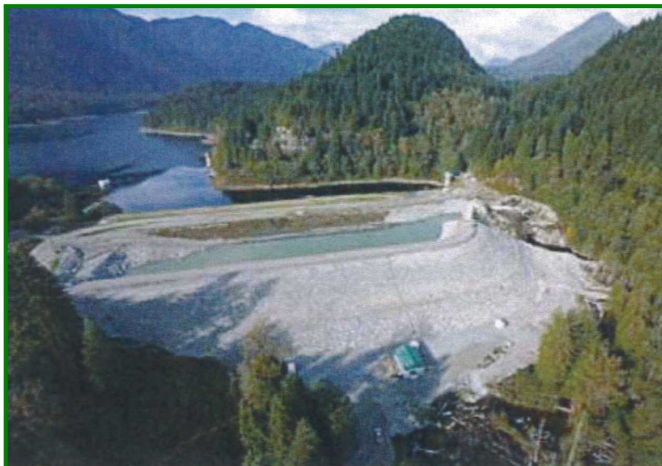
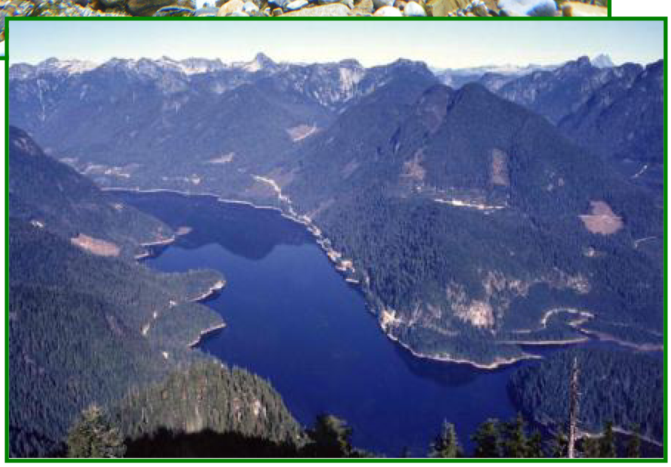
Coquitlam Smolt Outmigration – Phase 2 Report
Sockeye Passage Design
for Coquitlam Reservoir Forebay
FWCP Project No. COA-F18-F-2362





Prepared for:

Fish & Wildlife Compensation Program (FWCP)

Prepared by:

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Prepared with financial support of the Fish and Wildlife Compensation Program on behalf of its program partners BC Hydro, the Province of BC, Fisheries and Oceans Canada, First Nations and public stakeholders.

31-May-2018

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CONTENTS

EXECUTIVE SUMMARY VIII
1. INTRODUCTION 1
2 GOALS AND OBJECTIVES 3
3. STUDY AREA 6
3.1 COQUITLAM DAM AND RESERVOIR 6
3.2 RESERVOIR OPERATIONS 6
3.2.1 Buntzen Tunnel Power Diversion 8
3.2.2 Metro Vancouver Diversion 9
3.2.3 Sluice Tower with Low Level Outlets 11
3.2.4 Spillway 16
3.2.5 Operating Reservoir Levels 17
3.2.6 Operating Flow Rates 18
4. PHASE 1 – OPTIONS FEASIBILITY ASSESSMENT 20
4.1 ASSESSMENT OVERVIEW 20
4.2 ASSESSMENT CRITERIA 20
4.3 OPTIONS REVIEWED 21
4.4 RESULTS OF ASSESSMENT 25
5. 2017 BIOLOGICAL FIELD STUDIES 27
5.1 LGL ACOUSTIC TAGGING STUDY 27
5.2 LGL SMOLT PASSAGE STUDY 33
5.3 DOWNSTREAM ROTARY SCREW TRAPS 37
5.4 CONCLUSIONS AND REMAINING QUESTIONS 38
6. IMPLEMENTATION PLAN 40
6.1 LIFE-CYCLE MODEL 40
6.2 OPTIMIZED OUTMIGRATION OPERATIONS 41
6.3 POTENTIAL MODIFICATIONS 42
7. DOWNSTREAM PASSAGE MODIFICATION ALTERNATIVES 43

7.1 DESIGN CRITERIA 43
7.1.1 Migration Season 43
7.1.2 Flow Rate 44
7.1.3 Reservoir Elevation 44
7.1.4 Capture Velocity 44
7.1.5 Fish Screens 44
7.1.6 Bypass Pipe 45
7.2 ALTERNATIVE 1 – MODIFIED SLUICE TOWER 46
7.2.1 Alternative Description 48
7.2.2 Operations and Maintenance 51
7.2.3 Advantages and Potential Concerns 52
7.2.4 Optional Considerations 54
7.3 ALTERNATIVE 2 – FLOATING SURFACE COLLECTOR 54
7.3.1 Alternative Description 55
7.3.2 Operations and Maintenance 61
7.3.3 Advantages and Potential Concerns 62
7.3.4 Optional Considerations 62
8. CONSTRUCTION AND O&M COST ESTIMATES 64
8.1 ALTERNATIVE 1 – MODIFIED SLUICE TOWER 65
8.2 ALTERNATIVE 2 – FLOATING SURFACE COLLECTOR 67
9 RECOMMENDATIONS 69
10 ACKNOWLEDGEMENTS 71
11. REFERENCES 72

APPENDICES

Appendix A: Fish Passage Decision Framework for BC Hydro Facilities
Appendix B: KSRP Meeting Minutes (July 26, 2017)
Appendix C: Implementation Plan
Appendix D: Design Criteria Technical Memo
Appendix E: Concept Drawings
Appendix F: Reservoir Outlet Operations and Water Levels for Months of April and May 2009-2017

FIGURES

Figure 1. Aerial View of the Lower Reservoir with the Locations of the Four Outlets Highlighted. 7
Figure 2. Section View through the Buntzen Diversion Tunnel Power Diversion Intake. 9
Figure 3. Section View through the GVWD Diversion Intake 10
Figure 4. Photograph of the GVWD Diversion Intake. 10
Figure 5. Composite Photograph of the Sluice Tower and Forebay. 11
Figure 6. Plan View of the Sluice Tower (metric dimensions scaled from drawing). 12
Figure 7. Section Views of the Sluice Tower and Low Level Outlet Gates. 12
Figure 8. Photograph of Sluice Tower Outlet. 13
Figure 9. Reservoir Level vs. Discharge Curves for LLO-1 and LLO-2 (source: email communication from BC Hydro to P. Christensen, September 22, 2016). 14
Figure 10. Reservoir Level vs. Discharge Curves for LLO-3 (source: email communication from BC Hydro to P. Christensen, September 22, 2016). 15
Figure 11. Knife Gate Shape Open 27%. 15
Figure 12. Photograph of the West End of the Spillway. 16
Figure 13. First and Last Detections of Tagged Fish in the Forebay (provided by LGL). 29
Figure 14. Forebay Tracking of Fish Tag 104 (provided by LGL). 31
Figure 15. Forebay Tracking of Fish Tag 406 (provided by LGL). 31
Figure 16. Forebay Fish Detection Heat Map for 3 m^3/s (provided by LGL). 32
Figure 17. Forebay Fish Detection Heat Map for 8 m^3/s (provided by LGL). 32
Figure 18. Fyke Net in Tailrace below the Discharge Tunnel (provided by LGL). 34
Figure 19. Fish Release Tube Assembly at LLO-1 Trashrack (left) and LLO-3 Knife Gate (right). 36
Figure 20. Photo of a Rotary Screw Trap. 37
Figure 21. Cross-Sectional View through the Existing Sluice Tower. 47
Figure 22. Bracket Bosker Automatic Raking Machine (from the ovivowater.com website). 51

Figure 23. Lower Baker FSC in Operating Position (left) and Raised Non-Operating Position (right). 58

TABLES

Table 1. Target and Reduced Minimum Releases to the Lower Coquitlam River. 19

Table 2. Summary of Phase 1 Options Comparisons Relative to the Assessment Criteria. 26

Table 3. Timing of Discharge Flows and Gate Operations during the 2017 Acoustic Tag Study. 28

Table 4. Study Fish Release Times, Locations, and Numbers. 28

Table 5. Sluice Tower Smolt Passage Study Data and Results (provided by LGL). 35

Table 6. 2017 Wild Smolt Catches at the RST R4 Downstream of Coquitlam Dam. 38

Table 7. Salmonid Fish Screen Design Criteria (NMFS 2011). 45

Table 8. Salmonid Bypass Pipe and Outfall Design Criteria (NMFS 2011). 46

Table 9. Summary of Estimated Construction and Annual O&M Costs for Alternative 1. 65

Table 10. Breakdown of Estimated Construction and Annual O&M Costs for Alternative 1. 66

Table 11. Summary of Estimated Construction and Annual O&M Costs for Alternative 2. 67

Table 12. Breakdown of Estimated Construction and Annual O&M Costs for Alternative 2. 68

ABBREVIATIONS

DFO	Department of Fisheries & Oceans Canada
el.	Elevation
fps	Feet per Second
FSC	Floating Surface Collector
ft	Feet
FV	Fish Valve
FWCP	Fish & Wildlife Compensation Program
GS	Generating Station
GVWD	Greater Vancouver Water District
HEP	Hydroelectric Project
kg	Kilograms
km	Kilometres
KSRP	Kwikwetlem Salmon Restoration Program
LLO	Low Level Outlet
LLOG	Low Level Outlet Gate
m	Metres
m^2	Square Metres
m^3/s	Cubic Metres per Second
max	Maximum
MAET	Minimum Adult Escapement Threshold
min	Minimum
mm	Millimetres
MOE	B.C. Ministry of Environment
MV	Metro Vancouver
MWh	Megawatt-hours
NMFS	U.S. National Marine Fisheries Service
O&M	Operation & Maintenance
s	Seconds

EXECUTIVE SUMMARY

BC Hydro and the Kwikwetlem Salmon Restoration Program (KSRP) have been working together since 2003 towards the goal of restoring an anadromous Sockeye Salmon run in the Coquitlam River. To further this goal, BC Hydro selected R2 Resource Consultants, Inc. (R2) to perform a two-phase study of downstream fish passage alternatives to efficiently and safely pass downstream migrating juvenile Sockeye smolts from the Coquitlam Reservoir to the lower river downstream. This report addresses the study requirements stated in the following excerpt from Step 4 of the Fish Passage Decision Framework for BC Hydro Facilities (Appendix A):

- *"The proponent is responsible for identifying the fish passage solutions that will best address requirements to meet its stated restoration goals. This includes a review of fish passage options, an analysis of fish passage efficiencies and effectiveness (e.g. survival), a description of operations, conceptual design and an estimate of cost."*

This study also addresses the following priority action items from two Fish & Wildlife Compensation Program (FWCP) Coquitlam/Buntzen Watershed Plans:

Salmonid Action Plan (FWCP 2011a):

- *"Continue to collect baseline data for anadromous salmonids in relation to re-introduction above Coquitlam Dam."*

Watershed Plan (FWCP 2011b):

- *"Completion of feasibility assessments for fish passage and the re-anadromization of Kokanee are of high priority."*
- *"Improvement of the outmigration of smolts is of very high priority. Migration of smolts through the tunnel should also be addressed."*

The Phase 1 study provided a review of fish passage options relative to the conditions at Coquitlam Dam, and was funded by BC Hydro. This Phase 2 study has been funded through a grant from the FWCP and has involved development of conceptual designs and cost estimates, technical advice to LGL with the design of biological field studies performed in the spring of 2017 (under a separate grant from the FWCP) to provide baseline data concerning smolt behaviour in the forebay area, and operational recommendations to increase smolt attraction and outmigration at the dam while minimizing migration of smolts through the Buntzen Tunnel. Throughout the Phase 2 project, R2 has worked closely with BC Hydro and the KSRP to ensure that all stakeholder, community, and First Nation concerns were addressed.

The Phase 1 study was completed in July of 2017, and presented to the KSRP along with the preliminary results of biological field studies (performed by LGL under a separate FWCP grant) at a meeting on July 26, 2017 (Appendix B). Based on the Phase 1 options review, and the field study results which provided information on passage efficiencies and effectiveness, the KSRP chose two design alternatives to take to a conceptual design level with descriptions and cost estimates as part of the Phase 2 study.

Three field studies were performed during the spring of 2017. LGL released tagged artificially reared kokanee smolts and tracked their movement in the forebay of the Coquitlam Reservoir Sluice Tower. LGL also released marked smolts directly into the Sluice Tower to assess the safety of passage through the discharge tunnel. Finally, BC Hydro contracted with a third party to operate rotary screw traps (RSTs) in the Coquitlam River downstream of Coquitlam Dam. R2 provided planning support for the LGL studies, and reviewed the results of all three studies relevant to design of potential downstream passage alternatives including:

- The artificially-reared smolts, raised from kokanee eggs, do not appear to exhibit a strong tendency to migrate downstream out of a reservoir, although 2 of the 48 fish released directly into the forebay did appear to migrate out through the Sluice Tower.
- These same fish exhibit a wide variety of behaviours when released into the reservoir.
- Fish behaviour in the forebay appears to be affected by the flow volume through the Sluice Tower. At lower release flows, the fish showed a strong tendency to occupy the deepest portion of the forebay. At higher flows, the fish were distributed more evenly throughout the forebay.
- Under conditions of high flow releases through the Buntzen Diversion Tunnel, fish released near the diversion tunnel entrance did not tend to migrate to the dam forebay downstream.
- Few injuries were reported for fish passing through the discharge tunnel at the Sluice Tower appears to be safe, even at the higher than usual reservoir levels experienced in 2017. Injuries attributed to fish passage through the tunnel in previous studies were more likely due to passage through the partially-open knife gate.
- There appears to be a direct correlation between higher flow rates and higher rates of out-migrating kokanee smolts from the reservoir.

The acoustic tags and receivers used by LGL for the tracking study had the ability to track the fish in three dimensions; however, at the time of the writing of this report, only the 2-D tracking results were available. When the 3-D results become available, we recommend that BC Hydro assess the following behavioural characteristics of the tagged fish:

- What is the predominant depth of fish observed in the forebay?
- Did the predominant depth vary between the 3 m^3/s and 8 m^3/s exposures?
- Did fish tend to sound deeper as they approached the Sluice Tower?
- If fish did sound to depth did they stay there long?
- Did fish that stayed in the forebay longer tend to go deeper?

R2 worked with BC Hydro and the KSRP to develop recommended modified operations for the Coquitlam Reservoir during the Sockeye/kokanee outmigration season designed to improve the attraction and safe passage of downstream migrating smolts. These recommendations, incorporated into the Kwikwetlem Sockeye Restoration Project- Sockeye Restoration Implementation Plan (Appendix C), include curtailing (reducing or eliminating) the Buntzen diversion flow to the extent possible, increasing the outlet flow through the Sluice Tower to 8 m^3/s throughout the season, and passing the flow through Low Level Outlet 2 (LLO-2) to avoid passage through the knife gate located in LLO-3 and to maximize the distance from the outlet to the tunnel lining downstream.

Concept designs were developed for two potential physical modification alternatives designed to improve collection and passage of smolts. These fish passage alternatives would be considered if future studies reveal that the modified operations cited in the Implementation Plan, attract fish to the Sluice Tower forebay but fail to collect and/or safely pass fish needed to support the restoration goals. The first alternative involves a structure added to the upstream face of the Sluice Tower designed to create a surface flow into the Sluice Tower over a range of reservoir levels. The second, more extensive, alternative involves a floating fish collector located in the forebay, and includes a bypass pipe around the Sluice Tower providing safe passage to the tailrace downstream. Concept-level construction cost estimates for these two alternatives are $3,823,300 and $22,153,500, respectively

1. INTRODUCTION

British Columbia Hydro and Power Authority (BC Hydro) owns and operates the Coquitlam-Buntzen Hydroelectric Project (HEP). In 2003 BC Hydro, Metro Vancouver, the Kwikwetlem First Nation, Department of Fisheries and Oceans Canada (DFO), BC Ministry of Environment (MOE) and local municipalities formed the Kwikwetlem Salmon Restoration Program (KSRP) with the goal of restoring anadromous fish to the Coquitlam watershed. A primary KSRP goal is the restoration of Sockeye Salmon in Coquitlam Reservoir. To further this goal, BC Hydro contracted with R2 Resource Consultants, Inc. (R2) to perform a two-phase assessment of feasible options for providing safe downstream passage for outmigrating Sockeye smolts from the Coquitlam Reservoir to the lower Coquitlam River downstream. Phase 1 involved a feasibility assessment of 10 options relative to their applicability to the conditions and requirements at the Coquitlam Project. Phase 1 was completed in June 2017. This Phase 2 study provides concept-level designs and cost estimates for two alternatives carried forward after the conclusion of the Phase 1 options assessment.

This Phase 2 study has been funded through a grant from the Fish & Wildlife Compensation Program (FWCP). The FWCP grant (Project No. COA-F18-F-2362) includes the following scope of work. The description of each item in the scope of work below is followed by a statement describing the status of the task.

- Task 1: R2 will meet with the KSRP to review the results of the Phase 1 assessment and choose optimal alternatives that meet the goals of the restoration plan and fit into the expectations of BC Hydro and the local First Nations and communities.

  A meeting was held with the KSRP on July 26, 2017 to review the results of the Phase 1 options assessment and the 2017 acoustic tagging study performed by LGL Limited (LGL). During the meeting, two design alternatives were chosen for further development to concept-level design as part of the Phase 2 study. Summary notes of the meeting are attached in Appendix B.

- Task 2: Based on historic data, daily reservoir elevations and outlet flows will be proposed, and modifications suggested as needed, to increase attraction flows to encourage smolts to move in the direction of the outlet forebay during the Sockeye outmigration period for wet, moderate, and dry years.

  R2 worked closely with BC Hydro and the KSRP to develop an Implementation Plan defining reservoir operations designed to optimize attraction of smolts to the forebay area, and potential physical modifications if the existing Sluice Tower does not pass an adequate number of the smolts. The Implementation Plan is attached in Appendix C. R2 *also produced a Design Criteria Memo which among other things defines the range of operating reservoir levels and outlet flows recommended for operations during the smolt outmigration season. The Design Criteria Memo is attached in Appendix D.*

- Task 3: Planning assistance and summary review of results will be provided for a concurrent project application submitted to the FWCP that would look at assessing the behavior of Sockeye smolts in the reservoir outlet forebay in response to various operation flow regimes.

  R2 worked closely with BC Hydro and LGL prior to and during the 2017 acoustic tag study performed by LGL, providing input to the study plan and review of the results defining the types of data and results presentation that would be helpful to the design of the potential modifications. A description of the study and results is provided in Section 5 of this report.

- Task 4: Results of the previous tasks will be used to optimize the chosen passage alternatives with regards to attraction, collection, and safe passage of downstream migrants. Concept-level drawings and cost estimates will be developed for the chosen alternative.

  Two potential project modifications were developed to concept-level designs, as described in Section 7, and drawings were submitted to BC Hydro and the FWCP via email. The drawings are attached in Appendix E. Construction and operation and maintenance (O&M) cost estimates were developed for these designs and are provided in Section 8 of this report.

- Task 5: Draft and final project reports will be developed summarizing all phases of the project and detailing the chosen concept designs.

  This report, summarizing the work performed and the results of the project, represents the completion of the Phase 2 Concept Alternatives Design project.

2 GOALS AND OBJECTIVES

The planning and process associated with fish passage projects at BC Hydro projects is directed by the steps defined in the Fish Passage Decision Framework for BC Hydro Facilities (FPDF). A copy of the FDPF is provided in Appendix A. The following is an excerpt from Step 4 of the FPDF:

- *"The proponent is responsible for identifying the fish passage solutions that will best address requirements to meet its stated restoration goals. This includes a review of fish passage options, an analysis of fish passage efficiencies and effectiveness (e.g. survival), a description of operations, conceptual design and an estimate of cost."*

The Phase 1 study, completed in July 2017, provided a review of fish passage options for the Coquitlam Reservoir. Based on the results of the Phase 1 study, and in coordination with the KSRP, two fish passage designs were chosen for further development as part of this Phase 2 study. These alternatives may be considered for installation in the event the existing conditions in the Sluice Tower outlet prove to be inefficient and/or unsafe for passing the outmigrating smolts downstream through the dam. The primary goal of this study is to produce conceptual designs, descriptions of operations, and estimates of construction and operations & maintenance costs for these two alternatives. These are addressed in Sections 7 and 8.

Initial estimates of fish passage efficiency and survival (R2 in progress) have been developed in support of the life cycle modeling effort being conducted by Dr. Eduardo Martins, University of Northern British Columbia. However, it is not possible to accurately predict collection efficiency and survival estimates of fish passage facility concepts. Site-specific information on the behaviour of target species and lifestages are typically scarce and the influence of the fish passage structure during wet, average, and dry years may only be understood following several years of operation. Performance of existing fish passage facilities typically reflects years of site-specific monitoring and adaptive management and may not be directly transferable to other sites. Our response to analyzing fish passage efficiencies and effectiveness of conceptual designs was to develop a range of values based on available site-specific information, comparisons to results observed at other fish projects, and professional experience and judgement. For instance, information on Sockeye smolt migration behaviour has been inferred from studies of juvenile kokanee at the Coquitlam Project and observations of outmigrant behavior at other projects. Our response to this uncertainty has been to develop Low/Best/High estimates for alternate fish passage routes/facilities under the assumption that they primarily reflect comparisons between alternate facilities rather than an accurate estimate of post-construction performance. The rationale for the range of performance estimates and associated assumptions will be presented in the memo describing life cycle modeling assumptions. Future fish monitoring studies performed under the conditions described in the recently established Implementation Plan, including curtailed Buntzen diversion flows and increased Sluice Tower outlet flows during the outmigration season (as described in Section 6.2), will provide an increased knowledge base to improve passage efficiency estimates.

Additionally, the objectives of this study include assistance developing information associated with three priority action items from two FWCP Coquitlam/Buntzen Watershed Plans.

The following high-priority action item is stated in the Coquitlam/Buntzen Watershed – Salmonid Action Plan (FWCP 2011a):

- *"Continue to collect baseline data for anadromous salmonids in relation to re-introduction above Coquitlam Dam."*

As part of this FWCP grant, R2 assisted LGL Limited with development of a fish tagging study designed to provide baseline data associated with fish behaviour in the Sluice Tower forebay. R2 also provided an assessment of the results of the study with a focus on how the information may help guide the design of potential future fish passage designs (as described in Section 5.1).

The following action item is stated in the Coquitlam/Buntzen Watershed – Watershed Plan (FWCP 2011b):

- *"Completion of feasibility assessments for fish passage and the re-anadromization of Kokanee are of high priority."*

Under separate contract to BC Hydro, R2 is assisting Dr. Eduardo Martins with the development of a life-cycle model to assess the feasibility of restoring a self-sustaining, naturally-reproducing run of Sockeye Salmon to the Coquitlam system. The life-cycle model is described in Section 6.1, and is designed to be a living program that becomes more refined as new data becomes available. Ultimately, the goal of the model is to define the greatest limitations to restoration and determine whether those limitations can be addressed through operational or physical modifications to the project, or whether the limitations are beyond the scope of the project and cannot be addressed locally (such as poor smolt-to-adult returns from the ocean).

The following action item is also stated in the Coquitlam/Buntzen Watershed – Watershed Plan (FWCP 2011b):

- *"Improvement of the outmigration of smolts is of very high priority. Migration of smolts through the tunnel should also be addressed."*

As part of this FWCP grant, R2 assisted LGL Limited with development of a fish passage study designed to provide baseline data associated with fish passage through the existing Sluice Tower discharge tunnel (as described in Section 5.2). R2 also provided real-time consultation during the study recommending modifications to the release procedures after the majority of the initial releases failed to actually pass through the outlet. This study provided useful information concerning the safe passage conditions through the tunnel, contradicting previously unstudied speculations about hazardous conditions in the tunnel.

