-15 there had been only minimal stranding in Reach 1 and 2a during scheduled rampdowns. Stranding has been observed on only 5 of 36 scheduled rampdowns to date in these two Reaches. However, it is important to note that the increase in stranding in Reach 1 is entirely due to the June 1 flow reduction.

The majority of unscheduled rampdowns involve large flow releases, often seeing flow reductions of all 3 LLO gates on Coquitlam River which can release up to 40-45 m^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 4).

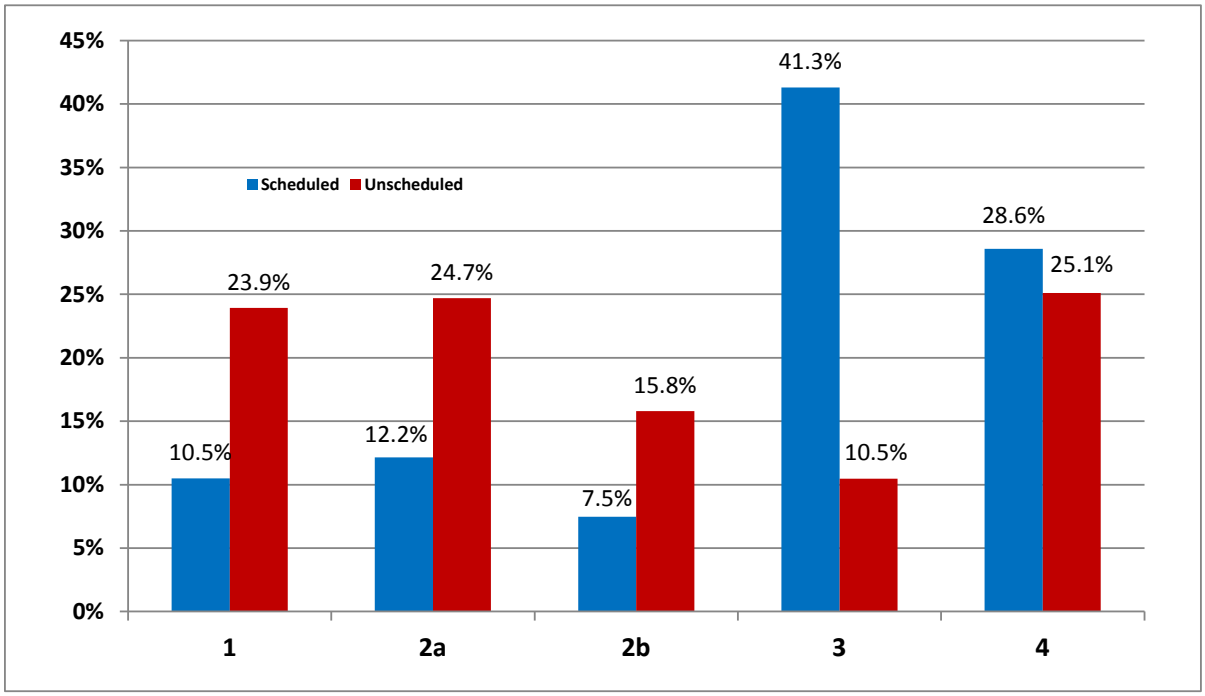

Figure 3 Stranding distribution by Reach, 2004-2016 highlighting the difference in stranding distribution between scheduled and unscheduled rampdowns.

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 10). 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 3.3 unscheduled rampdowns per year. With respect to the number of full 3 LLOG spills, a reduction has been evident in the past five 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 only 8 (as of June 2015) in the past seven years of monitoring. Of the 22 unscheduled rampdowns since the initiation of Treatment 2, 8 have been full three LLO gate release rampdowns, the remainder have been due to dam maintenance and for experimental flows designed to attract Kokanee smolt migration.

Flow transects performed throughout the 2015-2016 monitoring year indicated that flow releases from the Coquitlam Dam have been consistently within the targeted range throughout the monitoring year (estimated flows must be within 10% for the targeted value), with the exception of the months of July-Sept 2015 (Table 1). Record setting drought conditions combined with a low snow pack resulted in extremely low inflow conditions into the Coquitlam River and Coquitlam Reservoir during the summer of 2015. These extreme conditions required operational flexibility in order to ensure that municipal water reserves were not threatened. This lead BC Hydro to make the operational decision to observe the minimum required release (See table 1) which held the flow release to between 1.3 m^3/s and 0.86 m^3/s between the months of June-September 2015.