3. STUDY AREA

3.1 COQUITLAM DAM AND RESERVOIR

The Coquitlam Lake Reservoir and dam are located about 30 km Northeast of Vancouver, BC, near the towns of Coquitlam and Port Coquitlam. Upstream passage of anadromous fish including Sockeye, Coho, and Chinook salmon, and steelhead was blocked when the dam was rebuilt and enlarged in 1914. Following the blockage of upstream fish passage, a self-supporting kokanee population developed in the reservoir, presumably from the remnant Sockeye Salmon remaining in the upstream habitat. Anadromous Sockeye Salmon have been captured in the adult trap located downstream from the dam, and genetic testing has revealed that the majority of these fish are directly related to the kokanee population in the reservoir (Plate et al. 2014). As is commonly observed in other anadromous salmonid populations that become land-locked, it appears that a small proportion of the kokanee population undergoes smoltification, emigrates from the reservoir, and exhibits an anadromous life history.

Coquitlam Dam has a crest length of approximately 400 m and a height of approximately 30 m. The reservoir has a surface area of 12 km^2, a mean depth of 87 m, at normal full pool, and a maximum depth of 187 m. The full reservoir volume is 1,044,000 m^3. The watershed area upstream of the dam is 193 km^2, and includes a significant majority of the available Sockeye habitat in the overall Coquitlam River watershed. Average inflow to the reservoir is 23 m^3/s, with an average annual inflow volume of 725,000 m^3, resulting in an average exchange rate of approximately 1.4 years, assuming the reservoir is generally at or near full pool elevation.

3.2 RESERVOIR OPERATIONS

The Coquitlam Lake Reservoir is primarily operated to provide storage for power generation at Lake Buntzen Generating Station (GS). The reservoir also provides flood control for the cities of Coquitlam and Port Coquitlam, and serves the Greater Vancouver Water District (GVWD) with a source for drinking water. Metro Vancouver and BC Hydro have their own licences to use water from Coquitlam for beneficial purposes. Metro Vancouver and BC Hydro are reviewing options to withdraw additional drinking water from Coquitlam Reservoir as per the allocations originally contemplated in the Coquitlam-Buntzen Water Use Plan (BC Hydro 2005). Any changes in Water Use Plan allocations from this review will need to be evaluated with respect to effects on smolt migration behaviour.

To facilitate these operations, and provide for dam safety and continuous flow downstream in the Coquitlam River, there are four discharge outlets from the reservoir (the Buntzen Diversion

Tunnel, the Metro Vancouver GVWD Diversion, the Sluice Tower, and the Spillway). The four outlets are identified on the aerial photo of the lower portion of the reservoir in Figure 1. BC Hydro provided daily records of the average reservoir discharges through each of these outlets, along with the average daily reservoir water surface level, from February 2, 2003 through August 15, 2017 (see Appendix F). The four outlets are described below relative to their likely impacts on potential Sockeye smolt outmigration from the reservoir:

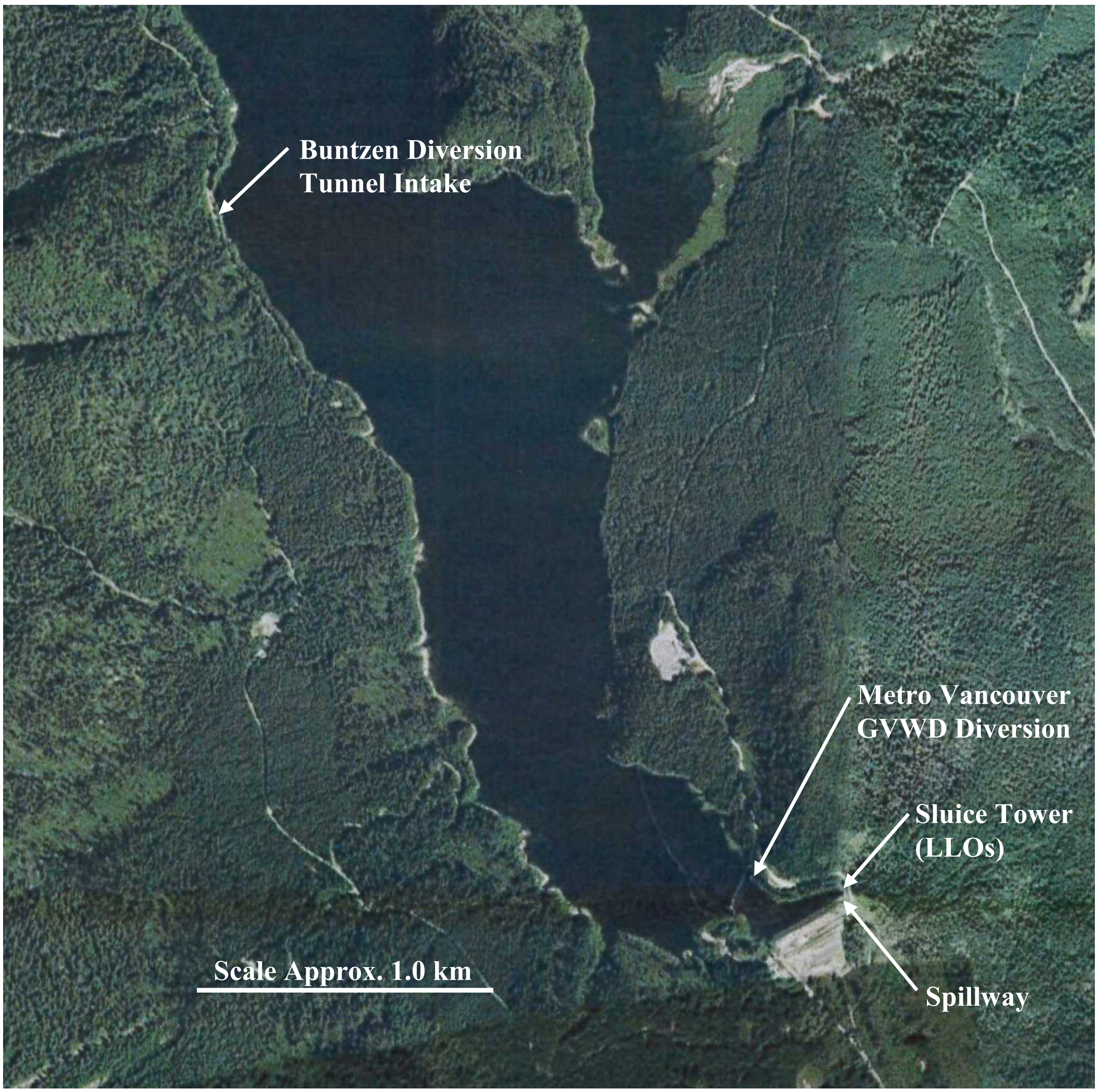

Figure 1. Aerial View of the Lower Reservoir with the Locations of the Four Outlets Highlighted.

3.2.1 Buntzen Tunnel Power Diversion

Hydropower operations involve diverting water from the Coquitlam Reservoir to the Buntzen Reservoir, where the powerhouse is located. The maximum capacity of this diversion is 40 m^3/s, and the data record reveals that daily average diversions often approach this capacity (BC Hydro, Alf Leake, personal communication, August 16, 2017 and Appendix F). At times there are extended periods that diversion does not occur and the powerhouse is not being operated. At times, this occurs for periods of up to several months in duration. For flood control purposes there are also extended periods when significant flow may be diverted through the Buntzen Diversion Tunnel while the powerhouse is not operating, and the flow is simply spilled at the Buntzen Dam.

The Buntzen Diversion Tunnel intake is located approximately 3.4 km upstream of the dam along the right bank of the reservoir (looking downstream). The tunnel intake includes three intake valves each 2.74 metres in diameter with an invert at elevation 132.0 m (Figure 2). While the intake closure valves are positioned fairly low, the top of the actual intake at the reservoir is significantly higher, approximated from the drawing to be at approximately El. 140 (Figure 2). There is ancillary information, although based on limited data, that outmigrating smolts may be attracted to this outlet during periods of operation, especially during low reservoir levels when the tunnel intake is closer to the surface. This attraction could also be exacerbated during periods of elevated discharge when a significant majority of the total outlet flows from the reservoir are diverted out through the Buntzen Diversion Tunnel (see historic outlet flows in Appendix F). The attraction of juvenile fish passing through the Buntzen Diversion Tunnel may also increase as the population of juvenile Sockeye Salmon increases and searches for reservoir outmigration routes when undergoing smoltification.

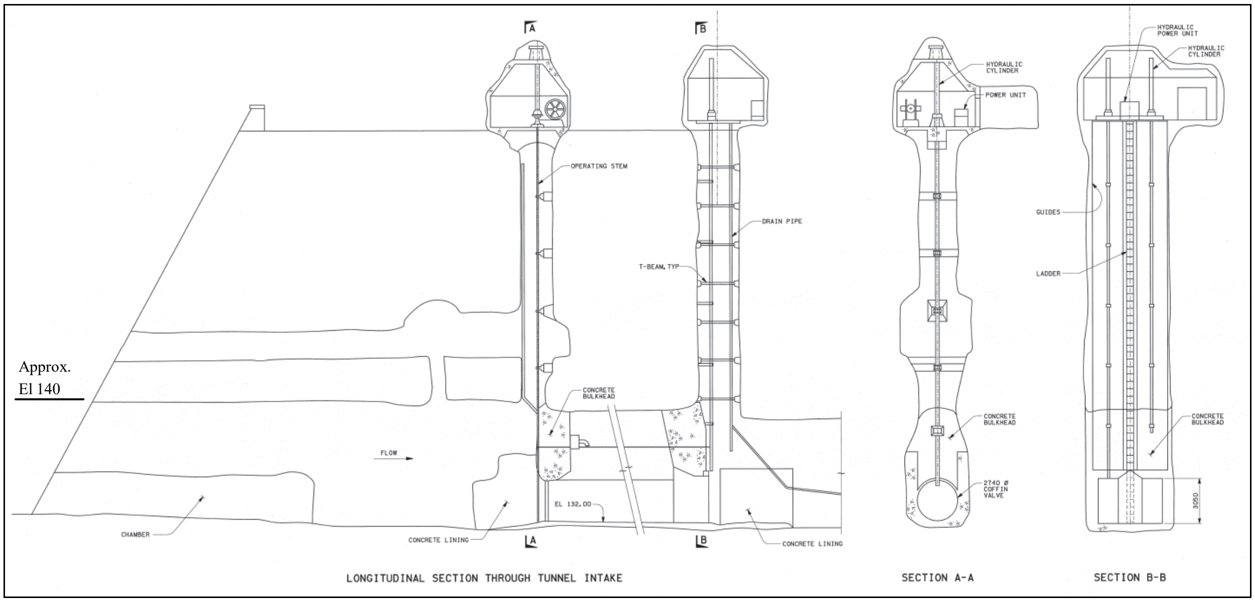

Figure 2. Section View through the Buntzen Diversion Tunnel Power Diversion Intake.

3.2.2 Metro Vancouver Diversion

Metro Vancouver's diversion for the Greater Vancouver Water District (GVWD) is located about 350 metres upstream of the reservoir outlet at the Sluice Tower. The diversion has a maximum flow rate of 13.7 m^3/s, although typical flow releases are about 4 to 6 m^3/s, with average daily flows during the period of record provided varying between about 2.5 to 9.2 m^3/s (Appendix F). Flows through the GVWD Diversion are often significantly higher than the simultaneous flow through the Sluice Tower outlet to the lower Coquitlam River. A section view through the GVWD Diversion intake and a photograph of the intake tower are provided in Figures 3 and 4, respectively. The intake invert is at elevation 131.92 m. While this diversion is reported to include rotating screens with a 1 cm^2 mesh, Sockeye smolts in the vicinity of this outlet may be attracted to the flow release, even though the screens may prevent their entry, resulting in confusion and/or delay in finding the Sluice Tower outlet.

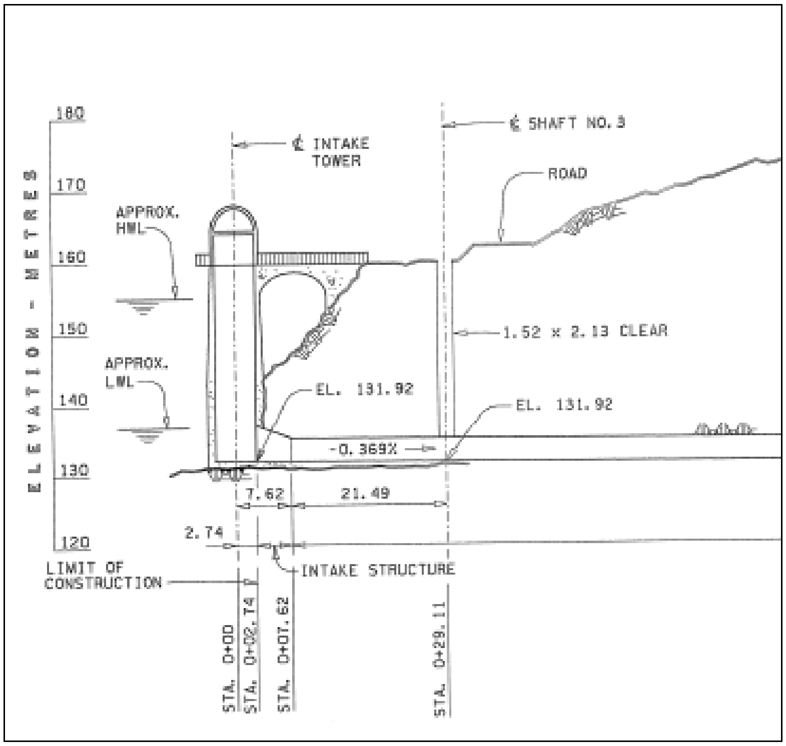

Figure 3. Section View through the GVWD Diversion Intake

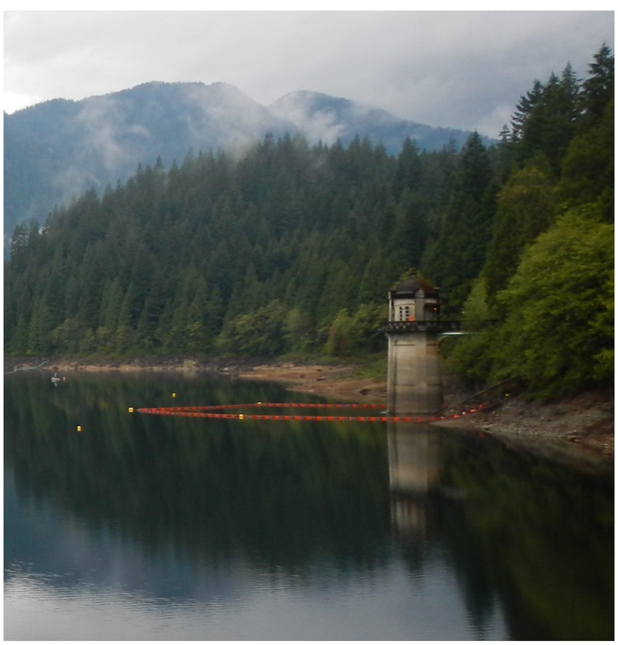

Figure 4. Photograph of the GVWD Diversion Intake.

3.2.3 Sluice Tower with Low Level Outlets

The Sluice Tower is located at the downstream end of the reservoir adjacent to the Coquitlam Dam (Figure 1). This outlet represents the only typical discharge to the lower Coquitlam River. The Coquitlam Dam forms one side of the Sluice Tower forebay, with the Sluice Tower at the extreme east end of the forebay. A composite photograph of the Sluice Tower forebay is provided in Figure 5. The Sluice Tower is visible on the right side of the photograph, and the GVWD Diversion tower is located in the center, just upstream of the inlet to the forebay. The Sluice Tower includes three low level outlets (LLO) and two fish valves (FV). A floor plan view of the Sluice Tower, with overall dimensions scaled from the drawing, is provided in Figure 6, a section view in Figure 7, and a photograph of the Sluice Tower in Figure 8.

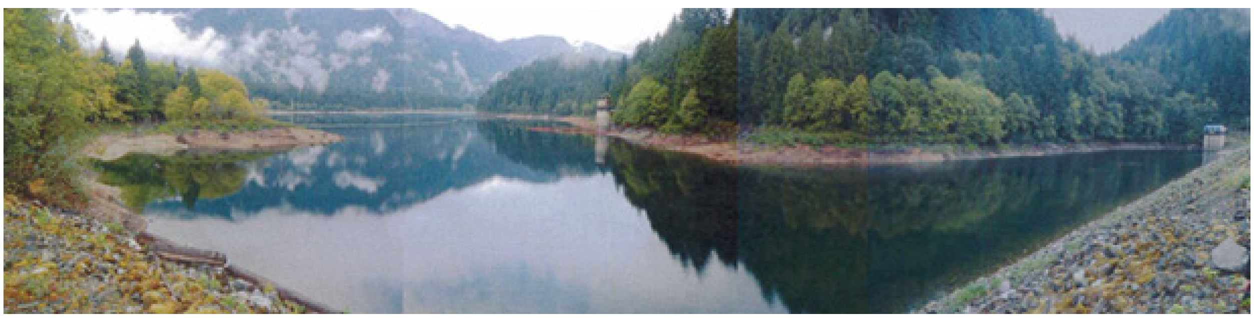

Figure 5. Composite Photograph of the Sluice Tower and Forebay.

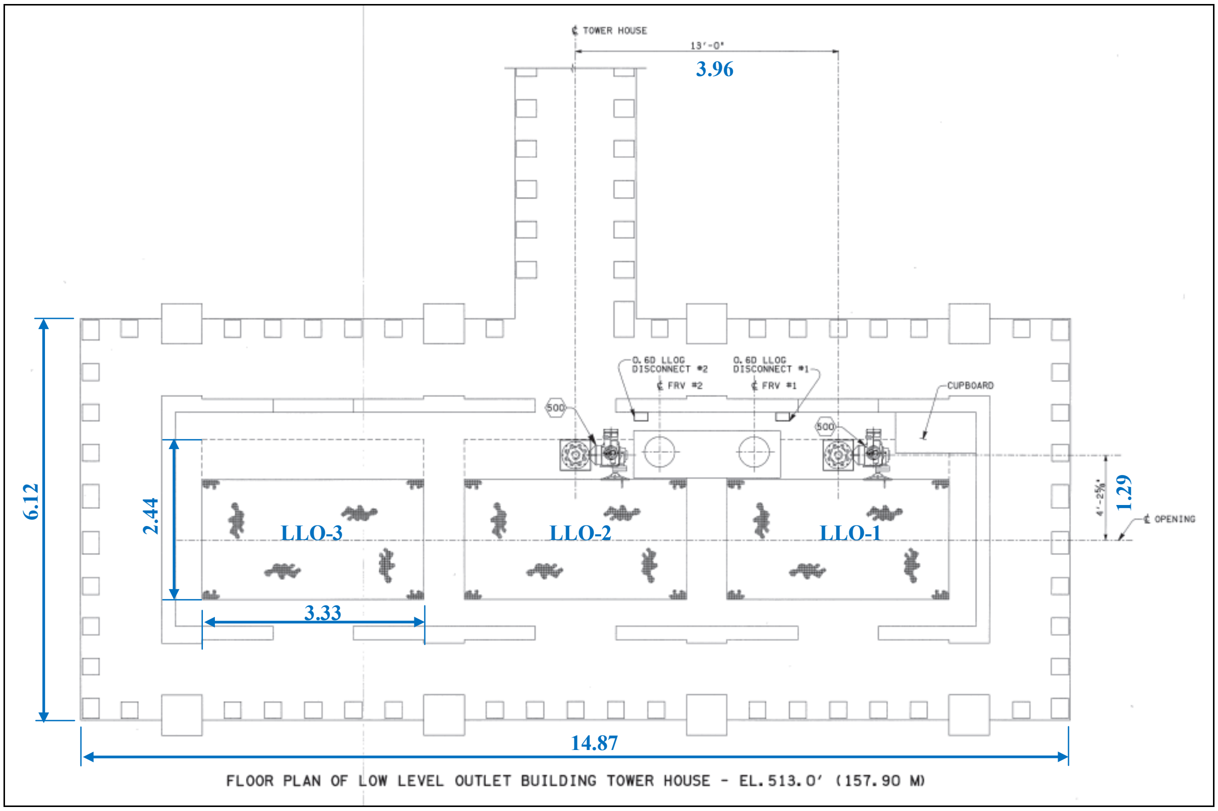

Figure 6. Plan View of the Sluice Tower (metric dimensions scaled from drawing).

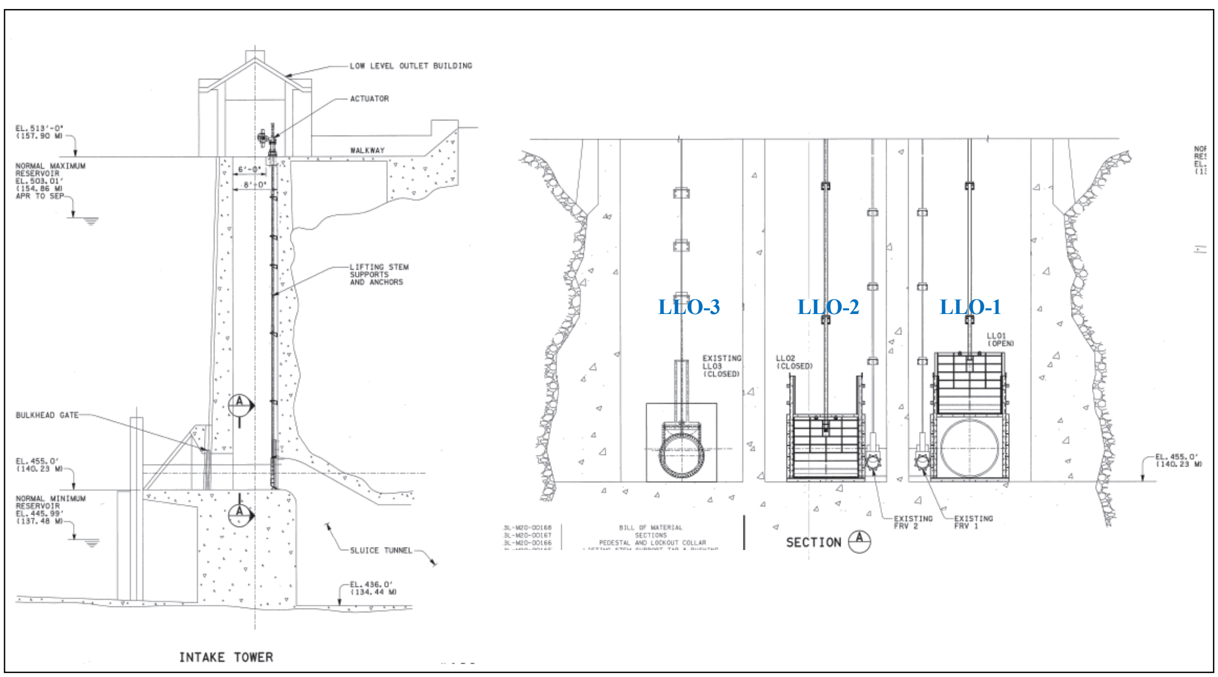

Figure 7. Section Views of the Sluice Tower and Low Level Outlet Gates.

Figure 8. Photograph of Sluice Tower Outlet.

There are three LLO gates in the tower. LLO-1 and LLO-2 are the original design with 1.52-metre-diameter openings controlled with rectangular slide gates on the upstream sides of the openings (Figure 7). The centerline elevation of the LLO-1 and LLO-2 openings is at elevation 141.10 m, with inverts at 140.34 m, and a floor sill in the Sluice Tower at elevation 140.23 m. Discharge through the gates varies with reservoir level and the percentage of gate opening (Figure 9). Each of these two LLOs can convey a maximum flow of 17 m^3/s, at a reservoir level of about 151.5 m.

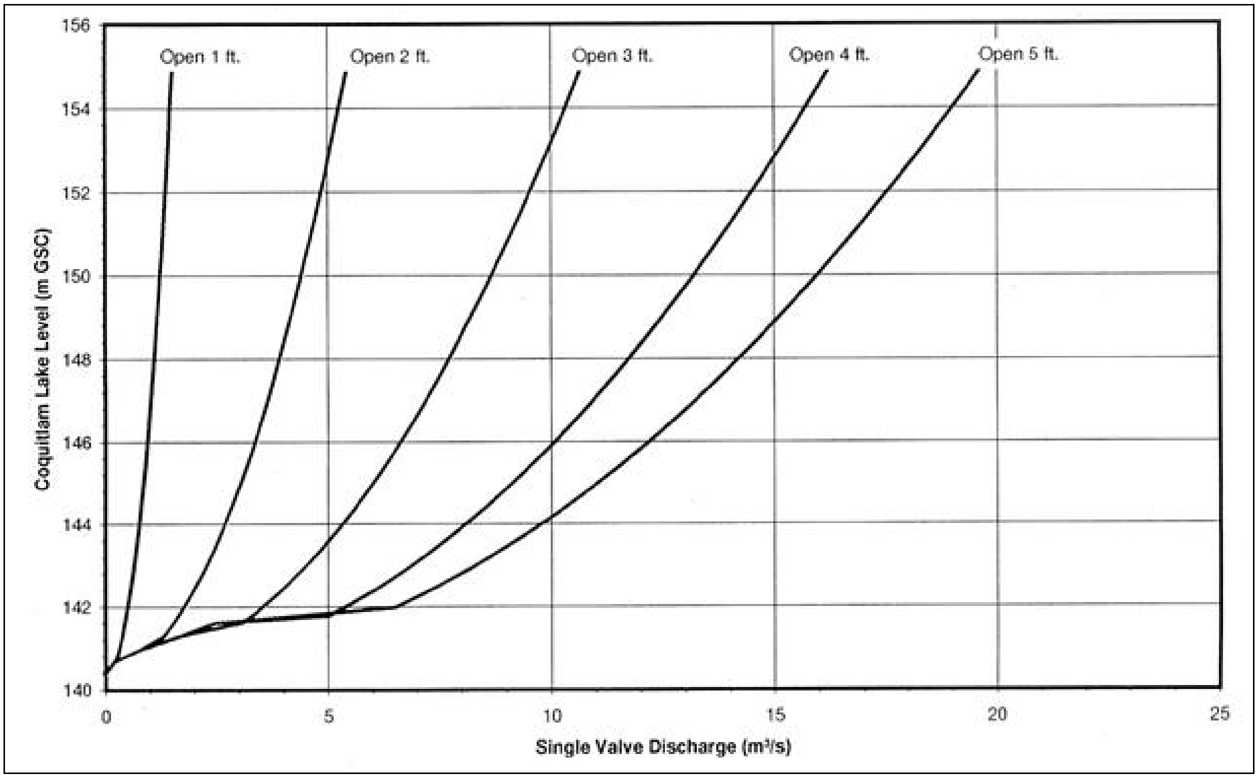

Figure 9. Reservoir Level vs. Discharge Curves for LLO-1 and LLO-2 (source: email communication from BC Hydro to P. Christensen, September 22, 2016).

LLO-3 was modified in 2008 to include a 1.22-metre-diameter flow control knife gate, decreasing its maximum flow capacity to about 10 m^3/s at a reservoir elevation of 151.5 (Figure 10). The LLO-3 knife gate has a centerline elevation of 140.99 m and an invert at 140.38 m. There are questions concerning the safety of knife gates for the passage of fish. In the U.S., the National Marine Fisheries Service (NMFS) does not generally allow for the passage of fish through a knife gate if the gate is used for flow control. This concern is based on the shape of the opening when in a partially open configuration. A partially open knife gate forms a crescent-moon shape with sharp points on each side at the top. The points represent hazards that can injure fish and/or accumulate debris that can in turn injure fish passing through the gate opening. In communications with NMFS by R2 personnel (email communication from Ed Meyer, NMFS engineer, to P. Christensen, September 13 and 21, 2016), they were unable to provide any test or other field data that documented a measureable basis for this concern; however, fish safety concerns for small openings of the gate appear justified. For example, a knife gate opening configuration of 27% open (the gate opening observed during a site visit on September 1, 2016) is depicted in Figure 11. It is clear that the upper portions of the opening at each side could be hazardous for fish passage.

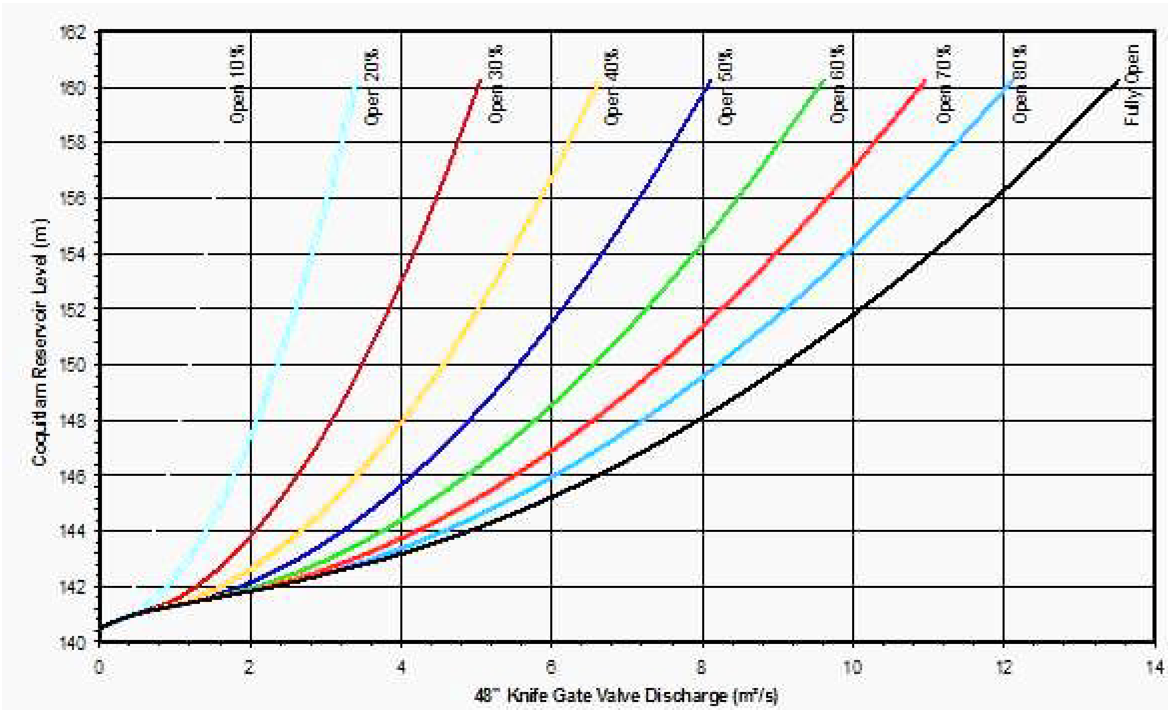

Figure 10. Reservoir Level vs. Discharge Curves for LLO-3 (source: email communication from BC Hydro to P. Christensen, September 22, 2016).

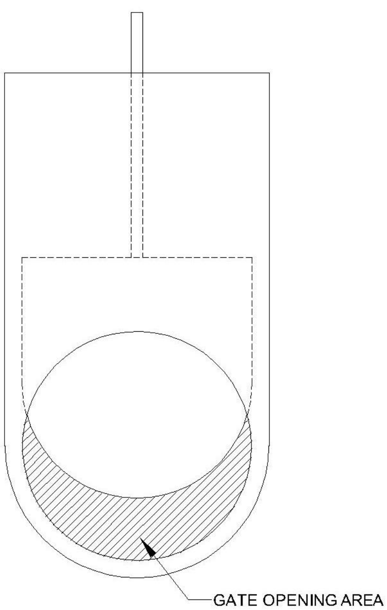

Figure 11. Knife Gate Shape Open 27%.

The two FV passages are 0.305-metre-diameter pipes at a centerline elevation of 140.76 m, with inverts at 140.61 m. The FVs convey a maximum flow of 0.85 m^3/s. Historically, the FVs were used as the first open valves for providing the minimum flow requirements in the lower Coquitlam River. Since the 2008 modifications, LLO-3 is used as the first open conduit to provide downstream minimum flows, and the two FVs are rarely used.

Each of the five outlets in the Sluice Tower, three LLOs and two FVs, discharge into a common unlined tunnel, and it had been speculated that the conditions in this tunnel may be injuring fish under certain flow scenarios (discussion during KSRP meeting September 2, 2016); however, the results of the 2017 field studies did not show this to be the case (see Section 5 of this report). There is also indication, based on screw trap catches located downstream from the tunnel, that smolt outmigration rates are positively correlated with increased flows through the Sluice Tower (Plate et al. 2014, and 2017 field study results).

3.2.4 Spillway

The largest capacity outlet from the reservoir is the spillway at the dam. The spillway is located at the east end of the dam, near the Sluice Tower. The spillway consists of a rock outcropping at the end of the dam, with a short concrete sill weir at elevation 154.86 m. A photograph of a portion of the spillway is provided in Figure 12. The spillway has a maximum flow capacity of 11,000 m^3/s at a reservoir water surface level of 160 m. Given the high crest elevation of the spillway, it would only be used during extreme high flow events when the inflow to the reservoir exceeds the capacity of the remaining outlets, and the reservoir rises to the level of the spillway. This would be considered a very rare occurrence. During the period of record provided (February 2, 2003 through August 15, 2017), the reservoir elevation never exceeded 153.5 m.

Figure 12. Photograph of the West End of the Spillway.

3.2.5 Operating Reservoir Levels

BC Hydro defined a range of normal maximum reservoir operating levels as cited below. It can be seen from these maximum operating levels that spill is not considered a normal operating condition.

El. 154.86 m 01 April to 30 September (License Maximum)

El. 153.86 m 01 October to 31 March, 1 m (License Maximum)

El. 152.86 m 01 December to 31 March, 2 m flood buffer (agreement)

El. 151.86 m 01 October to 30 November, 3 m flood buffer (agreement)

Minimum reservoir levels are defined by the minimum level to provide the GVWD Diversion with adequate water depth for their operation (minimum levels are depicted below).

The minimum operating levels to provide GVWD operation are:

El. 141.10 m 01 May to 31 August

El. 137.48 m 01 September to 30 April

During the 16.5 years of reservoir data provided by BC Hydro (Appendix F), the minimum reservoir level was 141.24 m on October 6, 2003, and the maximum level was 153.49 m on June 17, 2017. In 2008, BC Hydro completed construction of seismic upgrades to the Coquitlam Dam. An analysis of the reservoir level data relative to the completion of the upgrades shows an overall increase in reservoir levels post seismic upgrade. The range of minimum to maximum reservoir levels from 2003 through 2008 was from 141.24 m to 152.05 m, with an average elevation of 146.07 m. For the period of 2009 through 2017 the minimum to maximum range was 143.2 m to 153.49 m, with and average elevation of 148.83 m. This analysis revealed that the average reservoir elevation was over 2.5 metres higher for the post seismic upgrade period.

For the purposes of the designs presented in this report the relevant period of operation is the outmigration period for Sockeye Salmon smolts. Based on run timing for Sockeye Salmon outmigration in the U.S. northwest and southern British Columbia this is estimated to be the months of April and May. A reanalysis of the data for only these two months revealed a pre seismic upgrade range of elevations from 142.97 m to 147.83 m, and a post upgrade range from 144.52 m to 152.14 m. Therefore, for the purposes of these concept-level designs the post upgrade range was considered more relevant and the design reservoir range was set for an 8-metre range from 144.5 m to 152.5 m.

Water surface elevations can potentially play a big part in the success or failure of a smolt outmigration plan, depending upon reservoir operations and conditions through the collection and bypass facilities. At low reservoir levels, anadromous outmigrants may be more likely to be attracted to and diverted out of the reservoir through the Buntzen Diversion Tunnel due to the reduced submergence on the tunnel resulting in increased attraction for the surface-oriented migrants. This condition could be addressed if the Buntzen diversion flows were reduced or eliminated during the smolt migration season. A similar issue at the GVWD Diversion intake could result in disorientation and/or migration delay for smolts before they reach the ultimate outlet downstream. On the other hand, high reservoir levels may reduce attraction to the Buntzen Diversion Tunnel, but could also hinder smolt attraction to the deeper intakes to the LLOs in the Sluice Tower, and reduce the overall collection and passage efficiency. Additionally, decreased reservoir elevation results in higher velocities toward the downstream outlet, which should provide enhanced smolt attraction characteristics. Although this change would likely be insignificant in the large deep area of the upper reservoir, the higher velocities in the confined forebay area near the outlet may increase attraction to the Sluice Tower. Drawings 1 through 3 in Appendix E provide existing details of the Sluice Tower and forebay area. Drawing 1 (Appendix E) provides a plan view of the forebay area with topography and bathymetry. The contour lines for the low and high design water levels (144.5 m and 152.5 m, respectively) are highlighted, and it can be seen that the difference in area and depth between these two elevations is dramatic, resulting in higher downstream velocity at low design level given a common flow rate.

3.2.6 Operating Flow Rates

The current 2005 Coquitlam-Buntzen Project Water Use Plan cites the target minimum flows to the lower river during the months of April and May as 3.50 and 2.91 m^3/s, respectively (BC Hydro 2005). However, during years with lower than normal inflows to the reservoir the minimum downstream flows can be as low as 1.10 m^3/s in both months. The target and reduced minimum flows to be released to the lower Coquitlam River by month are provided in Table 1. To avoid downstream erosion, BC Hydro has stated that the maximum release during normal operation is 14 m^3/s (personal communication Alexis Hall, BC Hydro to P. Christensen, R2).

Table 1. Target and Reduced Minimum Releases to the Lower Coquitlam River.

Month	Jan 1-15	Jan 16-31	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Instream Flow Release Target (m^3/s)	5.90	2.92	2.92	4.25	3.50	2.91	1.10	1.20	2.70	2.22	6.07	3.96	5.00
Reduced Instream Flow Release Target (m^3/s)	3.60	2.92	2.92	1.77	1.10	1.10	1.10	1.10	1.10	1.10	3.59	1.49	2.51
Maximum GVRD Withdrawal Nomination (m^3/s)	11.9	11.9	11.9	11.9	12.0	12.0	12.0	18.0	23.0	23.0	12.0	12.0	11.9
Maximum % GVRD Nomination Reduction	10%	10%	10%	10%	10%	8%	9%	12%	12%	9%	10%	10%	10%

Based on the daily reservoir operating data provided by BC Hydro, the post seismic upgrade (2009 through 2017) minimum daily outflow for April and May though the Sluice Tower was 0.75 m^3/s (May 29-31, 2012), and the maximum was 8.13 m^3/s (April 24, 2017). It should be noted that the high discharge in 2017 was due to the biological study being performed in the spring of 2017, as described in Section 5 of this report. Prior to 2017, the maximum daily discharge downstream was 6.80 m^3/s (May 17, 2011). After 2011, discharges downstream were reduced, with typical daily maximums of about 4.0 m^3/s until the study performed in 2017. This reduction appears to have coincided with a significant reduction in the trapping of kokanee outmigrants in the screw traps downstream (Plate et al. 2014).

4. PHASE 1 – OPTIONS FEASIBILITY ASSESSMENT

4.1 ASSESSMENT OVERVIEW

BC Hydro contracted with R2 to perform an Options Feasibility Assessment reviewing options for providing safe and effective downstream passage for out-migrating salmonid smolts as part of an overall goal of restoring an anadromous Sockeye Salmon run above Coquitlam Dam. The Feasibility Assessment was performed in conjunction with the KSRP to learn more about the potential for restoring a sustainable run of Sockeye Salmon in the Coquitlam River, and served as a precursor to this Phase 2 Concept Alternatives Design. The Phase 1 Feasibility Assessment was completed in June 2017, and presented at a KSRP meeting on June 26, 2017 as part of Task 1 on this Phase 2 design effort.

The Phase 1 Feasibility Assessment included the following scope of work:

- Conduct a Literature Review of case studies and published reports related to Sockeye restoration and downstream Sockeye passage projects and experiences, with a focus on gleaning lessons learned from the projects.
- Attend a site visit to the Coquitlam Reservoir and Dam in coordination with BC Hydro and the KSRP. *The site visit occurred on September 1, 2016.*
- Attend a criteria workshop conducted by the KSRP. *The KSRP meeting occurred on September 2, 2016.*
- Review six passage options provided by the KSRP.
- Develop additional passage options based on R2's experience and results of the literature review.
- Assess passage options relative to the established criteria.
- Apply for a Phase 2 grant through the FWCP. The application was successful and led to this Phase 2 Concept Alternatives Design.
- Prepare a Phase 1 summary report summarizing the activities and results of the items above.

4.2 ASSESSMENT CRITERIA

The following criteria were developed for assessing the options reviewed in the Phase 1 Options Feasibility Assessment. For each of the options evaluated, a score (ranging from 1 to 5) was given for each of the six criteria listed below, with a rating of 1 being lowest (or worst) and a rating of 5 being highest (or best).

Proven Technology: Are there successful applications of the concept technology in use at similar sites that effectively pass salmonid smolts downstream?

Focus on Sockeye Passage: Has the concept technology been used to specifically collect and pass Sockeye Salmon smolts?

Effective Attraction of Migrating Smolt: Will the facility be expected to attract a significant majority of the migrating smolts that are near it?

Safe and Effective Collection of Migrating Smolt: Has the collection facility concept been shown to safely transfer fish from the fish entrance to the downstream transport facilities?

Safe and Effective Transport to the River Downstream: Are the downstream transport facilities, ultimately delivering the fish to the river downstream, shown to be safe for fish passage at other projects?

Cost: Will the construction and O&M costs of fish passage be commensurate with the expected benefit compared to the other options being evaluated?

4.3 OPTIONS REVIEWED

There were six options proposed by the KSRP for review, and four additional options developed by R2. These ten options are listed below with brief descriptions. More extensive descriptions with sketches and figures are provided in the Phase 1 summary report (R2 2017). In some cases, features of some of these options were incorporated into the two alternative concept designs developed in this Phase 2 study.

Option A: Smolt Ladder

Description as provided by the KSRP:

> *"This option has not been explicitly defined and would very likely be modeled after the Cle Elum Fish Passage."*

It was assumed for the purposes of the Phase 1 assessment that this option referred to the helix collector and passage currently being installed at the Cle Elum Reservoir.

Option B: Modifications to the Sluice Tower and Tunnel

Description as provided by the KSRP:

> *"Modify the Sluice Tower to create a controlled lower velocity flow of surface water to direct or carry outmigrants into and through the tower into improved conditions in the sluice tunnel. Possibilities that have been discussed are outlined in Fletcher 2016."*

This option was deemed during the initial KSRP meeting on September 2, 2016 to be similar enough to Option D that it could be eliminated, and was therefore not reviewed.

Option C: Capilano Smolt Trapping

Description as provided by the KSRP:

> *"Investigate Metro Vancouver Smolt Collection work at Capilano Dam."*

Metro Vancouver provided information on the fish collection operations they utilize at Capilano during the Phase 1 review.

Option D: Outmigration by a New Surface Intake Chamber on the West Side of the Sluice Tower

Description as provided by the KSRP:

> *"Spilling water from the reservoir over an elevation controlled sliding spill gate, which operates between elevations 145.0 and 150.0 m (approx.) into a new reinforced concrete chamber. This chamber would be attached to the west side of the existing Sluice Tower to direct water through a gated opening into the west shaft of the tower at elevation 145.0 (approx.) to deliver it to the fully open 60 inch sluice valve (invert elevation 140.0 m) and into the sluice tunnel (Fletcher 2016)."*

This option was described in more detail during the KSRP meeting on September 2, 2016.

Option E: Outmigration by a floating pipeline connected to the west side of the Sluice Tower

Description as provided by the KSRP:

> *"A pontoon supported 30 inch diameter floating pipe intake system, with flexible pipe connections, extended and anchored into the forebay area from larger diameter (possibly 48") piping embedded at invert elevation 145.0 m (approx.) in a large reinforced concrete thrust (anchor) block, anchored into the solid granitic*

rock core of the dam and the west concrete wall of the Sluice Tower by Dywidag steel bars. Flow into the pipe system could be induced by a low lift siphon and/or a low head, axial flow, fish friendly pump (which are in use in the Netherlands). The flow would be delivered through the fully open 60 inch sluice valve at invert elevation 140.0 m (approx.) into the sluice tunnel."

This option was described in more detail during the KSRP meeting on September 2, 2016.

Option F: Outmigration by reinforced concrete control structure built in a trench across the dam

Description as provided by the KSRP:

"A reinforced concrete, dual slide gate controlled flow passage to be constructed in a trench cut into the rock of the dam at elevation 145.0 m (approx.). Outmigrating smolts would be carried by the flow and dumped into the river from the spillway bench at elevation 145.0 m, at the downstream end of the sluice tunnel. With the addition of a trap near the downstream end of the tunnel, a basket lift capability and either sequential operation of the dual gates or a second basket lift, this installation could also be used to return adult Sockeye to the reservoir (Fletcher 2016)."

Two versions of this option (Options F1 and F2) were described during the KSRP meeting on September 2, 2016, and both were assessed.

Option G: Modified Operation of the Existing Sluice Tower

Description as provided by R2:

Prior to the Phase 1 Options Assessment there was a general belief that passage through the existing tunnel downstream of the Sluice Tower was injurious to fish. R2 proposed as part of the Phase 1 review that it was possible the injuries being seen could be the result of passage through the knife gate located in LLO-3, and not the tunnel conditions. If the tunnel is shown to be safe for fish passage, then modified operations of the reservoir and Sluice Tower might bring increased numbers of smolts to the forebay area and encourage them to pass downstream through the Sluice Tower. These modifications include the following:

- Reduce, or eliminate if possible, flows through the Buntzen Diversion Tunnel during the Sockeye smolt migration season.

- Increase the discharge through the Sluice Tower, with a target flow of approximately 8 m^3/s. Trial and error may ultimately define the optimal flow rate and that rate may vary year to year based on the inflow to the reservoir.
- Develop an operating plan that maintains a relatively low reservoir level to the extent possible.
- Pass the Sluice Tower discharge through LLO-2, as this outlet has a safer gate design than the knife gate in LLO-3, and the unlined discharge tunnel roof is located further away from this central gate than it is at LLO-1.

<u>Option H: Modify Sluice Tower Discharge Tunnel for Safer Passage</u>

Description as provided by R2:

Option H is essentially a backup option for Option G, should studies show that conditions in the Sluice Tower discharge tunnel are not safe for passage at these velocities. The approach would be to line the inside of the tunnel with curved steel plate grouted and anchored to the rock or with curved pipe sections with diameters equal to or slightly greater than, the diameters of the associated LLO openings.

<u>Option I: Fixed Screened Surface Collector Adjacent to the Sluice Tower</u>

Description as provided by R2:

Fixed surface screen facility attached to the south side of the existing Sluice Tower. In this way, it is similar to Option D, with the exception that it separates the fish from the majority of the flow through the Sluice Tower, and places them into a dedicated bypass pipe providing a potentially safer passage route downstream. LLO-1 would be used as a gravity source of the attraction flow. The fish flow would pass into a dedicated fish bypass pipe tunneled below the roadway into the existing Sluice Tower discharge tunnel. In this way, the fish would avoid passage through the potentially hazardous LLO conditions. The range of reservoir levels over which this design could operate successfully is limited by the ability to control the fish bypass flow out of the collector.

<u>Option J: Floating Screened Surface Collector (with Guide Nets)</u>

Description as provided by R2:

Installation of a floating surface collector (FSC) in the forebay upstream from the Sluice Tower outlet. Guide nets are included to lead fish toward the FSC entrance, and prevent them from passing by the entrance and continuing downstream to the Sluice Tower. Screened flow is pumped back to the reservoir downstream of the nets and would pass downstream through the Sluice Tower. Fish would pass downstream in a small manageable flow rate via a dedicated safe transport pipe to the lower Coquitlam River. Over the last 10 years, there have been six large-scale FSCs installed in the northwestern U.S., along with several smaller experimental facilities. Additional FSCs are also being considered at various locations. One of the first large-scale FSCs was installed at Upper Baker Dam in 2008 in Washington State, and grew out of decades of testing with a small floating barge collector (the 'gulper') that failed to attract enough Sockeye Salmon smolts away from a high volume power intake. The much larger Upper Baker FSC has been very successful at attracting and safely collecting the downstream migrating Sockeye smolts, and this success led to the installation of a near identical second FSC at Lower Baker Dam downstream. These two FSCs have played a major role in facilitating the overwhelmingly successful restoration of Sockeye Salmon in the upper Baker River watershed.