Table 10 Number of rampdown per year 2001-2016

Monitoring Year	Scheduled	Unscheduled	Total
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	5	5	10
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	**42**	**45**	**87**
Treatment 2		**3.3**	**8.5**
Treatment 1		**2.7**	**2.7**

There were also a few incidents where communication and technical problems impacted rampdown salvages. The first incident occurred on the afternoon of December 18, 2015 and was due to a miscommunication between staff at Fraser Valley Operation Centre 2015 (FVO). The third and final gate closure was scheduled for December 19, but was instead ramped down on the evening of December 18 and not the following day as planned. This error meant that salvage crews could not be on site during the final gate closure. This situation lead to a greater than normal amount of stranding and fish mortality as a result of the rampdown being unmonitored.

A second incident was the result of a technical problem with the remote gate operation on March 14, 2016. Salvage crews were on site at 0800hr on March 14 for the beginning of the rampdown but the gate could not be closed remotely due to a technical problem between FVO and the LLO gate at the Coquitlam Dam. The scheduled gate closure and fish salvage had to be postponed until the following day as a result of this issue. Fish salvage operations were not impacted by this incident.

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 2248900 and 958000 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 14479 and 4242 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.

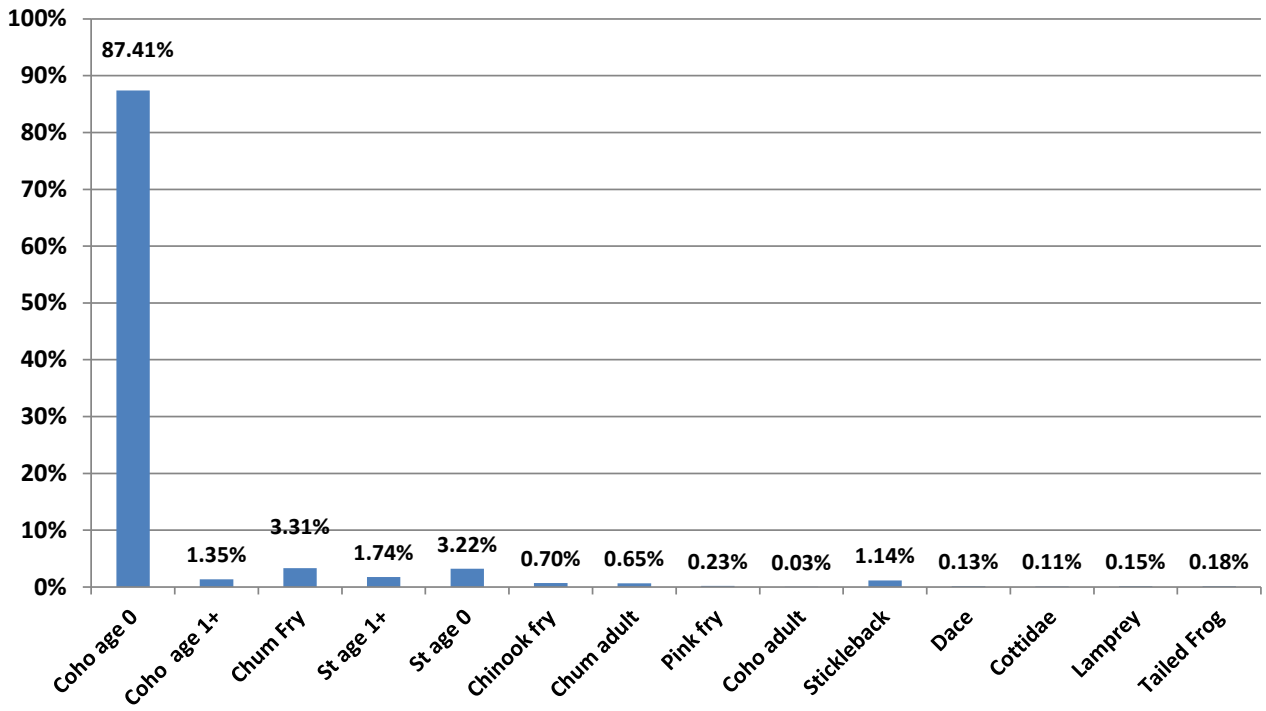

Figure 4 Stranding distribution by species and age class, 2004-April 2016, all rampdowns. In addition one Kokanee, Pink adult and Northern Pike Minnow have been found.