4.4 RESULTS OF ASSESSMENT

Detailed assessment notes for each option relative to each assessment criterion are provided in the Phase 1 summary report. Table 2 below provides a summary of the option comparisons from the Phase 1 Assessment Report. During the subsequent KSRP meeting on July 26, 2017 the results of the Phase 1 assessment were presented, along with the preliminary results of the 2017 biological field studies. These studies are described in greater in Section 5 of this report below; however, a significant finding was that fish passage through the existing tunnel downstream of the Sluice Tower did not appear to result in injury to the study fish or to naturally produced kokanee smolts migrating downstream out of the reservoir. Based on the information presented at the meeting, it was agreed that an Implementation Plan would be developed including the development of a Life Cycle Model to guide future decisions about the restoration activities, and that the initial activity would be to operate with 8 m^3/s during the outmigration season through the existing Sluice Tower, but not through the knife gate (Option G). Two concept design alternatives will be developed which may be implemented in the event the initial activity fails to meet the outmigration targets. One will be a surface flow weir entrance attached to the Sluice Tower (a modified version of Option D) to increase attraction and passage through the Sluice Tower, and the other will be an FSC with Guide Nets (Option J) to be considered in the event passage through the Sluice Tower is deemed to be unsafe for fish passage.

Table 2. Summary of Phase 1 Options Comparisons Relative to the Assessment Criteria.

Option	Proven Tech.	Sockeye Focus	Smolt Attraction	Safe Collection	Safe Transport	Cost	Total
A: Smolt Ladder (Cle Elum Helix)	1	2	1	3	3	2	**12**
B: Sluice Tower Mods (*Not Reviewed*)							
C: Capilano Smolt Trapping	1	1	1	3	2	4	**12**
D: Surface Entrance at Sluice Tower	2	2	5	3	2	2	**16**
E: Floating Pipeline to Sluice Tower	1	3	2	3	2	3	**14**
F-1: Spillway 1 (Free-Flowing)	3	3	5	4	3	1	**19**
F-2: Spillway 2 (with Upstream Passage)	2	3	5	2	2	1	**15**
G: Modified Sluice Tower Operation	3	4	4	3	3	5	**22**
H: Modified Sluice Discharge Tunnel	3	4	4	3	5	3	**22**
I: Fixed Surface Collector & Bypass	5	4	4	5	5	2	**25**
J: FSC with Guide Nets & Bypass	5	5	5	5	5	1	**26**

5. 2017 BIOLOGICAL FIELD STUDIES

During the spring of 2017 three biological studies occurred at Coquitlam focussed on gathering information concerning the outmigration of Sockeye/kokanee smolts through the Sluice Tower. LGL conducted an acoustic tagging study in the forebay and a smolt passage study through the Sluice Tower, and BC Hydro continued operation of the rotary screw traps (RST) in the river downstream of the dam. The sections below provide brief descriptions of these studies and the conclusions that were reached. Greater detail on these studies can be found in associated reports developed by LGL and BC Hydro.

5.1 LGL ACOUSTIC TAGGING STUDY

LGL released 103 acoustically tagged smolts in Coquitlam Reservoir in April and May of 2017. The fish were raised from kokanee eggs taken from spawning beaches and artificially reared to the size of Sockeye smolt. The acoustic tags placed in the fish allowed for tracking in three dimensions when the fish were in the vicinity of receivers. 15 receivers were placed throughout the forebay area to track the fish within 200 metres of the Sluice Tower. In addition, a receiver was placed in the tailrace downstream of the Sluice Tower discharge tunnel, and one was placed late in the study at the downstream end of the Buntzen Diversion Tunnel, after tagged fish were released near the tunnel entrance. The LGL summary report and 3D tracking results were not yet available during preparation of this report. So the information provided here is based solely on the 2D tracking and preliminary data provided by LGL. For more detail concerning the study the LGL summary report should be referenced when it becomes available.

During the study, the goal was to close the Buntzen Diversion Tunnel, so that all flow in the reservoir was moving downstream toward the south end of the reservoir. However, due to high inflows to the reservoir during the spring of 2017 this proved to not be possible. The tunnel was closed on April 18 and remained closed until April 24, when the decision was made to re-open the diversion. During this six-day period, the reservoir level rose 1.4 metres from an elevation of 150.7 m to 152.1 m, and with no reduction of inflows in sight this condition was not deemed to be sustainable. Diversion flows through the tunnel remained constant for the remainder of the study at flows between 37 and 38 m^3/s. Release flows through the Sluice Tower were alternated between 3 m^3/s and 8 m^3/s for approximately one-week periods during the study, to assess the impact of the higher flow rate on fish attraction and/or passage. Flow was also alternated between LLO-1 and LLO-3 to assess in difference in fish attraction and potential difference in injury to fish that pass through one gate versus the other. The timing of the flows and LLO gate operation was as shown in Table 3. Receivers were operated until May 16, three days after operations had been returned to normal.

Table 3. Timing of Discharge Flows and Gate Operations during the 2017 Acoustic Tag Study.

Start Date (Time)	End Date (Time)	Flow Rate	Outlet Gate
April 18 (11:00)	April 23 (13:00)	3 m^3/s	LLO-1
April 23 (14:00)	May 3 (9:000)	8 m^3/s	LLO-1
May 3 (10:00)	May 3 (14:00)	Transition	LLO-1
May 3 (15:00)	May 4 (13:00)	3 m^3/s	LLO-1
May 4 (14:00)	May 4 (17:00)	3 m^3/s	Transition
May 4 (18:00)	May 8 (15:00)	3 m^3/s	LLO-3
May 8 (16:00)	May 13 (9:00)	8 m^3/s	LLO-3
May 13 (10:00)	May 13 (15:00)	Transition	LLO-3
May 13 (16:00)	May 16 (24:00)	3 m^3/s	LLO-3

The tagged smolts were released on four separate days (April 18, April 23, May 3, and May 8), at the beginning of each new flow rate regime. The releases occurred at three locations in the reservoir; at the boat ramp in the forebay about 25 metres south of the Sluice Tower, at the south end of the reservoir boom approximately 350 metres west of the Sluice Tower, and near the Buntzen Diversion Tunnel approximately 3.4 kilometres upstream in the reservoir. Table 4 provides the release dates and times, locations, and numbers of fish released.

Table 4. Study Fish Release Times, Locations, and Numbers.

Release Date	Time	Location	# of Fish	Tag IDs	Flow Rate	Res. Elev.
April 18	14:16 – 14:30	Forebay	15	101 – 115	3 m^3/s	150.75
	13:56 – 14:08	Boom	10	151 – 160		
April 23	09:10 – 09:31	Forebay	10	201 – 210	8 m^3/s	151.79
	09:47	Boom	5	251 – 255		
May 3	15:15	Forebay	10	301 – 310	3 m^3/s	150.80
	15:39	Boom	10	351 – 360		
	16:17	Buntzen	10	381 – 390		
May 8	18:11	Forebay	13	401 – 413	8 m^3/s	151.37
	18:37	Boom	10	451 – 460		
	17:45	Buntzen	10	481 – 490		

Of the 103 tagged smolts released, 73 were recorded and tracked by the 15 receivers located in the forebay. This included all 48 of the fish released at the boat ramp in the forebay, plus 24 of the 35 fish released at the boom, and 1 of the 20 fish released upstream near the Buntzen Diversion Tunnel. Figure 13 provides an aerial view of the forebay area with the location of the 15 receivers, and the initial and final locations of the fish that were tracked by the receivers. First detections clumped together near the south end of the Sluice Tower represent the fish released at the boat ramp in the forebay. Fish first detected upstream near the mouth of the forebay represent fish released upstream at the boom, or the one tracked fish that was originally released near the Buntzen Diversion Tunnel.

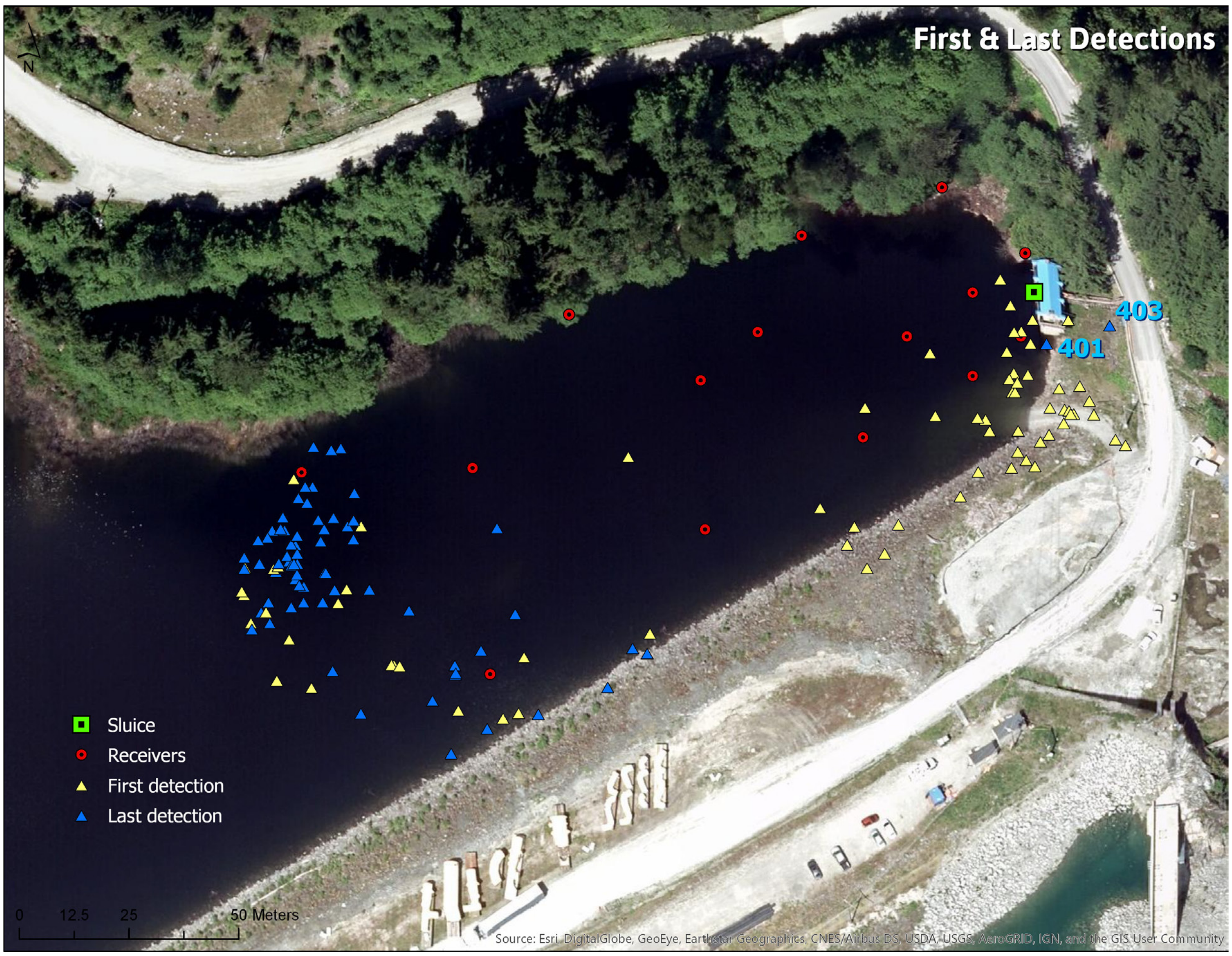

Figure 13. First and Last Detections of Tagged Fish in the Forebay (provided by LGL).

All but 2 of the tracked fish were last detected near the upstream end of the forebay, presumably swimming upstream out of the area. Two of the fish (Tag IDs 401 and 403) were last detected near the Sluice Tower, and presumably passed downstream in a flow rate of 8 m^3/s through the knife gate in LLO-3 (the open gate and flow rate at the time of the last detection). Both of these fish were released at the boat ramp and spent very little time in the reservoir (time between release and last detection), only 4 minutes for fish 401 and 2 hours 13 minutes for fish 403. It is notable that both of these two fish were part of the final release on May 8, and were presumably part of the most mature batch (or at least somewhat more mature than fish released 1, 2, and 3 weeks earlier). It is unclear as of the writing of this report whether either of these fish was ever detected at the receiver placed in the tailrace downstream of the Sluice Tower discharge tunnel.

As can be seen in Figure 13, that vast majority of the fish tracked in the forebay did not pass through the Sluice Tower, but chose to remain in the reservoir and move upstream. It is unclear if this was due to conditions at the Sluice Tower not being attractive to a fish desiring to move downstream, or if it was that the artificially raised fish reared from kokanee eggs did not have a strong impetus to move downstream out of the reservoir. The fish that ultimately moved upstream spent varying lengths of time in the forebay area. LGL provided 2-D tracks of each of the fish tracked by the receivers in the forebay. Figures 14 and 15 provide tracks of extreme cases of a fish that spent a very short period in the forebay and one that spent an extended period moving about throughout the entire forebay. The time difference between the first and last detections for Fish 104 (Figure 14) was 44 minutes; whereas for Fish 406 (Figure 15) the difference was 7 days 16 hours and 11 minutes. The blue tracking lines represent time spent during 8 m^3/s operation and the yellow lines during 3 m^3/s operation. Fish 406 remained in the forebay during significant portions of two different operating conditions. Other fish residence times varied over the entire spectrum between these extremes. Note that during the study the reservoir level was significantly higher than when the aerial photo used as a background was taken, which may explain why relative to the photo some of the tracks appear to be on land.

LGL also created fish detection heat maps of the forebay, in which the forebay was divided up into 2-metre square areas. The number of individual fish that were detected in each square area was counted (an individual fish was only counted once per area regardless of how long it may have spent in the area or how many times it may have visited the area). The more individual fish that were detected in a particular area defines the shade of blue for the area represented on the heat map. The darker the blue shade the more individual fish visited that area. Two-dimensional heat maps were produced for the 3 m^3/s (Figure 16) and 8 m^3/s (Figure 17) treatment periods. The area of maximum depth in the forebay has been highlighted on each of the maps in Figures 16 and 17.

Figure 14. Forebay Tracking of Fish Tag 104 (provided by LGL).

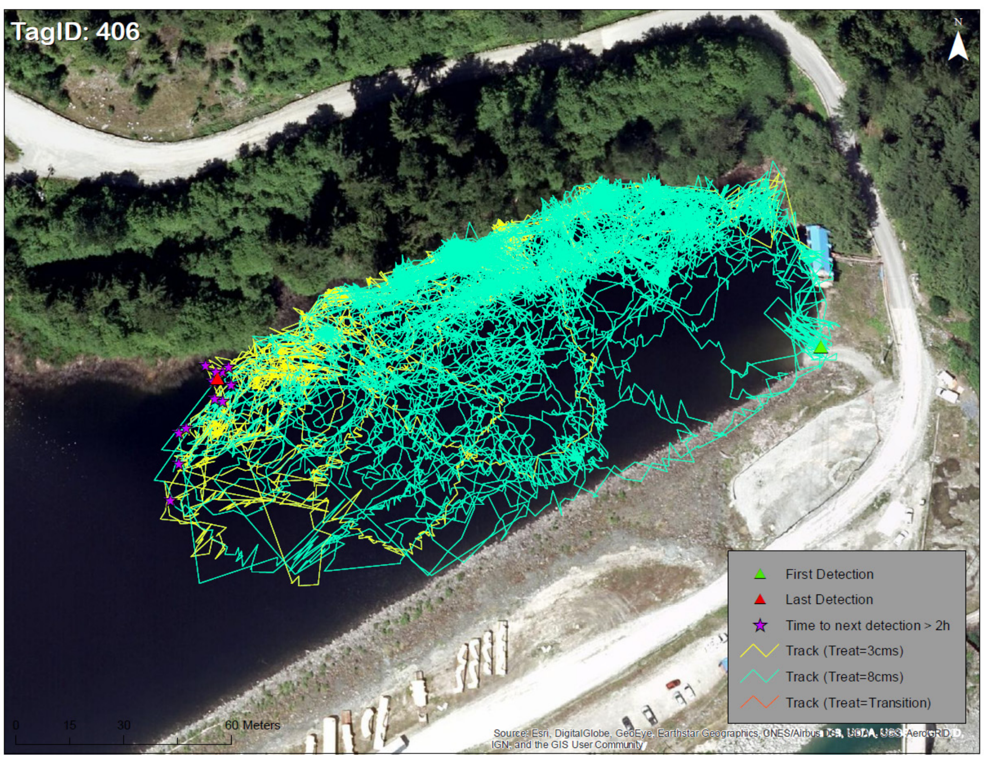

Figure 15. Forebay Tracking of Fish Tag 406 (provided by LGL).

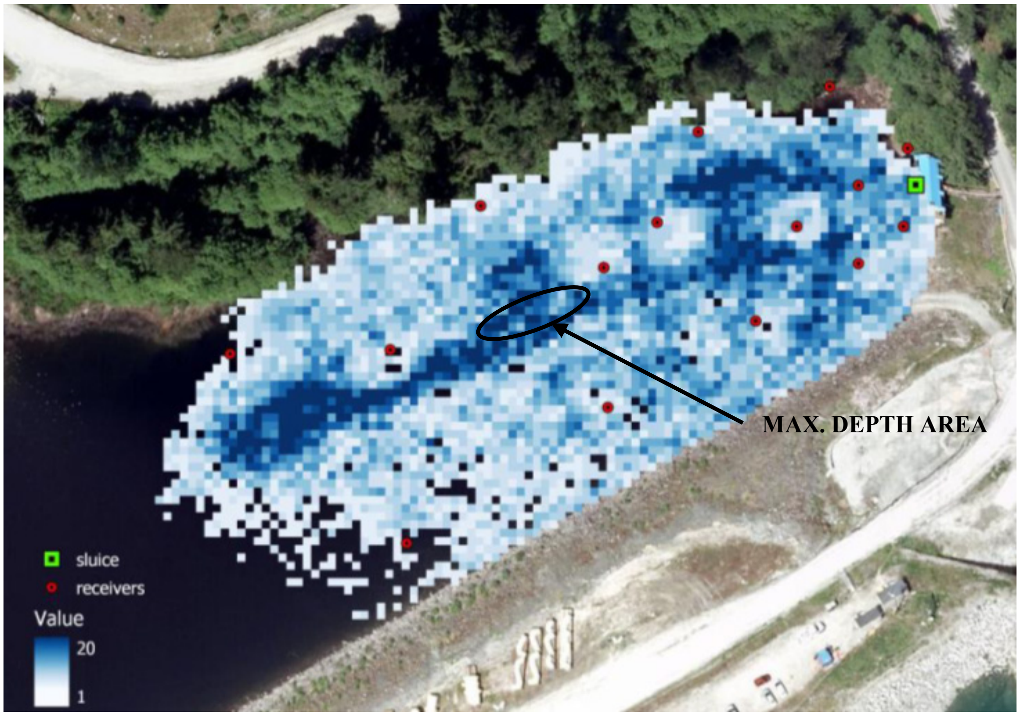

Figure 16. Forebay Fish Detection Heat Map for 3 m^3/s (provided by LGL).

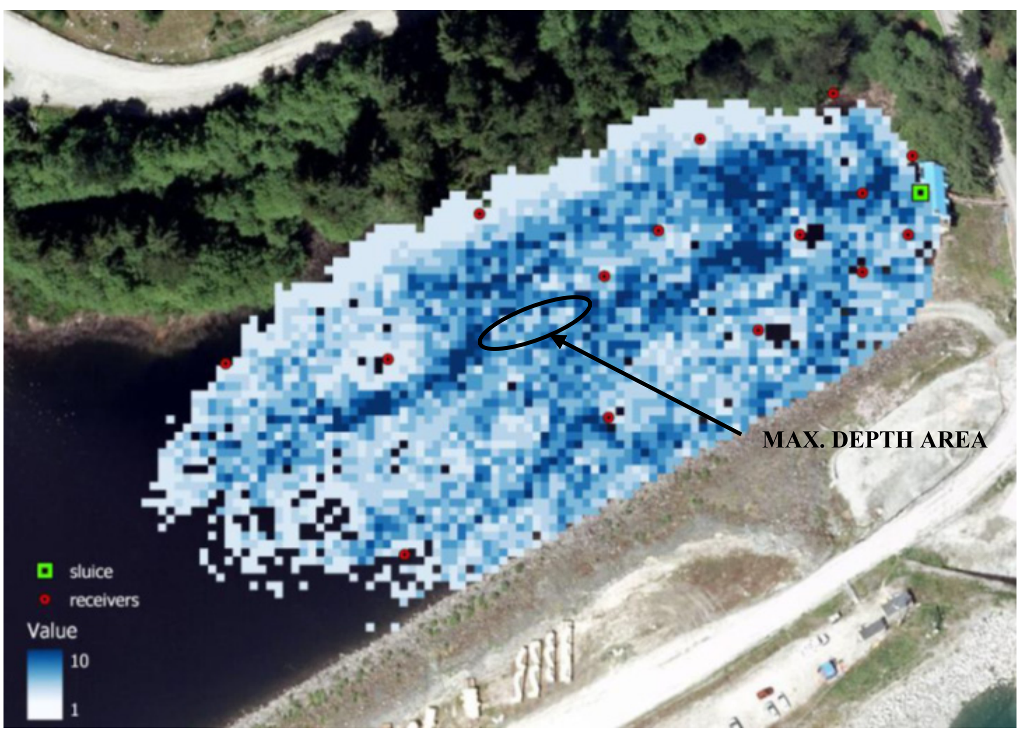

Figure 17. Forebay Fish Detection Heat Map for 8 m^3/s (provided by LGL).

It can be seen in Figures 16 and 17 that the fish are more spread out around the overall forebay area during the 8 m^3/s treatment period; whereas they tend to occupy the deepest part of the forebay during the 3 m^3/s treatment period until they get to the vicinity of the Sluice Tower and then they spread more across the width of the forebay. In either case, the upstream end of the deepest part of the forebay tends to be an area visited by a significant percentage of the fish at some point as they move around the forebay. If a fish collection entrance were to be located remote from the Sluice Tower this would appear to be a good location for attracting fish.

As previously stated, the 3-D tracking results were not yet available at the time of the writing of this report. These tracks, when available, may reveal information about the fish behavioural response to the conditions at the Sluice Tower. Questions that should be investigated when the 3-D results become available include:

- What is the predominant depth of fish observed in the forebay?
- Did the predominant depth vary between the 3 m^3/s and 8 m^3/s exposures?
- Did fish tend to sound deeper as they approached the Sluice Tower?
- If fish did sound to depth did they stay there long?
- Did fish that stayed in the forebay longer tend to go deeper?

It may also be considered to monitor outmigration rates at lower reservoir levels, when the Sluice Tower intakes are not as deep, and the cross-sectional area of the forebay is smaller, resulting in higher velocities in the forebay toward the Sluice Tower (assuming the same flow rate).

Of the 20 fish released near the Buntzen Diversion Tunnel entrance only one was detected by the receivers in the forebay. However, as previously discussed the goal had been to turn off, or at least greatly curtail, the Buntzen diversion flow during the study, but due to extremely high inflows during the spring of 2017 this was not possible, in fact the diversion tunnel was running at near capacity for the entire time after it was reopened six days into the study. No fish were released near the Buntzen entrance early in the study when it was closed, so there is no data to provide comparison between tunnel on and tunnel off conditions.

5.2 LGL SMOLT PASSAGE STUDY

During the spring 2017 biological field studies, LGL also released untagged fish directly into the Sluice Tower to assess the safety of passage through the Sluice Tower gates and discharge tunnel. All released fish had the adipose fin removed for differentiation from any resident kokanee that might have migrated naturally out of the reservoir. A fyke net was located in the tailrace downstream of the discharge tunnel outlet to retrieve and inspect the fish after passage. Figure 18 provides a photo of the fyke net assembly.

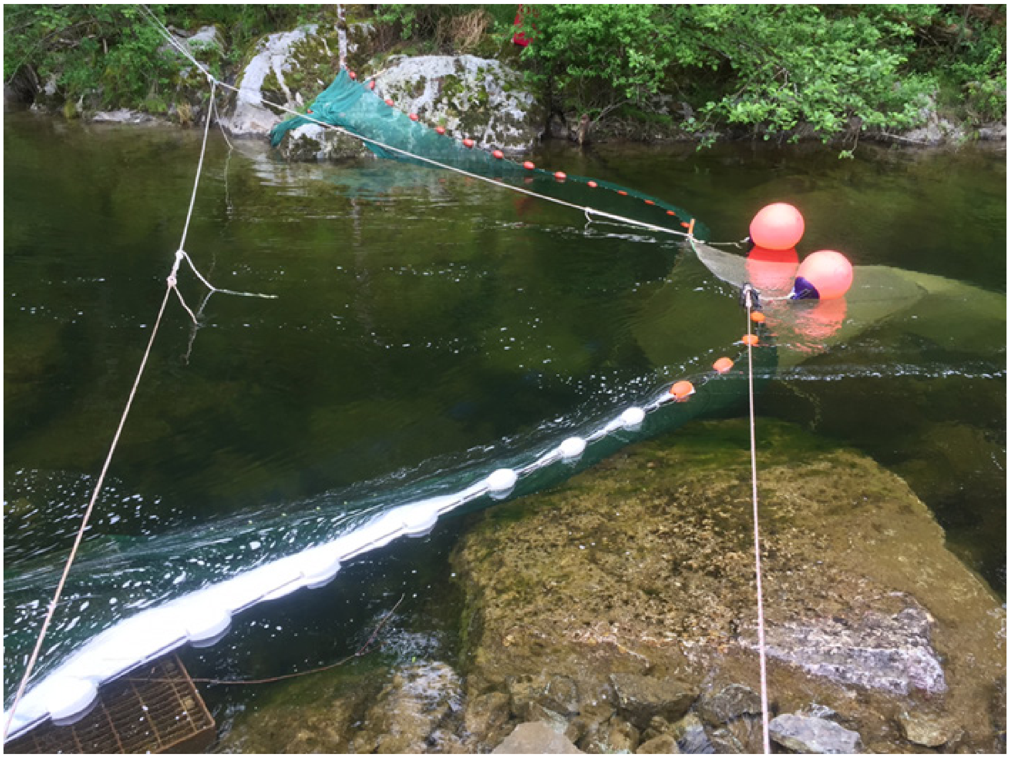

Figure 18. Fyke Net in Tailrace below the Discharge Tunnel (provided by LGL).

Initially, live fish were released into the trashracks in front of LLO-1. Releases were made on May 2, 3, and 4. The May 2 release was performed during 8 m^3/s operation, and the May 3 and 4 releases were performed at 3 m^3/s operation. Due to availability of test fish, most of the fish used in this study were smolt-sized Coho Salmon used as a surrogate for Sockeye, although some Sockeye (artificially-reared kokanee) were included in the May 4 release. Numbers of fish released, and results of the passage study are provided in Table 5. Based on very low numbers of fish recovered in the fyke net, it appeared that a significant number of the released fish were turning back upstream before being pulled into the LLO. Therefore, a decision was made to relocate the fish release assembly to release fish directly into the LLO so that all released fish would have to pass through the discharge tunnel.

Table 5. Sluice Tower Smolt Passage Study Data and Results (provided by LGL).

Date (mm/dd/yy)	05/02/17	05/03/17	05/04/17	Summary	05/31/17	05/31/17	06/01/17	Summary
Time (12 h hh:mm)	14:30	18:00	12:30		22:10	22:30	12:00	
Discharge (m³/s)	8	3	3		3	3	3	
Number Coho released (N)	106	97	50	253	100	100	100	300
Number Sockeye released (N)	0	0	50	50	0	0	0	
Dead or Alive (D or A)	A	A	A		D	A	D	
Release Location (Trash, LLO or LT=Lower Tunnel)	Trash	Trash	Trash		LLO	LLO	LT	
Clip (A=adipose; UC=upper caudal; LC=lower caudal	Adi	Adi	Adi		Adi + UC	Adi	Adi + LC	
Fyke Net (or Visual) Number Recovered Alive (N) Coho	1	3	1	5	0	29	0	29
Average Condition of Captured Smolts (1 - 5; 1 = no trauma visible)	1		12 x 1, 1 x 2		1	1	1	
Fyke Net (or Visual) Number Recovered Dead (N)	0	0	0	0	47	3	25	75
Total RST Number Recovered Alive (N)	11	11	12	34	0	55	0	55
Total RST Number Recovered Dead (N)	0	0	0		0	0	0	
Total %Recovered Alive from Alive (%)	11.32%	14.43%	13.00%	12.87%	NA	84.00%	NA	84.00%
Total %Recovered Dead from Dead (%)	NA	NA	NA	0.00%	47.00%		25.00%	36.00%
Total %Recovered Dead from Alive (%)	0.00%	0.00%	0.00%		NA	3.00%	NA	3.00%
Comments		3 Coho smolts observed holding in bay					55 dead found at tunnel outlet in deep water	

The fish release tube assembly was relocated from the LLO-1 trashrack outside the Sluice Tower, to a position inside the Sluice Tower at the knife gate in LLO-3. Figure 19 shows the arrangements of the fish release tube assembly in each of the two locations. The release tube is shown in yellow, and the red box and dark black line represents the pump and water supply hose for providing flow to the release tube. A significant feature of the relocated assembly is that a flexible hose section was added to the end of the release tube, which got pulled through the opening in the knife gate and released the fish on the downstream side of the knife gate blade. This additional hose piece is shown in blue in Figure 19.

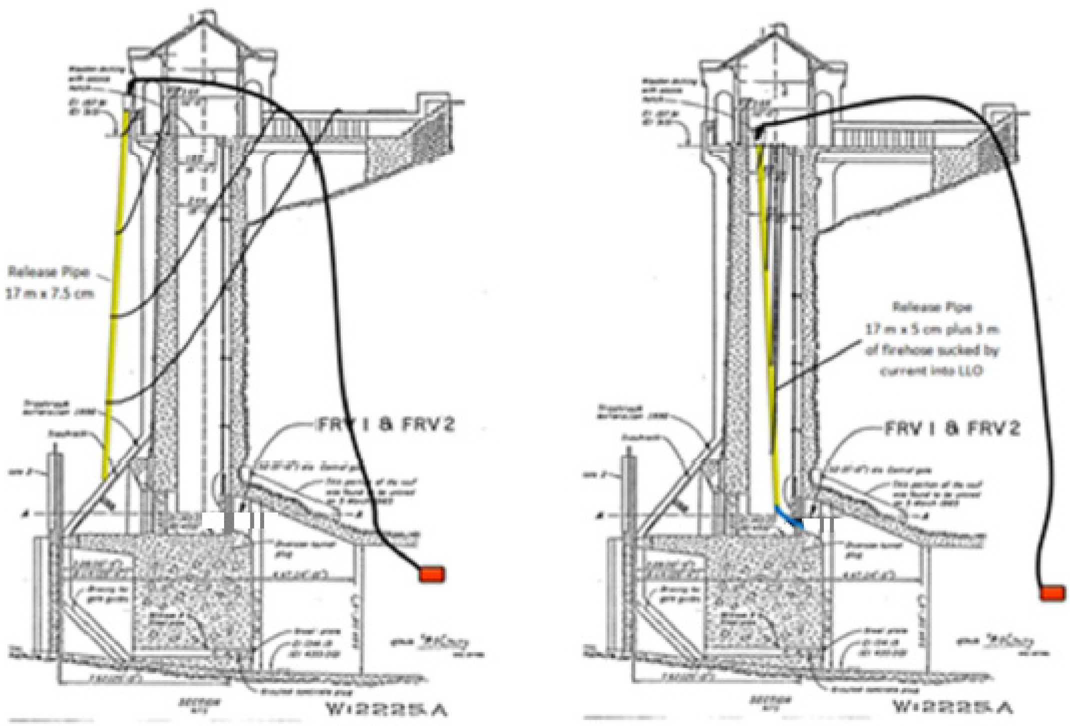

Figure 19. Fish Release Tube Assembly at LLO-1 Trashrack (left) and LLO-3 Knife Gate (right).

Three releases were made through the relocated assembly at LLO-3 on May 31 and June 1. In all cases, the flow rate was 3 m^3/s. One release on May 31 used 100 live Coho smolts, and two releases (on May 31 and June 1) used dead Coho smolts. Dead fish releases were included to resolve questions concerning the ability of the fyke net to have captured any fish from the initial releases through LLO-1 that might have been killed by the passage through the Sluice Tower and discharge tunnel.

Results of all of the fish releases through the Sluice Tower are provided in Table 5. It was determined that the ability of the fyke net to capture dead fish was about equal to its ability to capture live fish. The fyke net captured 47 of the 100 dead fish in the first release on May 31, and 25 of the 100 dead fish released on June 1. It also captured 29 of the 100 live fish released on May 31. It is interesting to note, that the RST downstream (see Section 5.3 below) captured 55 of the 100 live fish released on May 31. So the RST appears to have been more efficient at capturing the fish than the fyke net was. Likewise, the downstream RST captured 34 of the 303 fish that were previously released at the LLO-1 trashrack; whereas the fyke net only captured 5 of those fish. It is also of interest that the RST did not capture any of the 200 dead fish released, so apparently dead fish exiting the Sluice Tower discharge tunnel do not make it downstream as far as the RST location.

Finally, it is notable that all fish captured downstream in either the fyke net or RST were labelled as being in good condition with no visible signs of injury or trauma from having passed through the Sluice Tower discharge tunnel, with the exception of one fish from the early releases through LLO-1 at a flow of 3 m^3/s, and even that fish was rated as a 2 on a scale of 1 to 5 with 1 being no visible signs of trauma.

5.3 DOWNSTREAM ROTARY SCREW TRAPS

For several years, BC Hydro has contracted the operation of RSTs downstream from the Sluice Tower in the lower Coquitlam River. In 2017, five RSTs were operated in the lower Coquitlam River. BC Hydro provided the results from the operation of the RSTs in 2017, and a summary of the results relative to the operations during the 2017 migration season are presented below. Figure 20 provides a photo of an RST.

Figure 20. Photo of a Rotary Screw Trap.

The largest of the RSTs is the upstream trap located in Reach 4, approximately 1.5 km downstream of Coquitlam Dam. This is the trap that captures the greatest number of fish, and is generally believed to have a capture efficiency of approximately 50%. This is the trap that captured 55 of the 100 marked live fish passed though LLO-3, and 34 of the earlier 303 study fish released through LLO-1, as described above.

In addition to providing information concerning the study fish, the RST located in Reach 4 captured a number of wild kokanee smolt migrating naturally downstream out of the reservoir.

Table 6 provides a summary of these wild smolt catches and their timing relative to the operations of the reservoir outlet during the LGL studies.

Table 6. 2017 Wild Smolt Catches at the RST R4 Downstream of Coquitlam Dam.

Dates	Flow Rate	Wild Smolts
April 18 – April 23	3 m^3/s	0
April 24 – May 3	8 m^3/s	7
May 3 – May 8	3 m^3/s	0
May 9 – May 13	8 m^3/s	48
May 14 – June 2	3 m^3/s	6

It is interesting that wild kokanee smolts began to migrate out of the reservoir after the first increase in flow to 8 m^3/s, and then stopped when the flow was returned to 3 m^3/s. When the flow was again increased after May 8 another larger run of wild kokanee smolts migrated out. After the flow returned to 3 m^3/s trapping continued at the RST for about 3 more weeks, but capture of migration of wild smolts slowed to about two fish per week. These capture counts give a strong indication that the higher flow rate discharging from the reservoir though the Sluice Tower encourages increased numbers of wild kokanee smolts to migrate downstream out of the lake. This agrees with observations made in previous years where the outflow was increased to flows of about 6 m^3/s and operators of the RSTs downstream said they observed a significant increase in the kokanee counts. It can be reasonably speculated that if the reservoir discharge flow had been maintained at 8 m^3/s, from early April through the end of May, that significantly more wild kokanee Smolt would have migrated downstream.

The four smaller RSTs downstream of RST R4 also captured some wild kokanee smolts, but in much smaller numbers. These are smaller traps, with reduced capture efficiency, and there is the potential that some of the fish captured at these lower traps are some of the same fish released after capture from RST R4. Therefore, the best indication of the size of the run is the capture counts at RST R4.

5.4 CONCLUSIONS AND REMAINING QUESTIONS

The conclusions that can be extracted from the results of the three studies performed in the spring of 2017 include:

- The artificially reared smolts, raised from kokanee eggs, do not appear to exhibit a strong tendency to migrate downstream out of a reservoir, although 2 of the 48 fish released directly into the forebay did appear to migrate out through the Sluice Tower.

- These same fish exhibit a wide variety of behaviours when released into the reservoir.
- Fish behaviour in the forebay appears to be affected by the flow volume through the Sluice Tower. At lower flows the fish show a strong tendency to occupy the deepest portion of the forebay. At higher flows, the fish spread out somewhat more evenly throughout the forebay.
- With large magnitude flows through the Buntzen Diversion Tunnel it was observed that fish released near the diversion tunnel entrance did not tend to migrate to the forebay downstream.
- Passage through the discharge tunnel at the Sluice Tower appears to be safe, even at the higher than usual reservoir levels experienced in 2017, and injuries that may have been observed in previous years and attributed to the tunnel were more likely due to passage through the partially open knife gate.
- There appears to be a direct correlation between higher flow rates and higher rates of out-migrating kokanee smolts from the reservoir.

The following questions still remain unanswered until more information becomes available:

- At the time of the preparation of this report the 3-D tracking results were not yet available. When these results become available the following items should be investigated:
- What is the predominant depth of the fish in the forebay?
- Did the predominant depth vary between the 3 m3/s and 8 m3/s exposures?
- Did fish tend to sound deeper as they approached the Sluice Tower?
- If fish did sound to depth did they stay there long?
- Did fish that stayed in the forebay longer tend to go deeper?
- Due to the unusually high inflows to the reservoir during April and May of 2017 it was not possible to keep the Buntzen Diversion Tunnel flow off, or even reduced, so no information could be learned about any migratory advantages associated with reducing this diversion flow.
- Also due to the high inflows, the reservoir was higher than typical throughout the studies, so it was not possible to assess whether the smolts might have been more attracted to the Sluice Tower flow if the reservoir was lower and the tower intakes were not as deep.

6. IMPLEMENTATION PLAN

R2 worked closely with BC Hydro and the KSRP to develop an Implementation Plan to direct on-going activities associated with Sockeye Salmon restoration in the upper Coquitlam River. The Implementation Plan, including a written step-by-step plan and a decision flow chart, is attached to this report in Appendix C. The plan includes three major components; development of a life-cycle model to direct future decisions, initiation of optimized operations for smolt outmigration, and development of concept-level designs for potentially improving fish collection and passage efficiency if required. These components are described below.

6.1 LIFE-CYCLE MODEL

R2 is working with BC Hydro and Dr. Eduardo Martins (University of Northern British Columbia) to develop a life-cycle model for Sockeye Salmon restoration in the Coquitlam River. Life-cycle analyses provide a useful framework for leveraging fish population and habitat data that integrates life-stage specific demographics, movement dynamics, fish-habitat relationships, and various restoration scenarios. The model will be used to support future decisions regarding salmon restoration opportunities tailored to the complexity of the Coquitlam River system.

The r-based modeling of life cycle components is being developed to integrate available information for each of the primary life stages of a Sockeye Salmon migrating and reproducing in the Coquitlam River system, including:

- Number of pre-smolts in Coquitlam Reservoir
- Proportion of pre-smolt population exhibiting outmigration behavior
- Fish passage collection efficiency
- Fish passage survival efficiency
- Smolt-to-adult return percentage from ocean
- Proportion of returning adults captured below dam
- Number of adults passed upstream
- Number of female sockeye released into reservoir
- Fecundity of individual females
- Available spawning area in upper Coquitlam basin
- Available rearing capacity in Coquitlam Reservoir
- Egg to pre-smolt survival proportion

Where possible, information specific to the Coquitlam River watershed will be used to develop inputs for a particular life stage. However, for some of the life stages listed above there are no existing data specific to the Coquitlam River, in these cases, model inputs will include information from regional watersheds with Sockeye Salmon populations. A range of values for specific life stages will be evaluated to identify the relative contribution of each life stage to sustaining an anadromous Sockeye population. The model can also be updated when Coquitlam-specific data become available.

The life-cycle model will be used to quantify performance measures required to meet minimum adult escapement thresholds (MAET). Model results will be used to evaluate life stage metrics and whether a self-sustaining anadromous Sockeye population can be restored under realistic life stage production and survival targets. The life-cycle model will also identify those factors having the greatest influence on meeting minimum adult thresholds and the extent to which factors can be influenced by restoration efforts. This process will allow the KSRP to build a foundation to guide restoration efforts and evaluate restoration efforts despite annual variations in life stage production and survival. Initial life-cycle model results will be available by June 2018.

The two alternatives being investigated in this study would have impacts on improving the third and fourth components in the life-cycle model, fish passage collection efficiency and fish passage survival efficiency. These alternatives would not be expected to have any impact on the remaining life cycle components. If the developing life-cycle model shows, after a number of annual cycles and updates, that the fish passage collection and survival efficiencies are an impediment to the potential success of the restoration under the Optimized Outmigration Operations then one of these alternatives might be considered for installation.

6.2 OPTIMIZED OUTMIGRATION OPERATIONS

The implementation plan calls for optimizing the operations of the Coquitlam Reservoir for Sockeye Salmon smolt migration from the reservoir during the smolt out-migration season. This operating procedure was proposed as Option G in the Phase 1 options assessment. Starting in the spring of 2018, the following modification to reservoir operations will be initiated, and to the extent practicable, maintained through the months of April and May:

- Flows through the Buntzen Diversion Tunnel will be curtailed (eliminated or reduced depending on the volume of reservoir inflows).
- Releases to the lower river through the Sluice Tower will be maintained at 8 m^3/s.

- Flows through the Sluice Tower will pass through LLO-2, to avoid flows through the knife gate.

In addition to these operational modifications, installation and monitoring of the RSTs in the lower river downstream of the Sluice Tower will be continued to assess the effectiveness of the operational modifications. The RST program was previously scheduled to be complete at the end of the 2017 season.

6.3 POTENTIAL MODIFICATIONS

The initial phase of the Implementation Plan includes maximizing the natural outmigration of existing kokanee smolts in the reservoir, with the intent that they will migrate downstream to the ocean, rear in the ocean, and return as anadromous adults. The success of this approach will be monitored, and if indications are that the existing kokanee population will never be able to produce the MAET, then temporary hatchery supplementation may be considered. If studies determine that juveniles are undergoing smoltification, but the existing Sluice Tower is not adequately attracting, and/or is not safely passing them downstream, physical modifications may be required. At the KSRP meeting on July 26, 2017 it was decided that concept designs would be developed for two potential modifications as part of this Phase 2 study. The remaining sections of this report provide detailed descriptions of these concept designs, and estimates of construction and annual O&M costs.

7. DOWNSTREAM PASSAGE MODIFICATION ALTERNATIVES

Two design alternatives have been considered for modifications to the Coquitlam Reservoir outlet facilities to the lower Coquitlam River. Appendix E includes drawings of the existing conditions and the two alternatives considered. Drawings 1 – 3 (Appendix E) detail the existing forebay and Sluice Tower conditions. Alternative 1 is a modification to the existing Sluice Tower to provide for surface attraction flow into the tower. Drawings 4 – 8 (Appendix E) provide details of Alternative 1, and a description of the design is provided in Section 7.2. Alternative 2 includes the installation of a FSC in the forebay, and a dedicated fish passage to the lower river to bypass the Sluice Tower gates and discharge tunnel. Drawings 9 – 14 (Appendix E) provide details of Alternative 2, and a description of the design is provided in Section 7.3.

If future monitoring of smolt behaviour indicates that the optimized outmigration operations results in large numbers of smolts migrating down the reservoir to the forebay, but a significant percentage of these smolts are not finding the existing Sluice Tower intake, one of these two physical modification alternatives may increase the attraction efficiency of the passage facilities. Which alternative may be more appropriate will depend on the specific results of future behaviour studies, as described in the sections below.

It is important to understand that the two alternatives described below are concept-level designs only, and future information and/or operational decisions could alter these designs should they progress, impacting the size and cost. In general, conservative assumptions were made in the development of these designs, and it may be possible to downsize some of the components of these designs.

7.1 DESIGN CRITERIA

The following design criteria were forwarded to BC Hydro and the FWCP on March 8 in a technical memorandum. A copy of the memo is attached in Appendix D. Where applicable, these criteria are common to both alternatives.

7.1.1 Migration Season

Based on the outmigration season for Sockeye smolts in other regional watersheds in the U.S. northwest and southern British Columbia it is assumed that the Sockeye smolt outmigration season at the Coquitlam Reservoir would be during the months of ***April and May***. Although there may be early migrants in late March, and there was some indication during the 2017 RST trapping study that outmigration of resident kokanee smolts may extend into early June, any future decision to expand the timeframe of operations associated with the downstream Sockeye passage program would not impact the design features of the collection and passage alternatives.

7.1.2 Flow Rate

Results of the 2017 studies revealed a significant increase in the rate of outmigration during the periods of operation at 8 cms. As a result, BC Hydro and the KSRP agreed to increase the reservoir outflow rate through the Sluice Tower to 8 cms continuously during the Sockeye smolt outmigration season. Therefore, the concept alternatives are developed to accommodate a flow rate of ***8.0 cms***.

7.1.3 Reservoir Elevation

BC Hydro provided daily operations data for the Coquitlam Reservoir from February 2, 2003 through August 15, 2017. This data included daily reservoir water surface elevations. An analysis of this data for the months of April and May revealed a significant shift in operations starting in 2009. This coincides with the completion of the seismic upgrades to the dam and the installation of the knife gate in LLO-3 in the Sluice Tower, which were both completed in late 2008. For the 61-day period (April/May) during the years of 2003 to 2008 the minimum reservoir elevation was 143.0 (May 12, 2004) and the maximum was 147.8 (April 15, 2008). After the seismic upgrades, the April/May reservoir level rose significantly, with a minimum elevation of 144.5 (April 9, 2012) and a maximum elevation of 152.1 (May 31, 2016). The April and May daily reservoir elevations for the years of 2009 – 2017 are attached in Appendix F.

Based on the analysis of the data provided by BC Hydro, the more recent post seismic upgrade operations were considered, and an 8-metre range of operating reservoir elevations from ***144.5 m to 152.5 m*** was used in the design of the two modification alternatives.

7.1.4 Capture Velocity

The concept alternatives will be designed to include a capture location where the velocity is high enough that once a Sockeye Smolt passes through the capture location it will no longer be able to swim back upstream and leave the facility. Based on R2 experience with similar facilities in operation in the Northwest U.S., the design minimum velocity for capture is **2.1 m/s** (7.0 ft/s)

7.1.5 Fish Screens

The most comprehensive list of juvenile fish screen design criteria is the document "Anadromous Salmonid Passage Facility Design," published by the U.S. National Marine Fisheries Service (NMFS 2011). Table 7 provides a list of the fish screen design criteria used in the development of Alternative 2, taken from NMFS 2011. Note that Alternative 1 does not include fish screens.

Table 7. Salmonid Fish Screen Design Criteria (NMFS 2011).

Criteria	Design Value	Paragraph	Notes
Maximum Screen Approach Velocity	0.4 fps (0.12 m/s)	11.6.1.1	Average velocity perpendicular to screen
Uniformity of Approach Velocity	Peak point velocity <110% max. design average	11.6.1.4 & 15.2	Use baffles to ensure even flow distribution on screen
Minimum Sweeping Velocity	Greater than approach velocity	11.6.1.5	Velocity of flow parallel to the screen face
Maximum Rate of Velocity Increase	0.2 fps/ft (0.2 m/s/m)	11.9.1.8	Also, do not decelerate upstream of capture
Maximum Screen Exposure Time	60 seconds	11.9.1.2	Assume fish moving at the velocity of sweeping flow
Maximum Slotted Screen Opening Size	1.75 mm	11.7.1.2 & 11.1.7.1	3/32 inches (2.4 mm) holes for perforated plate
Screen Material	Corrosion Resistant	11.7.1.4	Sufficiently durable to maintain smooth surface
Minimum Open Area	27%	11.7.1.6	
Screen Cleaning	Automatic Screen Cleaning	11.10.1.2	Required for Active Screen Design Criteria
Trashrack Bar Spacing	8 inches clear (0.203 m)	4.8.2.5	Fish ladder exit rack for adult fish salmonids

7.1.6 Bypass Pipe

If fish are to be bypassed around the Sluice Tower to a discharge location in the lower Coquitlam River, the bypass conduit will be designed to meet the bypass pipe design criteria cited in NMFS 2011, as provided in Table 8 below.