Coho fry populations are typically the hardest hit with respect to stranding. Estimates of total fry productivity (based on fall standing stock estimates 2003-2014) range from 21000 to 105000 with a mean of approximately 56101 (Schick 2014). 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 5.1% of the Coho fry population (Figure 6). This level of loss could have the potential to have an impact on the Coho fry population. 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.

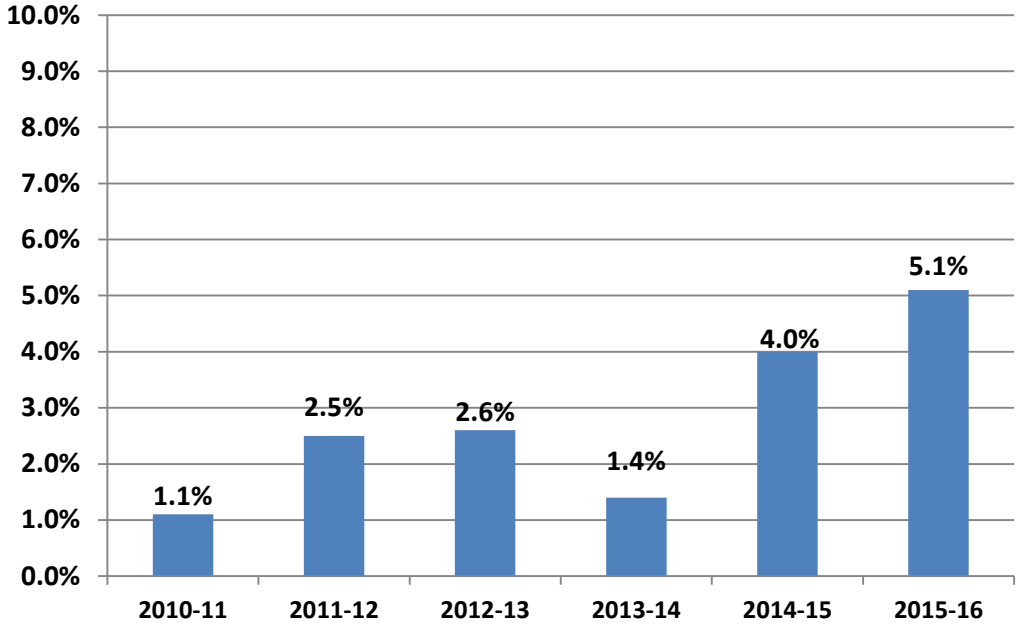

Figure 5 Estimated potential impact of rampdowns on Coho fry population in Coquitlam River. Values represent the estimated proportion of the total population of Coho fry that could be eliminated due to rampdowns each year.

5.0 Conclusions and Recommendations

The results of the past 7 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 5 show that under Treatment 1 survey crews observed an average of 254 stranded fish and 39 mortalities per year, while under Treatment 2 this has risen to 1512 stranded fish and 239 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 8.3 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 Month 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 have the potential to prevent a significant amount of stranding.

As Table 7 clearly demonstrates, fish stranding under scheduled rampdowns in the Coquitlam River is heavily concentrated in the June 1 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, flow releases are maintained at a constant rate each month, and flow reductions are generally small in proportion to the amount of flow in the entire river.

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, though primarily in Reach 4. 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.

Stranding sites examined under the previous flow regime have been reevaluated under the new Treatment 2 conditions. The results of the sixth 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.

Comparison of rampdown mortalities to fish productivity clearly shows the negligible impact that rampdowns appear to have on fish productivity in the Coquitlam River. However, results from the past few years show that greatly elevated Coho fry stranding during scheduled and unscheduled rampdowns at critical time periods is 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 outlined in the introduction, 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 the majority of 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.