Table 8. Salmonid Bypass Pipe and Outfall Design Criteria (NMFS 2011).

Criteria	Design Value	Paragraph	Notes
Flow Velocity	6 to 12 fps (1.83 to 3.66 m/s)	11.9.3.8	For given flow and pipe size velocity controlled by slope
Minimum Pipe Diameter	15 inches (0.38 m)	6.4.1.4	Uses fish distribution flume criterion
Minimum Bend Radius	5 times pipe diameter	11.9.3.4	Install facilities to minimize debris if bends are present
Minimum Depth of Flow	40% of Pipe Diameter	11.9.3.9	
Hydraulic Jumps	Avoid hydraulic jumps	11.9.3.12	There shall be no hydraulic jumps in the bypass pipe
Internal Conditions	Smooth conditions throughout pipe	11.9.3.1	Minimize turbulence, risk of catching debris, and potential for fish injury.
River Velocity at Outfall Location	Greater than 4 fps (1.2 m/s)	11.9.4.1	If not practical choose location with goal of minimizing predation
River Depth at Outfall Location	Adequate to ensure no bottom impact	11.9.4.1	
Maximum Outfall Impact Velocity	25 fps (7.6 m/s)	11.9.4.2	

7.2 ALTERNATIVE 1 – MODIFIED SLUICE TOWER

Alternative 1 consists of a modification to the existing Sluice Tower to provide for surface attraction flow into the tower, eliminating the need for the surface-oriented Sockeye smolts to sound to find the entrance. The depth to which the smolts need to sound to find the existing tower entrances varies depending upon the reservoir level. Figure 21 provides a cross-sectional view of the Sluice Tower through one of the LLOs. The bottom of the trashracks is at elevation 140.23 m, and the top is at elevation 143.00 m. At the minimum design reservoir level (144.5 m) the trashrack location is not deep, and should not represent an impediment to the fish locating the trashrack as a means of egress. At the maximum design reservoir level (152.5 m) a fish traveling near the surface would need to sound approximately 9 metres to locate the top of the trashracks.

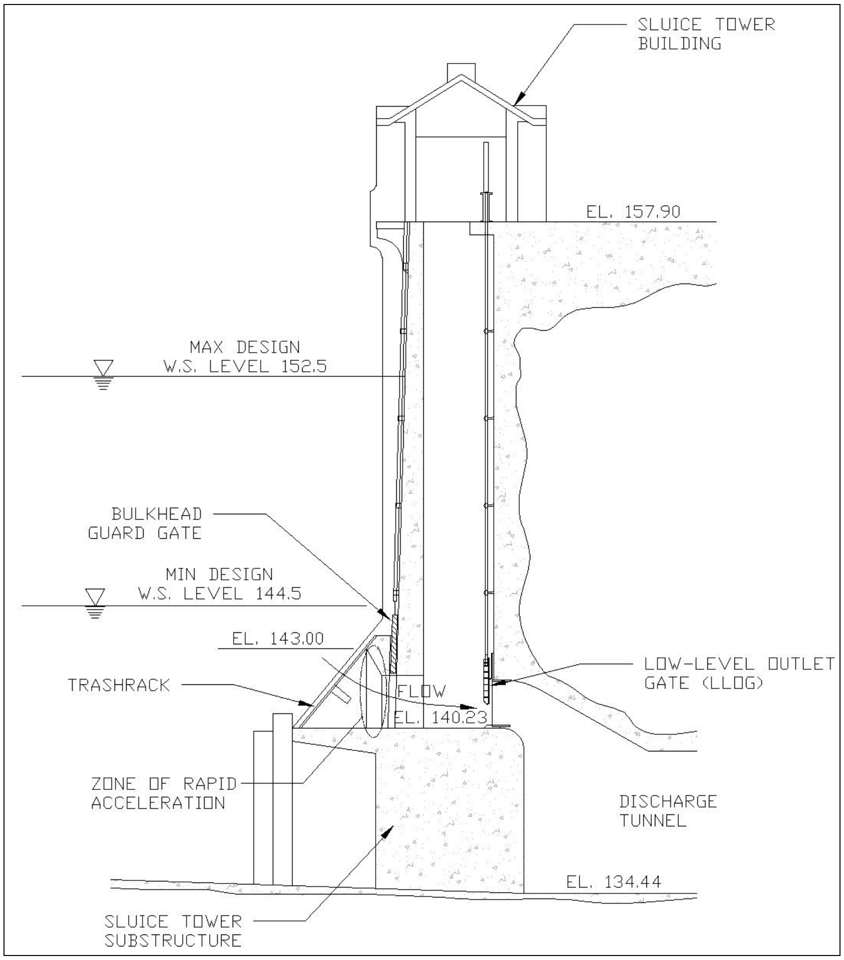

Figure 21. Cross-Sectional View through the Existing Sluice Tower.

Historically, significant numbers of kokanee smolts from the reservoir have not passed downstream through the Sluice Tower; however, numbers have been observed to increase when the outlet flow is increased. More interestingly, during the 2017 smolt passage study 303 marked smolts were discharged directly into the trashrack at LLO-1 with a flow rate of 8 m^3/s and only 34 of these fish were captured at the RST downstream. This means that the vast majority of these released fish must have turned and passed back upstream out of the trashracks rather than continue downstream. A reason for this might be the area highlighted in Figure 21 and labeled as the zone of rapid acceleration. As the flow passes through this zone, which is 0.54 m long, the cross-sectional area of the flow opening reduces on the sides and the top from an area of 9.25 m^2 to 3.35 m^2, and at a flow of 8 m^3/s, the velocity increases rapidly from 0.87 m/s to 2.39 m/s. This results in a rate of velocity increase of 2.8 m/s/metre. In the U.S., NMFS has a design criterion that to encourage fish to continue moving downstream without being startled the rate of velocity increase should not exceed 0.2 fps/ft (0.2 m/s/metre). The rate of velocity increase in the highlighted zone, at 8 m^3/s is 14 times the criterion maximum. At the upstream end of the zone the velocity is well below the capture velocity so if a fish finds the environment uncomfortable it could easily still turn and swim back upstream. Another possible explanation for the low passage rate of fish injected directly into the trashracks may have been the transition from a light environment to the dark entrance into the Sluice Tower.

7.2.1 Alternative Description

Alternative 1 is depicted on Drawings 4 through 8 in Appendix E. The design is similar in some ways to Option D from the Phase 1 Options Assessment, as proposed by Norm Fletcher and the KSRP, in that the goal is to utilize an adjustable overflow flow weir to create surface attraction for the fish, and ultimately pass then through one of the exiting LLOs. The concept was moved from the location adjacent to the Sluice Tower (as was shown in Option D) to a location in front of and upstream of the tower for cost saving reasons and to minimize structural modifications to the existing tower. The design was changed hydraulically to a single submerged weir, rather than two full overflow weirs, to reduce the turbulence and potentially harmful conditions downstream of the weir.

The design entails constructing a concrete extension of the Sluice Tower upstream of LLO-2, with an adjustable weir and trashracks on the upstream end. The extension could be located on either LLO-1 or LLO-2, with LLO-2 only chosen in this case because on the downstream side of the LLO gate the tunnel wall is furthest from the gate. This choice was somewhat speculative and the 2017 studies appeared to show that passage through LLO-1 was safe. LLO-3 should not be used because it includes the knife gate which is speculated to be the source on injuries seen in earlier studies. Also, it leaves LLO-3 unencumbered for use during the non-migration seasons for low-flow regulation.

Site Preparation

The only significant site preparation would be the removal of the existing trashracks at LLO-2. These would be removed because they would no longer be needed and could cause an unnecessary obstacle to unobstructed passage of the fish. Other site preparation would include the development of a contractor work space, laydown area, and access to the upstream face of the Sluice Tower.

Concrete Structure

The concrete structure is depicted in plan and section views on Drawings 4 and 5 (Appendix E). Concrete walls would be extended approximately 7.75 m upstream of the face of the Sluice Tower, located above and upstream of the existing submerged walls between the LLO bays. A pony wall would be constructed transversely between the two new side walls, located approximately 4.5 m upstream of the tower, to support lower edge of the weir and provide for a weir gate seal. A second pony wall would be installed transversely between the two new side walls, located at the upstream end to support the upstream trashrack. Near the upstream ends of the side walls the walls would include cut-outs for the side trashracks.

Weir Gate

The weir gate would consist of two leafs to accommodate the 8-metre range of design operating reservoir level. Both leafs would be roller gates as depicted on Drawings 7 and 8 (Appendix E). The gate leafs as shown have been designed to allow for full dewatering of the space between the weir gate and the existing Sluice Tower, resulting in very heavy substantial gate leafs. This was conservatively done to allow for inspection, maintenance, and cleaning in the dry with the weir gate raised to above the reservoir level.

The upper gate leaf is the functional weir that the flow passes over to enter the space between the weir and the Sluice Tower. The gate is mounted, and travels, in guides attached to the lower leaf, and includes seals along the sides and the bottom of the interface between the two leafs to prevent leakage. The weir crest is functionally 2.50 metres wide. The lower leaf serves as the frame and guides for the upper weir. It is a tall roller gate with a 2.50-metre-wide cut-out over the upper half to serve as the weir opening. Vertical guides are attached to the upstream face of the lower leaf to accommodate the upper leaf. The lower leaf is mounted, and travels, in guide slots cast into the new concrete walls, and includes seals along the sides to prevent leakage along the interface between the lower leaf and the guide slots, and across the bottom to seal the gate along the interface with the pony wall.

The weir gate operator is envisioned to be a split-drum wire rope hoist mounted on the top deck of the new concrete structure. This is not shown on the attached drawings because its final arrangement will be a final design issue depending upon the chosen equipment and operational considerations. The wire ropes will extend down from the hoist to lugs located on the upper gate leaf (Appendix E, Drawing 7). In this way, the upper leaf, which defines the crest of the weir, will be actively controlled by the hoist. After installation of the upper leaf into the guides on the lower leaf, stop blocks will be installed into the guides (Appendix E, Drawing 8) so that when the upper leaf reaches the top of its travel it will start lifting the lower leaf. Therefore, a single hoist is used to operate both gate leafs. The combined weight of the two gate leafs is estimated to be approximately 16,000 kg, and a hoist with an appropriate lifting capacity will be required.

Trashracks

The trashracks will consist of vertical flat bars spaced at 100 to 125 mm. Three trashracks are shown upstream of the weir gate (Appendix E, Drawings 4 and 5), but would not necessarily all be required. The two smaller side trashracks were conservatively included to maximize the range of influence of the inflow, in the event fish may be traveling along the shoreline and approach the Sluice Tower from the side. Although this would maximize the influence, the collection benefits are speculative; however, the cost and complication of cleaning three racks instead of one large one would be significantly increased. The side entrances and racks were included to conservatively represent the maximum facility that might be considered.

The racks would be cleaned with a mechanical trash rake. The rake considered for this installation is a Bracket Bosker rake (manufactured by Ovivo), designed to be lowered to the bottom of the rack, where the rake head is rotated so teeth rotate into the spaces between the bars and the rake is lifted pulling debris impinged on the rack up to the surface. Additional fingers are then rotated from the other side encapsulating the debris so it can be lifted out of the water and placed into a debris container or dumpster. A photo of a Bracket Bosker trash rake system, taken from the Ovivo website, is provided in Figure 22. The rake would travel on curved rail so that it could also be positioned over the side racks for also cleaning them. Further, it may be possible to extend the rail with an additional curve so that it could be positioned over the space between the weir and the Sluice Tower to reach down and grab debris that passed through the rack and is floating in the confined space. This would require that there be hinged openings in the upper deck for passing the rake head down into this area. Means of transporting the collected debris off the site would be considered during final design. The rake could be operated manually on an as needed basis and/or programmed to operate on a timer for routine cleaning.

Figure 22. Bracket Bosker Automatic Raking Machine (from the ovivowater.com website).

7.2.2 Operations and Maintenance

The operation of the weir is shown in section for three different reservoir levels on Drawing 6 (Appendix E). The section on the left depicts operation at the maximum design reservoir level (152.5 m). The crest of the weir is positioned at elevation 150.75 m, 1.75 metres below the reservoir level. The outlet gate LLOG-2 is open 40% resulting in a flow of 8 m^3/s at an upstream water level of 151.78 m. This results in a drop across the weir equal to 0.72 metres. This results in a submerged weir condition, where the downstream water surface is above the crest of the weir. This condition results in an average velocity across the weir of approximately 2.1 m/s, the target trapping velocity for Sockeye smolts (see Section 7.1.4). This should effectively commit any fish passing over the weir to the facility, and ultimately to passing through LLO-2 to the river downstream. In the event it is found that fish are not entirely committed to the facility, and some can still swim back upstream over the weir, the velocity can be increased by slightly opening LLOG-3 further, and slightly raising the weir, while maintaining the 8 m^3/s. Also, flow rates can be changed by adjusting the weir crest and LLOG-2 appropriately. In this way, the system is fully adjustable for flow and/or capture velocity across the weir.

As the reservoir level lowers the weir would be automatically lowered, tracking the reservoir level and remaining 1.75 metres below the reservoir level. LLOG-2 would automatically be opened based on a rule curve related to the reservoir level. The trapping velocity and 0.72-metre drop across the weir would be maintained, so entrance conditions remain constant. The middle section on Drawing 6 (Appendix E) represents the conditions when the lower gate leaf first contacts the bottom of its guides, and the upper weir starts dropping away from it guide stops. This would occur at a reservoir level of approximately 149.2 m. Also, at this point LLOG-2 would be open approximately 50% to maintain the same conditions. Finally, the Drawing 6 (Appendix E) section on the right shows the upper gate leaf fully lowered to the bottom of its guides, and LLOG-2 fully open. In the arrangement, it is estimated that the 8 m^3/s design flow will be maintained at a reservoir level of 145.14 m. Between this level, and the minimum design operating level of 144.5 m the magnitude of the flow will reduce, due to the reducing head on the gate. At a reservoir level of 144.5 m it is estimated that the flow will be about 6.1 m^3/s. Although this flow is below the target flow, it is likely justified that if the reservoir is at extreme low levels, and the Buntzen Diversion Tunnel flow is turned off, then outlet flows at the Sluice Tower should be reduced to prevent the reservoir from lowering any further.

As mentioned above, the weir gate leafs have been sized in this concept design to allow for full dewatering of the space between the weir and the Sluice Tower. This will not only allow for cleaning out of the space in the dry, but will also allow for inspection and maintenance of the inside of the weir gate in place in the dry. However, the reservoir level would need to be below elevation 150.5 to prevent over-topping of the weir in its fully raised position. With the reservoir at or below 145.5, the weir gate could be raised so that the upper cross member on the lower gate leaf is flush with the upper deck resulting in the entire gate being above the water for inspection of the outside face of the gate. This would result in the bottom of the gate rising above the top of the pony wall it seals against, so care would need to be taken to lower the gate back into position without damaging the seal.

7.2.3 Advantages and Potential Concerns

The obvious advantage of this alternative is the surface attraction of the surface-oriented smolts. Currently, there appears to be a very limited number of the naturally produced kokanee smolts in the reservoir passing through the Sluice Tower. Past studies have shown that the increase in flow through the tower should have a positive impact on increasing the number of smolt passing downstream (Plate et al. 2014 and BC Hydro, Alexis Hall, personal communication, September 11, 2017); however, they still have to find the entrance and choose to go through it. The surface entrance should create a much more apparent flow signature, and commits them to the facility upon entry.

Depth may not be the only concern that needs to be addressed. As discussed above, and depicted in Figure 21, there is a region of extremely rapid acceleration entering the Sluice Tower, just upstream of the existing bulkhead guard gate, where the spatial increase in velocity is 14 times what is allowed in the U.S. (at a flow of 8 m^3/s). The reason for this restriction in U.S. design criteria is that lab studies have shown that fish can sense varying velocities over the length of their body and when this differential becomes too extreme the condition startles them and they tend to turn back away from it. Under current conditions the fish have not yet passed through a trapping velocity, or any other condition that would prevent them from turning back, when they experience this condition. This could be why so few of the fish injected directly into the trashrack flow during the 2017 passage study failed to pass downstream through the Sluice Tower. With this Alternative 1 modified design, although the fish still have to pass through this zone they are already committed to the facility prior to experiencing it and tests of behavioural barriers have often shown that although fish will avoid an uncomfortable condition a few times after multiple experiences they generally will pass through it. It is unlikely that any fish will stay in the confined space upstream of this passage for extended periods of time. Even so, there may be a concern that any time the fish spend acclimating to this passage route could represent a delay that may be unacceptable. Two approaches, one operational and the other structural, may allow for reducing time fish spend in the confined space. Operationally, the flow rate through LLO-2 could temporarily be reduced to the point that the velocity change is less severe and the fish more readily pass through it. This could possibly be done for about an hour once a day during periods of peak migration, but would require transferring some flow to LLO-1 to avoid a rapid ramp-down of flow in the river downstream. A structural approach could entail cutting a hole, or series of holes, in the wall of the Sluice Tower allowing for passage of flow from the confined space outside directly into the gate well inside the tower to provide an alternate route for the fish; however, analyzing the feasibility of structural modifications to the existing Sluice Tower was beyond the scope of this concept design study.

Another potential concern would be an accumulation of floating debris that has passed through the trashrack into the space between the weir gate and the Sluice Tower. If there is too much debris bouncing around in this area it could create a hazardous condition for the fish. It is recommended that if this design were to be implemented that a means of easily cleaning out this area be incorporated into the design (such as potential use of the trash rake as discussed above) and that this area be maintained as free of debris as practical.

7.2.4 Optional Considerations

As discussed, there are a number of conservative decisions that went into the Alternative 1 concept design. Based on future operational and design decisions there are potential cost-saving modifications that might be considered. These considerations include:

- The height of the concrete extension was set to match the outside deck of the existing Sluice Tower. This was done to allow for ease of access and is not necessarily required. Lowering the top of the new structure would save some cost, but likely not a substantial amount.
- The weir gate leafs were designed to withstand full dewatering of the space behind the weir gate. This was done to allow for maintenance and inspection in the dry. If this is deemed to not be necessary, a lighter gate could be designed, with a corresponding reduction in the size of the hoisting equipment, and possibly the walls of the new concrete structure.
- Including the two side trashracks, and the additional requirements to the trash rake to accommodate them, represents a substantial cost. Potential benefits associated with these two additional trash racks should be considered in that context by BC Hydro and the stakeholders in the project to determine if they are deemed to be worth the cost.
- The location of the new structure and facilities at LLO-2 was considered to be prudent given that the wall of the discharge tunnel is further away from the LLO gate at this location than it is at LLO-1. However, any fish safety advantage to this is speculative and may not exist. If both gates are shown to be equally safe for passage, then a cost-benefit analysis should be performed for the two locations, considering both cost on installation and ease of access and operations, and the new facility should be located at the optimal location (LLO-1 or LLO-2).

7.3 ALTERNATIVE 2 – FLOATING SURFACE COLLECTOR

Alternative 2 consists of a FSC placed in the forebay upstream of the Sluice Tower. In addition to the FSC the major components of Alternative 2 include guide nets, a submerged flexible fish transport hose, a flow control structure adjacent to the Sluice Tower, and a dedicated fish bypass pipe leading to the river downstream. This alternative is significantly more complex and expensive than Alternative 1, but may be considered if an adequate number of smolts are found to migrate to the forebay but an inadequate number make it all the way down to the Sluice Tower, or if passage through the Sluice Tower is ultimately deemed to be unsafe.

7.3.1 Alternative Description

Alternative 2 is depicted on Drawings 9 through 14 in Appendix E. The concept was proposed by R2 as Option J in the Phase 1 feasibility assessment and received a high score. At least six FSCs have been installed at projects in the northwestern U.S. over the last 10 years, and others are in various stages of design. Two FSCs have been installed at the Baker Hydroelectric Project in Washington and have proven to be very successful, constituting a significant component of the successful restoration of Sockeye Salmon on the Baker River. A recent FSC installed at North Fork Dam on the Clackamas River on Oregon has proven to be very successful at collecting and safely passing Coho and Chinook salmon and steelhead. FSCs are well suited to projects that require screening of large flows to get the fish into a small manageable flow rate for passage downstream in operational environments with large reservoir fluctuations (more than a couple of metres).

Site Preparation

Constructing an FSC requires extensive and costly site preparation. The FSC is a large structure that needs to be assembled on site in the dry, and then launched into the reservoir and floated into position. Therefore, a fairly large area of level ground along the reservoir shore line needs to be cleared and prepared to serve as an assembly location, with contractor facilities and laydown areas. A ramp into the reservoir also needs to be prepared large enough to launch the FSC. We have not performed any on-site investigation as part of this study to identify an appropriate location. A significant cost line item has been included for site preparation (see Section 8); however, this is speculative and the ease of access to an appropriate site could significantly increase or reduce this estimated cost.

The installation of guide nets also requires some site preparation. Guide nets extend from the sides of the FSC to locations along the shore upstream to form a v-shaped barrier to fish passage that leads the fish toward the FSC and does not allow them to pass by it. The nets extend from the surface to the bottom of the reservoir, so when the reservoir level lowers, portions of the net may come to rest on the bottom and if there are jagged or irregular conditions on the bottom, such as tree stumps or large submerged jagged debris, the net can get caught on these objects and become damaged when the reservoir surface rises again. Therefore, the area on the bottom of the reservoir along the line of the nets needs to be cleared, grubbed, and smoothed out.

Floating Surface Collector

The proposed location of the FSC in the forebay is shown on Drawing 9 (Appendix E). The location is directly over the deepest part of the forebay, to maximize the ability to lower the reservoir without the FSC contacting the bottom. This location also places the FSC fish entrance at a location found in the 2017 acoustic tag study to have attracted a significant percentage of the tracked smolts that passed through the forebay (Figures 16 and 17). The design flow for the FSC is the full 8 m^3/s optimized migration season flow rate. Although the size of the FSC, and resulting costs, could be reduced by allowing some of the flow to pass through the nets, with only a portion of the flow going through the FSC to serve as an attraction flow at the downstream end of the v-shaped nets, we chose to assess the implications and cost of a full capacity FSC for three reasons.

- Represents the most conservative cost, can assess design reductions later
- Very little flow could go through the nets at low reservoir levels
- Provides for upward flexibility in the flow rate.

The FSC concept design is depicted on Drawings 10, 11, and 12 (Appendix E), and consists of a rectangular floating barge 32.0 metres long and 16.0 metres wide. The overall height of the barge is 5.20 metres. Under normal operating conditions the FSC would float with 4.20 metres below the water and 1.00 metre freeboard above.

Down the center of the barge is a screen channel designed to remove a majority of the attraction flow entering the FSC from the fish travelling down to the end of the channel. The channel has screens on the walls on both sides and a solid upwardly sloping floor. The screen walls are angled in, reducing the width of the channel in the downstream direction, and the floor slopes up reducing the depth (Appendix E, Drawings 10 and 11). In this way the cross-sectional area of the channel decreases as the flow is being removed so the velocity conditions are controlled as the flow rate is reduced. At the entrance the average velocity is 0.64 m/s, at the 8 m^3/s design flow. The initial section of screens is the primary screen channel. Through this section, 5.3 m^3/s is removed from the flow through four large screen panels on each side, and the velocity mildly increases to 0.82 m/s. The secondary screen channel contains seven smaller screen panels on each side. At the junction of the fourth and fifth panels the channel flow rate has been reduced to 0.90 m^3/s, and the velocity has been increased to the design capture velocity of 2.13 m/s. After the fish have passed this location they should be committed to continuing downstream through the facilities. The final portion of the screen channel reduces the flow to 0.20 m^3/s and mildly reduces the velocity for safe passage of the fish through the remaining downstream facilities.

The screens would be stainless steel profile bar screen panels with 1.75 mm slot openings between the bars, as manufactured by Hendrick Screen Company. These are approved in the U.S. for safe use as fish screens and have been installed in all of the FSCs currently in use. The screens are sized such that the average perpendicular velocity approaching the screen is less than 0.12 m/s. Adjustable baffles are placed behind the screen panels to evenly distribute the flow over the area of the screen, to prevent velocity ‘hot spots’ on the screen that might impinge fish. The baffles would be adjusted and set once when the FSC is first started up, and should never need to be adjusted again. A pressure backwash system is used to clean the screens. Small high-pressure, low-flow submersible well pumps are located in the water behind the screens and baffles to pump flow into pipes located between the screens and baffles. The pipes have small holes along their length pointing toward the backs side of the screens. The jets of water from the small holes dislodge debris that may have accumulated on the screens.

High-flow, low-head submersible pumps are located along the outside walls of the FSC to provide the 7.8 m^3/s attraction flow for the FSC. The pumps considered for this application, and shown on the drawings are Flygt PP-4680 pumps. Under these low-head conditions, each pump is capable of passing up to 1.8 m^3/s. Four pumps are associated with the primary screens, two behind each side of the channel. Two of these would be powered through variable frequency drives, one on each side, to provide for control of the overall flow rate. Two pumps are associated with the secondary screens, one on each side. Both of these would also be controlled with variable frequency drives. The pumps are installed on guide rails and can be easily removed for inspection and maintenance.

A trashrack and rake, similar to those described for Alternative 1, are included at the entrance to the FSC. These are required to keep large debris out of the FSC that might plug and/or damage the screen channel or bypass pipe. A debris trap is also included downstream of the screen channel to trap the mid-sized debris that did pass through the trashrack. Fish can easily pass through or around this trap, but debris large enough to cause problems in the hose and bypass pipe system downstream cannot.

Belly tanks are located on the bottom of the FSC below the screen channel and other functional components of the FSC. These tanks provide for the ability to raise the FSC to the point that all functional components are above the reservoir level, and available in the dry for inspection and maintenance. Also, the FSC can remain in place and be raised essentially raised out of the water during the 10-month, non-migration period, protecting it from potential damage and removing it as an impediment to flow when not in use. This would allow for reservoir levels below the design minimum level of 144.5 m during the non-migration period without the FSC bottoming out. This is done for approximately 8 months every year with the two FSCs on the Baker River. When in operation the belly tank would be full of water and the FSC would be lowered into the water as shown on Drawings 11 and 12 (Appendix E). To raise the FSC the water is pumped out of the belly tanks and they then serve as additional flotation cells. Figure 23 provides photos of the Lower Baker FSC in the lowered operating position and the raised maintenance/storage position.

The FSC would be moored in place with three mooring towers each consisting of three concrete filled steel pipe piles braced together into a single truss structure, as shown on Drawing 10 (Appendix E). Mooring the FSC in place with anchor lines was considered, but the forebay area is too shallow when the reservoir is at the lower end of the design operating range. In fact, some minor excavation may be required below the FSC to allow for operation at a reservoir level of 144.5 m without bottoming out the FSC, as can be seen on Drawing 13 (Appendix E).

Figure 23. Lower Baker FSC in Operating Position (left) and Raised Non-Operating Position (right).

Guide Nets

Guide nets are included to guide any fish migrating downstream into the forebay directly toward the FSC entrance and prevent them from passing beyond it. The guide nets are shown in plan on Drawing 9 (Appendix E) and in elevations on Drawing 13 (Appendix E). The nets would extend from shore to shore, and from the surface to the bottom of the forebay, to effectively provide full fish exclusion from the area downstream of the FSC. The shore anchors would be upstream of the FSC entrance, forming a V-shape that leads the fish toward the FSC entrance. The nets consist of high-strength Dyneema or Spectra netting material with 6.5 mm square mesh, a float line at the surface and a weight chain at the bottom, and internal float and weight lines to keep as much of the net off the bottom as possible when the reservoir level is lowered. Even so, at very low water levels the majority of the net will be laying on the bottom of the forebay. That is why the bottom area in the vicinity of the net needs to be cleaned of any large jagged material that the net could potentially get snagged on.

At other FSC installations the FSC flow rate is only a fraction of the overall downstream flow (typically 10 to 20%) and the majority of the flow passes through the nets, although the fish are excluded from passage by the net. At these facilities there is a powerhouse and/or spillway downstream and the overall flow rate is very large in comparison to the flow rate at Coquitlam. In fact, even the small fraction of the flows that pass through the FSCs is significantly more than the 8 m^3/s design flow for the Coquitlam FSC. Future consideration of a lower design flow for the FSC, to save on size and cost, with some of the flow passing through the nets could be considered. However, as can be seen in the elevation view of the nets at low design reservoir level (Appendix E, Drawing 13), there is very little net still available for flow when the reservoir level is that low. Also, if flow is routinely passed through the nets then keeping the nets clean becomes a maintenance concern; whereas without flow through the nets this becomes less of a concern.

At some FSC installations the float lines for the guide nets can be deflated to allow for extreme high flow events that might otherwise overload or damage the nets, and to allow for boat passage. At sites where there is no concern of a high flow event at the location of the nets, but boat passage is still required, a boat gate is added to the net system, which is less expensive and simpler than the intricate pneumatic system required to allow for deflation. At Coquitlam there are boat ramps both upstream and downstream of the nets, and boats are rarely even allowed on the reservoir, so no boat gate was included. Given the short duration of the migration season, it is recommended that for Coquitlam the nets be designed to be easily installed prior to the Sockeye migration season, and easily removed after the season has concluded. Leaving the nets in place year round would unnecessarily subject them to potential damage; whereas removing them for the majority of the year will significantly increase the life of the net and minimize expensive replacement costs.

Flexible Submerged Fish Transport Hose

After the fish have passed through the FSC they enter a submerged transport hose that leads them to the Flow Control Structure, as shown on Drawing 9 (Appendix E). The hose would be a fiber reinforced black rubber dredge hose about 0.40 metres in diameter and about 80 metres long. It would consist of eight 10-metre sections flanged together. At each flange, except the most downstream one, there would be a tie line up to a float to keep the overall hose from sinking. The final float is omitted to allow for the last two sections to take up the range of reservoir levels. The hose would be running full with a flow of 0.20 m^3/s, at a velocity of 1.6 m/s. This design is used to pass fish out of the FSC and ultimately downstream through the dam at North Fork Dam on the Clackamas River in Oregon.

Flow Control Structure

The Flow Control Structure would be located adjacent to the Sluice Tower on the south side, as shown on Drawing 14 (Appendix E). It is used to control the rate of fish flow discharging from the FSC and passing through the submerged transport hose. It also converts the flow from the full pipe flow in the hose to open-channel flow through the remainder of the bypass system. The Flow Control Structure consists of two major features, a rectangular concrete tower with a series of controlled outlets, and a helix pipe for passing the open-channel fish flow downstream at a controlled rate of velocity.

The internal dimensions of the concrete tower are 1.50 metres by 7.50 metres. The fish flow enters the tower on the west side near the bottom of the tower. The water level in the tower is slightly lower than the reservoir level due to losses in the FSC and flow through the hose, but still varies over an 8-metre range. Along the inside of the long south wall of the tower there are ten rectangular openings with adjustable overflow weirs. Each weir is designed to either be closed (fully raised covering the opening) or adjusted over a 0.8-metre range to maintain an outflow of 0.20 m^3/s from the surface of the tower water. At any given time, nine of the gates would be closed, and one would be open and flowing. Which one is open would depend upon the water level. This is an ideal condition for encouraging the fish to continue downstream because the tower is a confined space which the fish should be searching for a way out of, and the flow is from the surface where the fish should be searching for it.

The fish flow discharging from the tower passes into the helix pipe, which is a 0.40-metre diameter steel pipe curved into a helix with an 8.0-metre centerline diameter, and ten circular tiers to the helix. Each tier is connected to one of the ten gates in the tower, and the flow enters the helix at the tier connected to the open gate. The helix is based on a design by the U.S. Bureau of Reclamation that is currently under construction at Cle Elum Dam in Washington. The Cle Elum design was one of the options the KSRP suggested for review during Phase 1, but it was ruled out as a stand-alone option for the full flow because the size of the helix would have filled the entire forebay. But with the significant reduction in the fish flow provided by the FSC it does represent an efficient, relatively compact, way of controlling the fish flow conditions over a wide range of potential heads. The length of each circle, and the corresponding vertical drop of 0.80 metres per tier results in a velocity of 3.66 m/s with an approximately half-full pipe flow. At the bottom of the helix the pipe straightens out and goes east becoming the Bypass Pipe.

Bypass Pipe

As described above, the Bypass Pipe is essentially an extension of the helix pipe that ultimately discharges the fish in the river downstream of the Sluice Tower. The Bypass Pipe will continue downstream at a slope of 0.01 to 0.03 to maintain super-critical flow conditions with the pipe roughly half full. Like the helix, the Bypass Pipe is a 0.40-metre steel pipe that extends to a location inside the existing Sluice Tower discharge tunnel, or the river downstream, where the conditions are appropriate for safe discharge of the smolts (i.e., adequate depth and velocity). For cost estimating purposes the Bypass Pipe was conservatively assumed to extend all the way to the river outside the discharge tunnel exit, as shown on Drawing 9 (Appendix E).

Initially, the Bypass Pipe would be buried in the rock embankment between the helix excavation and the existing Sluice Tower discharge tunnel. This would be installed by core drilling a tunnel through the rock, inserting the section of Bypass Pipe, and grouting around the outside of the pipe. Once inside the existing discharge tunnel the pipe would turn to the right and then extend along the tunnel wall to the discharge location.

7.3.2 Operations and Maintenance

The significant routine operating costs are associated with operation of the major mechanical components. The attraction flow pumps are operated 24 hours a day for the duration of the migration season. It is estimated that this will require approximately 260 MWh. Other major mechanical components include the backwash screen cleaners and the trash rake, which are each intermittently operated automatically based on monitoring of hydraulic conditions and/or timers. During operation the FSC will also require a daily walk through to manually clean the debris trap and ensure that there are no problems occurring on the FSC.

Prior to the start of the migration season the FSC will need to be lowered down into its operating position by adding ballast water into the belly tanks. To perform this operation safely requires at least one full work day. The Guide Nets will need to be installed and attached to the FSC, possibly requiring divers to attach to the underside of the FSC. Once operations have started, the FSC simply floats up and down with reservoir level variations requiring no changes or modifications to its operating conditions. The two components that do need to be adjusted in response to changes in the reservoir level are the weir gates in the Flow Control Structure, and the LLOG being used at the time to maintain the design outflow through the Sluice Tower.

At the end of the migration season, the Guide Nets would be removed from the forebay, inspected, cleaned and transported to a safe storage location. The ballast water in the belly tanks would be removed and the FSC would be raised to its maintenance/storage position. Again, this should be assumed to require a full work day. The weir gates in the Flow Control Structure would be progressively opened and closed from the top one to the bottom one, minimizing the water level in the concrete weir tower and allowing the Bypass Pipe to drain out. With the FSC raised, annual inspection and maintenance of equipment on the FSC can occur in the dry. Also, with the concrete weir tower drained, inspection of the weir gates can be performed in the dry, but would likely require that a man-basket be lowered into the tower to provide access.

7.3.3 Advantages and Potential Concerns

The major advantage of the FSC alternative is that it attracts and collects the smolts near the entrance to the forebay and uses Guide Nets to lead the fish directly into the FSC entrance. The smolts are then rapidly moved through the FSC to the Bypass Pipe and on to the river downstream. There are no components within the system that should act to discourage the smolts from continuing downstream through the system. In this way, this alternative represents the greatest potential to attract the largest percentage of migrating smolts and move them downstream with the least delay.

Potential concerns with the FSC design include the shallow conditions in the forebay during low reservoir levels. The area below the FSC may need to be excavated to prevent the FSC from bottoming out during these conditions and/or the design of the underside of the FSC may need to be shaped to accommodate the bottom bathymetry. These shallow conditions will also result in the Guide Nets substantially settling on the bottom of the forebay for periods of time, which may result in some damage to the nets.

7.3.4 Optional Considerations

There are two modifications to the Alternative 2 design that could result in significant cost savings; however, each of them comes with some potential decrease in effectiveness and/or reliability of the overall system.

The flow capacity of the FSC could be reduced, allowing the remainder of the 8 m^3/s overall design flow to pass through the Guide Nets. This could significantly reduce the size and cost of the FSC, but it could also reduce the attraction to the FSC entrance, with fish being attracted to the Guide Nets and possibly not finding their way to the FSC. It would also increase concerns with debris accumulation on the net, since debris will be more attracted to the net, and it is being relied upon to pass some of the flow. Finally, at very low reservoir levels there is little net remaining in the flow path and overall flows may need to be reduced under these conditions.

Another potential cost savings, although not as substantial as reducing the size (diameter) of the FSC, would be to reduce the size of the transport hose and helix/bypass pipe, reducing the overall material cost. Although a smaller pipe could still safely pass the smolts, it would increase the risk that the hose/pipe system may become plugged with debris that got around the debris trap resulting in the need to shut down the system and clean the debris out. Therefore, reducing the hose/pipe size is not recommended.

8. CONSTRUCTION AND O&M COST ESTIMATES

Concept-level construction and annual O&M cost estimates have been developed for the two alternative project modifications described in this report. These estimates were based on R2's experience with the design and construction of similar projects in the U.S. Therefore, the estimates were developed using installed unit costs for the major components in the designs in U.S. Dollars (USD), but have been converted to Canadian Dollars (CAD) as presented here based on the March 28, 2018 exchange rate of 1.00 CAD equals 0.774 USD.

Both of these alternatives, and the Optimized Outmigration Operations scheduled to be initiated with the 2018 kokanee outmigration season, entail increasing the outflow through the Sluice Tower to 8 m^3/s for the months of April and May (a total of 61 days). This will entail a cost to BC Hydro resulting from lost energy production at the Buntzen HEP. This cost has not been included by R2 in these estimates because we do not have adequate BC Hydro internal information to assess the quantity of lost power associated with the lost flow (i.e., average head and efficiency of the units at the Buntzen Powerhouse), nor do we know the value BC Hydro places on lost energy per unit of loss (i.e., dollars per MWh). Therefore, the value of this lost revenue will need to be developed by BC Hydro. As a basis for this cost it should be considered that the average historic discharge through the Sluice Tower for the years of 2009 through 2016 was 3.6 m^3/s for the months of April and May. Therefore, the annual lost generation would be based on a loss of 4.4 m^3/s for a period of 61 days. This will be a consistent annual cost added to the annual O&M cost estimates provided below, and also represents the annual cost of the Optimized Outmigration Operations beginning in 2018 without any physical modifications. Other universal cost additions would include biological studies, such as the downstream RST studies and any upstream trapping and transport of adults to the reservoir.

Estimated costs are based on the concept design layouts provided on the drawings attached in Appendix E. The designs are intentionally conservative, providing maximum operational flexibility. Future decisions prior to final design could potentially reduce costs, as discussed in Section 7. Costs are also included for specialized equipment (such as hoists, trash rakes, screen cleaners, etc.) that may not be shown on the drawings. Given the concept-design level of these two alternatives, a 30% contingency has been added to account for the items required but not yet developed of identified at this level of design. From R2's experience, a 30% contingency at this level of design is generally representative of the final construction cost, and should not be considered to be optional, rather it should be assumed to actually be in the final cost.

8.1 ALTERNATIVE 1 – MODIFIED SLUICE TOWER

A summary of the estimated construction cost, and annual O&M cost for the Modified Sluice Tower alternative in 2018 Canadian Dollars is provided in Table 9. The total construction cost estimate is $3,823,300, including a 15% cost assumption for engineering design. The annual O&M cost is estimated to be $78,500. A breakdown of these costs is provided in Table 10.

Table 9. Summary of Estimated Construction and Annual O&M Costs for Alternative 1.

BC Hydro - Fish & Wildlife Compensation Program Kwikwetlam Salmon Restoration Program Coquitlam Passage Alternative 1: Sluice Tower Modifications		
DESCRIPTION	**COST**	**O&M COST**
Demolition	$21,800	$0
Concrete Structure	$896,200	$4,400
Traskracks and Rake	$879,400	$37,800
Weir Gate	$444,000	$9,400
Access Decking	$19,700	$100
Electrical & Controls	$174,500	$8,700
Subtotal	$2,435,600	$60,400
Mobilization-Demob(5%)	$121,800	$0
Contingencies (30%)	$767,200	$18,100
Direct Construction Related Costs	**$3,324,600**	**$78,500**
Engineering Design (15%)	$498,700	
Total Project Cost	**$3,823,300**	

Table 10. Breakdown of Estimated Construction and Annual O&M Costs for Alternative 1.

BC Hydro - Fish & Wildlife Compensation Program
Kwikwetlam Salmon Restoration Program
Coquitlam Passage Alternative 1: Sluice Tower Modifications

DESCRIPTION		COST	O+M
Demolition		$21,800	$0
	Trashrack Removal	$21,800	$0
Concrete Structure		$896,200	$4,400
	Over Sloped Pier Sections	$267,500	$1,337
	Over Flat Pier Ends	$104,600	$523
	Fixed Weir Wall	$176,800	$884
	Outer Side Walls	$274,600	$1,373
	Wall Below Outer Trashrack	$54,800	$274
	Slab Concrete	$17,900	$0
Trashracks and Rake		$879,400	$37,800
	Trashracks	$149,100	$745
	Trash Rake	$730,300	$37,032
Weir Gate		$444,000	$9,400
	Upper Leaf	$79,600	$713
	Lower Leaf	$217,700	$1,887
	Hoist	$146,700	$6,810
Access Decking		$19,600	$100
	Decking	$15,000	$75
	Handrail	$4,600	$23
Electrical & Controls		$174,600	$8,700
	Lighting	$25,900	$1,551
	Power Outlets	$19,400	$1,163
	PLC	$32,300	$1,939
	Instrumentation	$38,800	$2,327
	Miscellaneous Components	$25,900	$1,551
	Electrical Hookup Allowances	$32,300	$162
	Subtotal:	**$2,435,600**	**$60,400**
Mobilization-Demob (5%)		$121,800	
Contingencies (30%)		$767,200	$18,100
Direct Construction Related Costs		**$3,324,600**	**$78,500**
Engineering Design (15%)		**$498,700**	
Total Project Cost		**$3,823,300**	

8.2 ALTERNATIVE 2 – FLOATING SURFACE COLLECTOR

A summary of the estimated construction cost, and annual O&M cost for the Floating Surface Collector alternative in 2018 Canadian Dollars is provided in Table 11. The total construction cost estimate is $22,153,500, including a 15% cost assumption for engineering design. The annual O&M cost is estimated to be $387,000. A breakdown of these cost estimates is provided in Table 12.

Table 11. Summary of Estimated Construction and Annual O&M Costs for Alternative 2.

BC Hydro - Fish & Wildlife Compensation Program Kwikwetlam Salmon Restoration Program Coquitlam Passage Alternative 2: Floating Surface Collector		
DESCRIPTION	**COST**	**O&M COST**
Site Preperation	$424,300	$0
FSC Barge	$5,825,100	$38,100
Screens, Baffles, and Cleaners	$2,152,900	$54,400
Attraction Flow Pumps	$1,258,500	$97,300
Trashrack and Rake	$500,200	$28,000
Mooring	$1,019,400	$10,400
Guide Net	$120,600	$15,400
Fish Transport Hose	$142,900	$3,600
Floating Access Walkway	$64,300	$1,200
Flow Control Structure	$1,058,100	$13,300
Bypass Pipe	$228,100	$1,000
Electrical & Controls	$1,318,400	$35,000
Subtotal	$14,112,800	$297,700
Mobilization-Demob (5%)	$705,600	$0
Contingencies (30%)	$4,445,500	$89,300
Direct Construction Related Costs	**$19,263,900**	**$387,000**
Engineering Design (15%)	$2,889,600	
Total Project Cost	**$22,153,500**	

Table 12. Breakdown of Estimated Construction and Annual O&M Costs for Alternative 2.

BC Hydro - Fish & Wildlife Compensation Program
Kwikwetlam Salmon Restoration Program
Coquitlam Passage Alternative 2: Floating Surface Collector

DESCRIPTION		COST	O+M
Site Preparation		$424,300	$0
	FSC Assembly Site & Laydown Area	$38,100	$0
	FSC Launch Ramp	$12,900	$0
	Excavation for Flow Control Structure	$373,300	$0
FSC Barge		$5,825,100	$38,100
	Belly Tanks	$2,880,800	$14,404
	Upper Structure	$1,836,600	$9,183
	Decking, Handrails, and Stairs	$103,400	$517
	Ballast System	$836,300	$13,139
	Electrical and Maintenance Buildings	$168,000	$840
Screen, Baffles, and Cleaners		$2,152,900	$54,400
	Primary Screens & Baffles	$702,800	$6,050
	Secondary Screens & Baffles	$646,200	$5,513
	Pressure Backwash Screen Cleaners	$803,900	$42,862
Attraction Flow Pumps		$1,258,500	$97,300
	Submersible Attraction Flow Pumps	$900,300	$90,025
	Pump Adapter and Hardware	$131,900	$3,298
	Expansion Discharge Cones	$84,100	$420
	Discharge Flap Valves	$142,200	$3,555
Trashrack and Rake		$500,200	$28,000
	Trashrack	$47,800	$885
	Trash Rake	$452,400	$27,144
Mooring		$1,019,400	$10,400
	Mooring Towers	$728,600	$3,095
	Mooring Attachment	$290,800	$7,271
Guide Nets		$120,600	$15,400
	Dyneema Net Material	$81,500	$13,038
	Boom Floats	$17,400	$1,042
	Bottom Weight	$4,400	$262
	Internal Float Lines	$4,500	$273
	Internal Weight Lines	$400	$26
	Connection to FSS	$12,400	$745
Fish Transport Hose		$142,900	$3,600
	16" Flexible Dredge Hose	$119,800	$2,996
	Floats with Cabling to Hose	$12,800	$320
	Connections	$10,300	$259
Floating Access Walkway		$64,300	$1,200
	Decking	$19,000	$190
	Handrails	$7,600	$76
	Floats	$18,300	$457
	Framing, Connections, and Misc.	$19,400	$485
Flow Control Structure		$1,058,100	$13,300
	Concrete Containment	$400,100	$1,933
	Control Weir Gates	$131,900	$6,690
	Helix	$526,100	$4,717
Bypass Pipe		$228,100	$1,000
	Tunneling	$68,300	$0
	Bypass Pipe	$159,800	$1,022
Electrical & Controls		$1,318,400	$35,000
	Cables & Wiring	$575,200	$2,876
	Electrical Components	$743,200	$32,153
	Subtotal:	**$14,112,800**	**$297,700**
Mobilization-Demob (5%)		$705,600	
Contingencies (30%)		$4,445,500	$89,300
Direct Construction Related Costs		**$19,263,900**	**$387,000**
Engineering Design (15%)		**$2,889,600**	
Total Project Cost		**$22,153,500**	

9 RECOMMENDATIONS

The following steps are recommended in support of the Sockeye Salmon restoration plan for the upper Coquitlam River above Coquitlam Dam.