Summary of Recommendations

- The ramp rate for the June flow reduction should be modified to be more gradual in addition, a reexamination of the target flow level of 1.1 should be considered as it falls outside of the natural hydrograph for the Coquitlam 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 prevent 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.

6.0 Literature Cited

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

May 1, 2015

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	0.29	0930	0.70	0900	7.84	
1000	0.28	1130	0.69	1200	7.83	
1100	0.27	1300	0.68	1300	7.82	
1200	0.26	1430	0.67	1500	7.81	
1330	0.26	1530	0.67	1800	7.81	
1500	0.26					
	3.0		3.0		3.0	Max Stage Reduction (cm)
	1.0		1.0		1.0	Max Stage Reduction (cm)/hr

June 1 2015

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0830	.22	0900	.59	0900	7.74	
0930	.21	1030	.58	1100	7.74	
1000	.19	1200	.57	1200	7.73	
1100	.17	1400	.55	1400	7.71	
1200	.15	1600	.55	1600	7.70	
1600	.15			1800	7.70	
	7.0		4.0		4.0	Max Stage Reduction (cm)
	2.0		1.0		1.0	Max Stage Reduction (cm)/hr

June 2 2015

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0830	.15	0900	.55	1000	7.71	
0930	.14	1030	.55	1100	7.71	
1000	.13	1200	.54	1200	7.70	
1100	.11	1400	.53	1400	7.68	
1200	.10	1600	.52	1600	7.67	
1600	.10			1800	7.67	
	5.0		3.0		4.0	Max Stage Reduction (cm)
	2.0		1.0		1.0	Max Stage Reduction (cm)/hr

September 1, 2015

R4 Staff Gauge		R2B (at Galette)		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0830	.34	0900	.74	0800	7.93	
0930	.33	1030	.73	1000	7.93	
1000	.31	1200	.72	1100	7.93	
1100	.30	1400	.72	1200	7.92	
1330	.30	1600	.71	1400	7.91	
1530	.30			1600	7.91	
				1800	7.91	
	4.0		3.0		2.0	Max Stage Reduction (cm)
	2.0		1.0		1.0	Max Stage Reduction (cm)/hr

November 1, 2015

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0900	0.39	0800	0.68	0800	7.98	
1030	0.38	1000	0.68	1000	7.98	
1130	0.36	1130	0.66	1200	7.97	
1230	0.35	1400	0.66	1330	7.96	
1500	0.33	1600	0.65	1600	7.95	
1630	0.32	1700	0.64	1800	7.94	
				2000	7.94	
	7.0		4.0		4.0	Max Daily Stage Reduction (cm)
	2.0		1.0		1.0	Max Stage Reduction (cm)/hr

January 15, 2016

R4 Staff Gauge		R2B Staff Gauge		R1 WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	Time	Stage (m)	
0830	0.41	0930	0.73	1000	8.02	
1000	0.36	1100	0.70	1200	7.98	
1130	0.31	1300	0.66	1400	7.94	
1230	0.255	1430	0.63	1600	7.92	
1330	0.25	1600	0.62	1800	7.90	
1530	0.25			2000	7.90	
	16.0		11.0		12.0	Max Stage Reduction (cm)
	5.5		3.0		2.0	Max Stage 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 6 Site A1 showing gravel bar separating river mainstem (left) with isolated pool (right), following rampdown June 1 2012.

Figure 7 Showing trench dug to allow water from river mainstem to flow into isolated pool.

Figure 8 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 9 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 10 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

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.

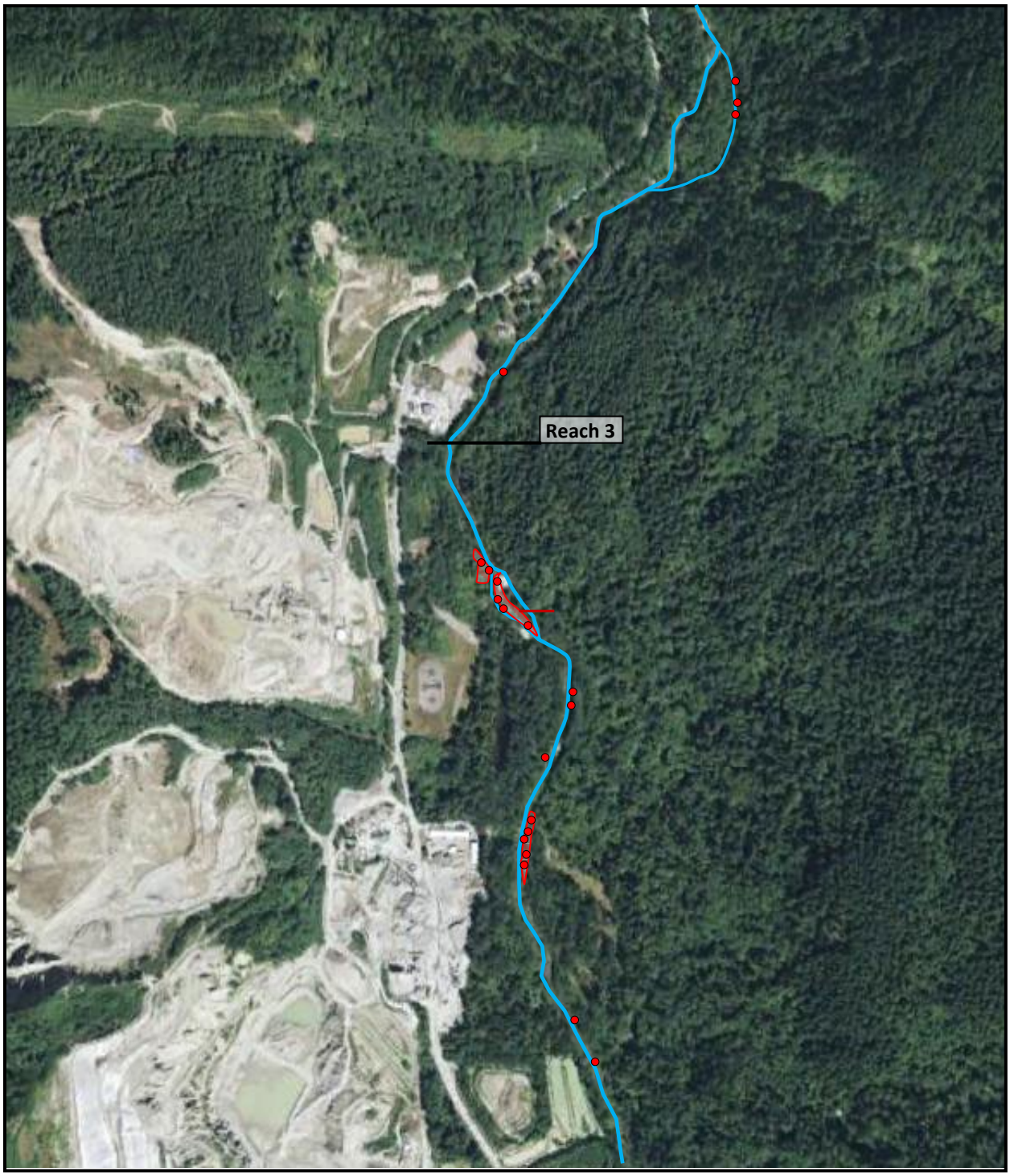


Figure B
Coquitlam River Stranding Reach 3 and 2b

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

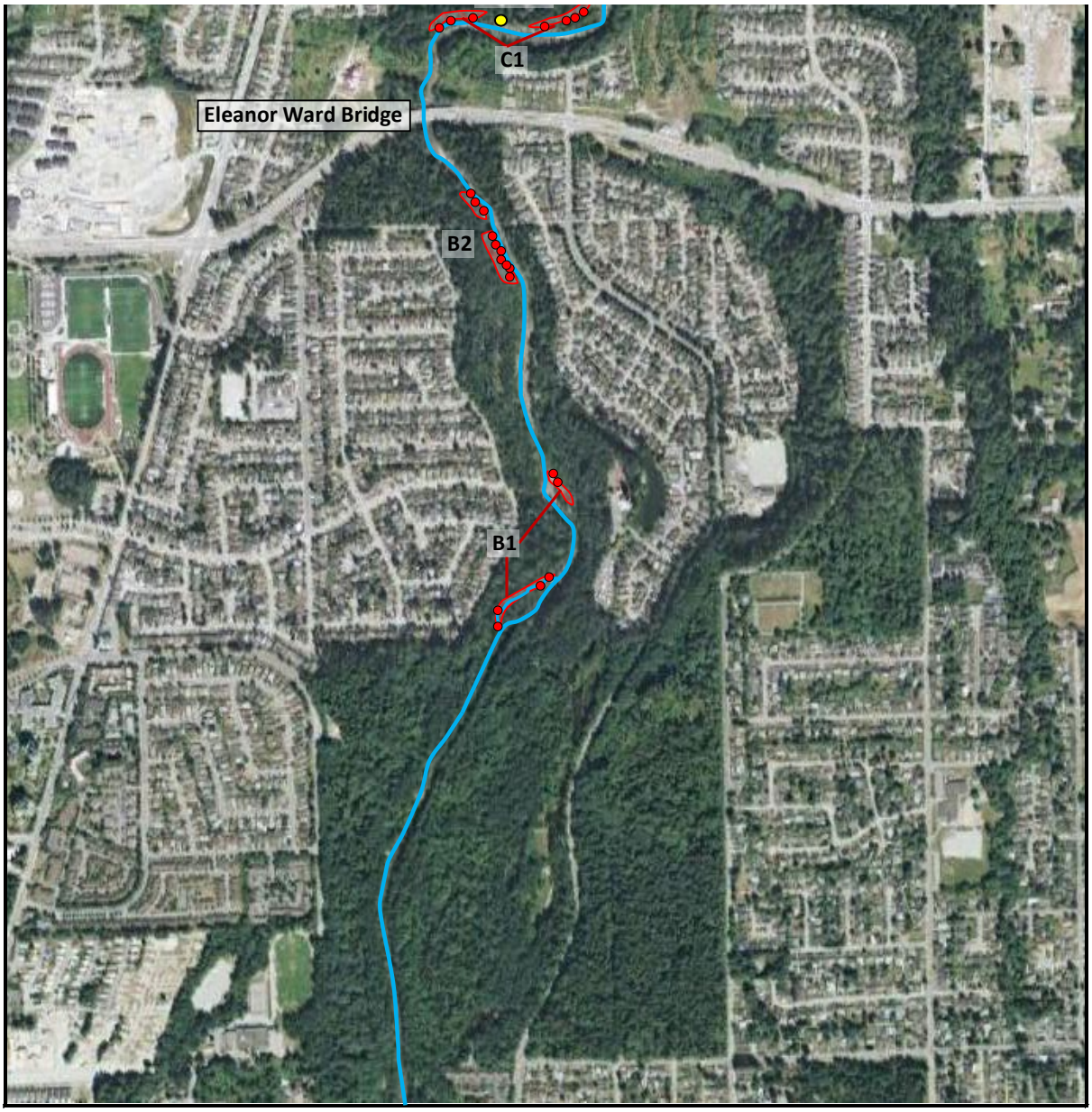


Figure D

0 250 500 750 1000

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

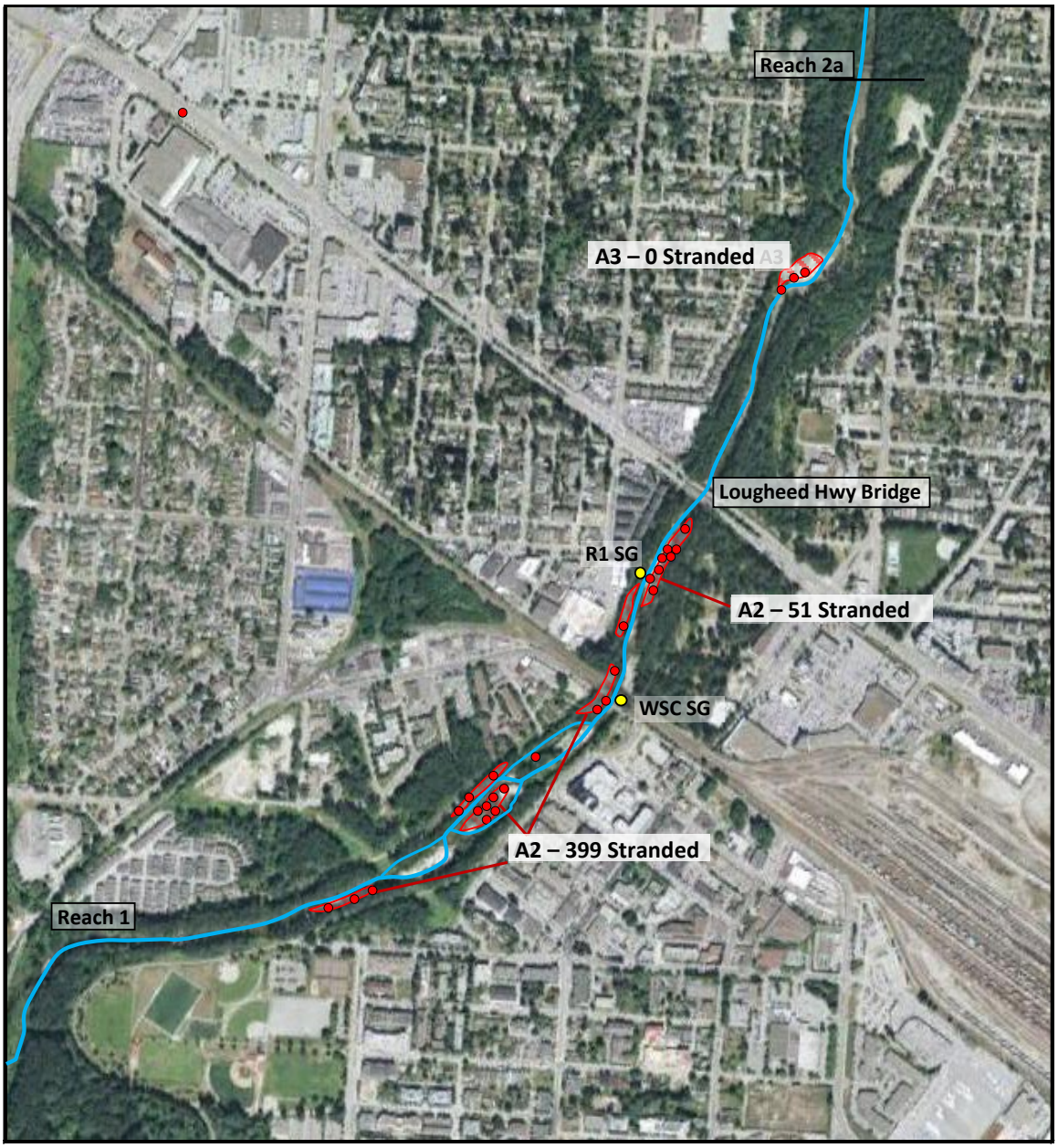


Figure E

Coquitlam River Stranding, Site A, Reach 1.

Appendix 4 Fish Stranding Summary June 2016 Rampdown

In response to the current flow regime (Treatment 2), the Low Level Outlet (LLO) release from Coquitlam Dam is scheduled to be reduced from 2.9 m^3sec to 1.1 m^3sec in the month of June. In light of large numbers of stranded fish and high mortalities during past scheduled flow reductions in June (Figure 1), 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 mortality due to stranding when compared to single day rampdowns, however it has not led to a reduction in the number of fish being stranded (which is influenced by several others factors unrelated to the ramping rate) (Figure 1).

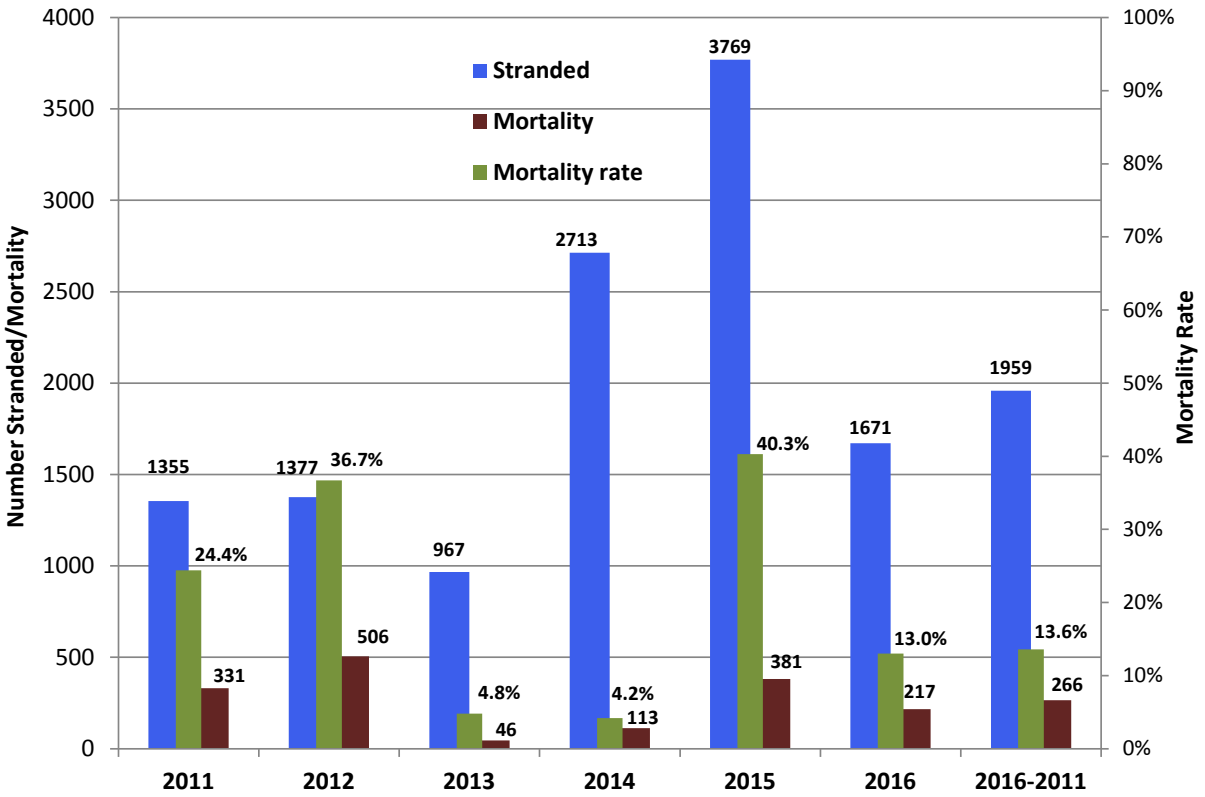
The scheduled flow reductions in 2016 were performed over 3 days, each beginning at approximately 0900hr. June 1st saw the flow decrease from 2.9-2.2 m^3/s, flow on June 8thdecreased from 2.2 – 1.8 m^3/s and from 1.8 m^3/s to 1.35 m^3/s on June 15, 2016. This staggered flow reduction reduced the maximum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

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 1). The mortality rate was 13.0%, an increase compared to the past three years and the highest yet for all multi-day rampdowns (Figure 1).

The act of spreading the flow reduction out over two weeks days appears to have had mixed success as the mortality rate was higher than the previous three years, but total stranding was down (Figure 1). Figure 1 shows the results of the past five scheduled flow reductions on this date. Based on the results of this fourth attempt at a modified ramping operation, we can conclude that it continues to be successful in reducing fish mortality related to stranding compared to a single day rampdown event. It is recommended that this operational approach to the June scheduled rampdown be repeated in the future.

Coquitlam River Fish salvage and mortalities by reach and species June 1, 8, 15, 2016.

			Reach						Stage Decrease cm		
Date	Sp.	Salv/Mort	1	2a	2b	3	4	Total	R4	R2b	R1
1-Jun-16	Co 0	s		250	160	80	210	700	3	3	3
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	4.5	3	4
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	7	4	5
15-Jun-16	Co 0	m			4	16	11	31			
	Total Stranded		**100**	**364**	**378**	**321**	**408**	**1571**			
	Total Salvaged		97	364	290	209	394	1354			
	Total Mortality		3	0	88	112	14	217			



Coquitlam River fish stranding and mortality rate 2011-2016, June scheduled rampdowns.