- Assess the 3-D fish tracking results from the 2017 LGL acoustic tag study when they become available to answer the following questions (cited in Section 5.1) concerning the behaviour of kokanee smolts in the forebay in response to flows through the existing Sluice Tower:
  - What is the predominant depth of fish observed in the forebay?
  - Did the predominant depth vary between the 3 m3/s and 8 m3/s exposures?
  - Did fish tend to sound deeper as they approached the Sluice Tower?
  - If fish did sound to depth did they stay there long?
  - Did fish that stayed in the forebay longer tend to go deeper?
- Complete development of the life-cycle model described in Section 6.1. Initial modeling results incorporated life stage parameter values based on regional Sockeye and/or kokanee data and assess which life stage limitations have the greatest influence on successful restoration. Use the model to quantify the likelihood of restoring a naturally-reproducing, self-sustaining Sockeye Salmon population; and if necessary, identify the minimum number of smolts that might be required to pass through the dam to increase the likelihood of restoring Sockeye production above Coquitlam Dam.
- Maintain the life-cycle model and refine the analysis with site-specific life stage parameters as they become available.
- Initiate the optimized operations during the defined Sockeye outmigration season, including curtailing the Buntzen diversion flow and increasing the Sluice Tower discharge, as described in Section 6.2. Monitor RSTs downstream for passage of kokanee smolts out of the reservoir.
- If the initial season of kokanee smolt passage with optimized operations appears promising continue optimized operations through the 2020 outmigration season with continued monitoring of outmigrants. In addition, monitor for injury and/or mortality associated with the passage; and monitor the forebay area for the presence of kokanee smolt that travelled to the forebay but did not pass through the Sluice Tower. A high presence of such fish might indicate the need for one of the two physical modifications described in this report.
- If the initial season of kokanee smolt passage with optimized operations is unsuccessful, there are two considerations for continuing the restoration plan. 1) Consider significantly

increasing the downstream discharge through the Sluice Tower to the extent practical, which will increase the attraction flow to the forebay. 2) Consider supplementation with hatchery-reared fish and/or Sockeye from another watershed.

- During the spring of 2017, approximately 5,000 artificially-reared kokanee smolts from the Coquitlam stock were released in the Coquitlam River downstream of the dam. Adult Sockeye returns at the dam should be monitored during the 2019/2020 seasons to identify the level of success from this release. A poor return may indicate that the use of kokanee as a seed stock for the restoration program may not be successful and/or prevailing ocean and in-river conditions lead to poor survival and low adult returns.
- If adult Sockeye do return during the 2019/2020 seasons from the 2017 juvenile release, consideration should be given to using these returning adult fish as brood stock for future juvenile releases.

10 ACKNOWLEDGEMENTS

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Finally, we would like to thank Julie Fournier and the FWCP for providing the grant funding for this project and making it all possible.

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APPENDIX A
FISH PASSAGE DECISION FRAMEWORK
FOR BC HYDRO FACILITIES

Fish Passage Decision Framework for BC Hydro Facilities

Revision 1 - December 2016

Note: this document was originally created in 2008 and signed off and endorsed by Fish, Wildlife and Hydro Policy Committee representatives. Subsequently in 2016, additional information was added to the document and reviewed and endorsed by the Fish, Wildlife and Hydro Policy Committee representatives in January 2017.

Purpose - To establish a process which will determine how BC Hydro will address fish passage issues at BC Hydro facilities. This document also clarifies the role of the Fish and Wildlife Compensation Program (FWCP) in supporting the development of fish passage proposals for BC Hydro consideration.

Background and Scope - The development of some of the BC Hydro dams in certain watersheds resulted in a blockage to migratory fish. The result often meant the elimination or the reduction of specific migratory fish species or populations in the rivers. Proposals for fish passage have been initiated by public and First Nation groups, with Fisheries Agencies support, at several BC Hydro facilities. The rationale for fish passage is to improve the productivity of affected watersheds through the re-establishment of selected species of fish to the portions of the watershed they historically utilized. This Framework has been endorsed by the FWCP in 2008 for application to facilities where fish passage has been identified as a priority at respective facility watersheds.

BC Hydro Statement of Strategic Intent - BC Hydro's long term goal, stewardship ethic and environmental policy establish the commitment to minimizing our impacts, and where possible, restoring the environment. The *Fish Passage Decision Framework* will ensure that fish passage decisions are based on a structured decision making approach, with sound defensible criteria.

Fish Passage Decision Framework for BC Hydro Facilities

Revision 1 - December 2016

The construction of several of BC Hydro hydro-electric facilities resulted in a barrier to fish that previously utilized areas of the watershed above and below the dam. Fish passage is required to re-establish selected species of fish to portions of the watershed that they historically utilized. There have been several fish passage proposals that promote the construction of fish ladders or other permanent fish passage facilities at hydro-electric facilities.

The Fish and Wildlife Compensation Program (Coastal, Peace and Columbia) was established by BC Hydro in partnership with the Department of Fisheries and Oceans (DFO) and the Province as a mechanism to help address footprint impacts. Each region is managed by a separate Board made up of members from the public, First Nations, DFO, the province and BC Hydro. The Policy Committee made up of senior managers from BC Hydro, the province and DFO sets the overall policy direction for the FWCP including the governance structure, establishes the strategic framework, overseas periodic FWCP evaluations, approves significant changes to the FWCP, and addresses disputes arising from within the FWCP when necessary (FWCP Governance Manual 2014). The FWCP was established to compensate for impacts to fish, wildlife and their supporting habitat resulting from the construction of BC Hydro dams (footprint impacts)." Whereas impacts caused by facility operations (e.g. water level changes and maintenance) are addressed through other programs such as Water Use Plans, the Fish Entrainment Strategy, and fish stranding protocols.

While the blockage of fish passage is defined as a footprint impact, there is insufficient funding in the FWCP to take on the funding of construction projects (e.g. fish passage infrastructure). As a result, the Policy Committee has endorsed a formalized approach to involve the FWCP Boards in the decision making process of analyzing the issue and to ultimately make decisions to address the technical feasibility and likelihood of success of fish passage. The Fish Passage Decision Framework ("the Framework") is divided into two parts:

- The FWCP role: a Proponent-led process whereby the proponent (typically a fish passage committee) seeks funding from the FWCP to evaluate the feasibility of restoring target species above respective BC Hydro facilities through the installation of some form of fish passage infrastructure. This part of the Framework is completed when a proposal is found to be "infeasible" or if the regional FWCP Board endorses the fish passage proposal; and

- The BC Hydro role: Once the regional FWCP Board endorses the fish passage proposal ("Step 5" of the Framework), the Proponent will submit a supported project proposal for fish passage which will then go to BC Hydro for business case and financial approval.

Currently, FWCP Coastal region is the only chapter to consider fish passage initiatives within its Action Plans. If other chapters identify and approve fish passage as a key priority in their watershed Action Plans, the Framework would apply accordingly.

FWCP Role:

The applicable FWCP Board needs to be convinced that the fish passage proponent has met the requirements of each step in the Framework before it endorses a fish passage plan. The FWCP Board can, at any time, utilize the regional FWCP Technical Review Committee within the FWCP proposal review process or an independent consultant (e.g. a fish passage expert) to inform its decisions. In addition, BC Hydro will provide a technical lead to support the proponent, and act as a liaison with the FWCP Board to ensure consistency and support communication between the FWCP Board and the proponent.

Although the Framework is intended to be implemented in as a linear process, studies and activities under Steps 3 and 4 may be implemented in order of priority or complexity in the process, as informed by the target species requirements and the facility context.

Step 1 - Preliminary Screening

To determine whether a fish passage proposal for a specific watershed addresses a footprint impact, the following screening question will be asked:

"Did the facility block passage of a migratory fish stock at the time of construction?"

Each of the of the FWCP regions has developed Watershed Action Plans in partnership with the FWCP Board, Technical Committees, BC Hydro, First Nations, DFO, the province, and other stakeholders through a series of consensus building workshops. The planning process establishes priority conservation, enhancement and restoration opportunities for each watershed.

Fish passage opportunities are prioritized within the Watershed Action Planning process. Within-watershed priorities are based on Provincial and Federal agency species objectives and on preliminary biological and technical feasibility criteria, including whether the facility blocked passage at time of construction. High priority opportunities are integrated into watershed or species specific Action Plans. If fish passage has not been identified as a priority in the Action Plan or by the FWCP Board, it would need further evaluation before the proponent could proceed to Step 2.

Step 2 –First Nations and Stakeholder Engagement

Fish Passage Decision Framework studies and activities outlined in Steps 3 and 4 below are funded through the normal FWCP application process, which requires that proponents demonstrate their applications have the support of regional First Nations, stakeholders and regulatory groups. To ensure that the proponent considers affected interests, it is highly recommended that a fish passage committee be established that includes representatives from local First Nations, community and regulatory groups, and BC Hydro. It is recommended that all participants carry the mandate to represent their interests and the authority to participate in fish passage committee decisions. The fish passage committee should document its fish passage plan objectives, including expected restoration goals, expectations of ongoing support, and consistencies with fish passage committee representative objectives (regulatory requirements, BC Hydro operating requirements, etc.). Based on the objectives, the fish passage committee can then identify its data gaps in developing a fish passage plan that will address Steps 3 and 4 below. The fish passage committee should establish a timeline for addressing its critical gaps, with those uncertainties deemed of most significance to plan success addressed earliest in the timeline. Changes to the plans based on inputs from studies or other sources should also be communicated and reviewed as needed.

Step 3 - Environmental Feasibility Studies

In order to assess the potential for success for a fish passage proposal, initial environmental feasibility studies must be undertaken. Environmental feasibility studies are undertaken to determine whether fish passage plan objectives described by the fish passage committee can be met given biologic inputs collected in the Framework. The environmental feasibility of each fish passage proposal must include the following assessments:

- Target species are available in the watershed in sufficient numbers to support rebuilding a sustainable population. If the target species is not available and a donor stock transplant is proposed, a thorough risk assessment related to suitability of the donor stock and impact on the donor stock must be undertaken;
- Potential genetic, ecological and disease impacts to native species;
- Existence of high quality spawning and rearing habitat below the dam;
- Other physical impediments, such as other adult migration barriers below the dam, or juvenile passage issues at the facility, or different flow regimes that may limit the potential for restoration goals to be achieved;
- Sufficient spawning and rearing habitat above the barrier to support the target fish population numbers established in the Watershed Action Plan, or the known potential to restore sufficient habitat. Feasibility studies must be undertaken to assess this potential; and
- An assessment of the biologic benefits of a fish passage plan, as well as a summary of the risks of biologic impact and regulatory requirements.

Assessments may be based on available literature, modeling, or direct empirical measurement as dictated by the complexity and understanding of the issue. In evaluating an assessment proposal, the FWCP Board will determine if:

(a) an appropriate review of options has been conducted;

(b) the assessment is required to determine feasibility; and

(c) whether the approach has a reasonable chance of addressing the uncertainty.

Depending on the number and complexity of data gaps, this step can take several years to complete. Multi-year study plans will be considered where the criteria above have been accounted for and the proposal represents a priority for funding. Some studies used to establish biological feasibility may require approval from the province or DFO.

Environmental feasibility is established where the fish passage committee and the FWCP Board agree that studies and activities demonstrate that fish passage plan objectives can be sustained under the appropriate technical circumstances. The proponent may request a meeting with the FWCP Board to determine whether Step 3 requirements have been met.

If environmental feasibility has not been adequately demonstrated, or any of the fish passage committee feels that their objective are not adequately considered in the process, the FWCP Board may direct proponents to re-submit to address their concerns, or deny their application.

Step 4 – Preliminary Technical Feasibility Consideration

The proponent is responsible for identifying the fish passage solutions that will best address requirements to meet its stated restoration goals. This includes a review of fish passage options, an analysis of fish passage efficiencies and effectiveness (e.g. survival), a description of operations, conceptual design and an estimate of cost. BC Hydro engineering will provide in-kind support to the proponent in its review and selection of fish passage options, to ensure that dam safety, operating requirements, maintenance standards and crew requirements are appropriately addressed in the final recommendation. The proponent needs to ensure that it responds to any concerns BC Hydro raises in its review.

The review and analysis of options can be based on case studies of technologies applied successfully in similar contexts, or may require more specific evaluation in lieu of relevant examples from the literature. The technical assessment will include a conceptual design and the costs of the preferred option.

Technical feasibility is established once the fish passage committee and the FWCP Board agree that the plan can support its biologic objectives using technologies and operations that are proven within the specific facility context. The proponent may request a meeting with the FWCP Board to determine whether Step 4 requirements have been met.

If technical feasibility has not been adequately demonstrated, the FWCP Board may direct proponents to submit applications that will address identified gaps, or deny their application.

Step 5 – FWCP Endorsement

After completing Steps 3 and 4, the proponent will prepare a fish passage plan and seek technical support with Fisheries and Oceans Canada and the province. The proponent will then present the fish passage plan to the FWCP Board for its endorsement to proceed to Step 6. The summary and presentation will be reviewed by the FWCP Board utilizing any additional technical resources dictated by the complexity of the fish passage plan and the understanding of FWCP Board members.

In addition to demonstrating technical and environmental feasibility, the FWCP Board and proponent must ensure that the information provided in the fish passage plan will adequately inform the development of a business case in Step 6:

- What are the risks associated with the fish passage plan:
    - likelihood of success?
    - Regulatory approvals?
    - Demonstrated success of the proposed technologies?
    - Population, genetic or ecosystem threats?
- What are the costs of the fish passage plan: operations, study costs, construction?
- What are the benefits: biologic (productivity), conservation, First Nations cultural and other societal benefits (tourism, education)?

The FWCP Board is not responsible for conducting the business case evaluation, but will ensure the proponent has provided the values in a meaningful summary to inform the next step in the Framework. Once the FWCP Board is satisfied the proponent has met the requirement in these 5 steps, it will endorse the fish passage plan for BC Hydro consideration.

Where the proponent has NOT met the Framework requirements to this point, the FWCP Board will provide feedback (according to its technical review or directly from the FWCP Board) to the proponent for further work. If the proponent's fish passage plan is deemed NOT feasible based on the weight of evidence provided, the FWCP Board must indicate that it cannot be endorsed and that future requests to support the its evaluation will not be funded.

BC Hydro Role:

Step 6 –Business Case Development

The business case recommendation will follow a structured approach that explicitly integrates environmental, social and financial objectives in evaluating alternatives for fish passage. The process will provide a rating from high to low for fish passage alternatives. The process will evaluate alternatives against objectives provided from the proponent with additional analysis of alternatives, updated costs and any gaps in the original proposal.

(a) **Environmental Assessment:** in consultation with FWCP and the original proponent, BC Hydro will further assess the environmental feasibility if required.

(b) **Financial/Technical Assessment:** options to provide fish passage will be analyzed to ensure technical feasibility for the proposed watershed.

- Dam structure integrity must be maintained; therefore designs for upstream and downstream passage facilities must undergo a BC Hydro engineering review.
- The fish passage proposal must be able to operate within the current Water Use Plan (WUP) operating parameters for the facility. If not, the proposal will be deferred until the scheduled WUP review takes place.
- Designs and costs for additional structures, such as screens to reduce potential juvenile migrant fish mortality, must be considered.

(c) **Social Benefits Assessment –** fish passage at the proposed site will be considered with respect to added societal value. Considerations may include:

- Intrinsic values – there is demonstrated evidence that the intrinsic value of the watershed will be positively impacted by the proposal (i.e. improved ecosystem biodiversity);
- Cultural – First Nation have identified the importance of returning fish providing food, social, ceremonial and spiritual values; and
- Socio-economic – there is demonstrated evidence that there will be an increase in tourism, recreation, jobs and / or a new or enhanced fishery.

The proposal will move to Step 7 if the evaluation of the above indicates it has a high potential for success. This process of developing a business case can take 3 months to 2 years to complete, depending on the level of information provided from Step 5 and the potential for additional options to be considered outside of the original fish passage plan.

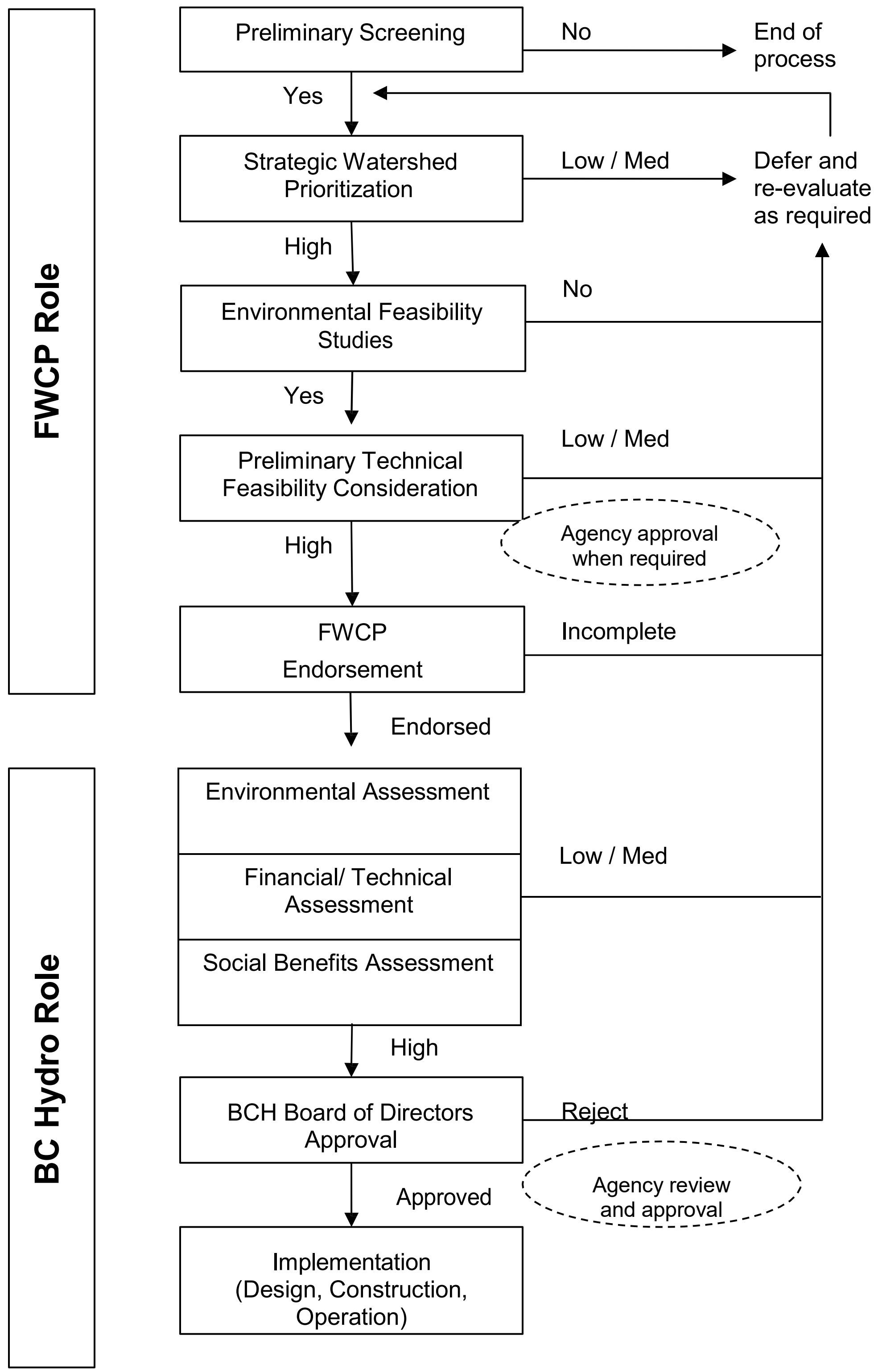
Step 7 –BC Hydro Board of Directors Approval

The proposed fish passage project will need to be evaluated with respect to BC Hydro's economic and business practices to determine whether it fits into BC Hydro's long term capital plan. The business case may include a detailed trade-off analysis and will include a detailed design.

If accepted by the BC Hydro Board of Directors, BC Hydro will be responsible for the management of design and construction of the passage facility. Regulatory Agency review and approval will be required. BC Hydro will be responsible for ongoing operation and maintenance of the passage facility.

Fish Passage Decision Framework for BC Hydro Facilities

Revision 1 - December 2016



APPENDIX B

KSRP MEETING MINUTES (JULY 26, 2017)

KSRP Committee Meeting Minutes

Coquitlam Smolt Outmigration – R2 Phase 1 Feasibility Study and LGL Field Study Summaries

Wednesday, July 26, 2017 - 9:00am – 3:30pm
BC Hydro, Edmonds Building – E01 Longhouse Conference Room
R2 Resource Consultants Meeting Notes

Attendees:

Alf Leake – BC Hydro
Brent Wilson – BC Hydro
David Strajt – BC Hydro
Chris Bray – BC Hydro
Julie Fournier - FWCP
Craig Orr – Kwikwetlem First Nation
Michael Crowe - DFO
Maurice Coulter-Boisvert – DFO
Dave Nanson – DFO
Scott Ducharme – DFO
Michael Wilcox – BC Ministry of Forest, Lands, and Natural Resources
Dave Dunkley – Metro Vancouver
Jesse Montgomery – Metro Vancouver
Hagen Hohndorf – City of Coquitlam
Dianne Ramage – Pacific Salmon Foundation
Norm Fletcher – Port Coquitlam & District Hunting & Fishing Club
Elmar Plate – LGL
Peter Christensen – R2
Phil Hilgert – R2

Introduction and Briefing:

- Alf indicated that BC Hydro and DFO recently updated the Fish Passage Decision Framework (FPDF). Craig Orr expressed concern that BC Hydro did not engage the Kwikwetlem First Nation in consultation during the update of the FPDF.
- Norm reported on the ceremonial smolt release. Approximately 5,000 kokanee/Sockeye juveniles from the Rosewell Hatchery were released into the lower Coquitlam River (minus 300 used for LGL test releases in the reservoir). 100 of the juveniles saved for the LGL tests died during a power outage and Coho juveniles were used instead for the LGL tests.
- Alf indicated they would like the Phase 2 report by September in order to identify potential 2018 activities. Applications for funding for 2018 must be submitted by Oct 27, so the KSRP wants some info to support future funding activities by September. Peter indicated the report would not be ready by then, but R2 could provide preliminary information to support potential funding decisions.

R2 Resource Consultants Presentations:

Phil Hilgert – Significant Literature Review Findings

Phil provided a summary of the literature review which was developed as a Phase 1 study task. He highlighted three restoration projects that used alternate Sockeye restoration strategies.

- The Baker River Project used artificial spawning beaches, hatchery supplementation, and floating surface collectors (FSCs) with guide nets at each of the two reservoirs. In 1985 (prior to the current FSCs) there were only 99 returning adult Sockeye in the river. In 2015, they had 52,243 adults return.
- A large FSC (without guide nets) has been installed at Round Butte Dam in Oregon. Although Chinook and steelhead were the target anadromous species , the reservoir supports a healthy population of Sockeye-origin kokanee. Some juvenile kokanee underwent smoltification, outmigrated through the FSC to the ocean, and returned as adults , which have been transported upstream. Since the FSC operation began in 2009 the average adult return has been 45 fish.
- Lake Cushman has a kokanee population that was heavily supplemented by hatchery outplants to support a recreational fishery. Tacoma Power constructed an FSC to provide downstream fish

passage, but is using Baker River sockeye eggs in an effort to restore an anadromous Sockeye population. The reintroduction effort is just beginning and results are not yet available.

- During a side conversation, Elmar commented on a reference from a BC researcher on the propensity of land-locked populations to express anadromy and can provide a citation.
- Phil also discussed the fish behavior associated with smolts approaching a reservoir outlet. Although the fish apparently seek a surface outlet similar to a natural stream outlet, during their search for an egress route they may find and use a low-level outlet. Sockeye smolts have used low level outlets in other reservoir systems. This potential attraction and confusion associated with multiple reservoir flow release locations was one reason R2 suggested that constraining Buntzen Tunnel releases during the smolt outmigration season could increase the success of fish passage at the Coquitlam Low Level Outlet (LLO). Although the ability of constraining Buntzen Tunnel releases may vary each year depending on reservoir inflow, monitoring the success of the LLO attraction over time under varying Buntzen flow conditions would identify the influence of the Buntzen Tunnel and a decision can then be made whether to eliminate or continue Buntzen release constraints.
- Elmar agreed with the Buntzen Tunnel approach described in the PowerPoint presentation.
- Metro Vancouver wants to move their intake and double the volume of their withdrawal. The location, timing, volume and method of withdrawal will affect fish passage. Craig Orr said he will be pushing to make sure fisheries impacts are considered when Metro Vancouver applies for the change.

<u>Peter Christensen – Phase 1 Draft Report Presentation</u>

Peter provided a summary of the Phase 1 Study Draft Summary Report. The study assessed 10 downstream passage options for the Coquitlam Reservoir and rates them relative to a common set of criteria.

- At the start of the presentation two comments were made concerning the background description of the project.
    - Hagen says it should say Port Coquitlam and not Port Moody in the first sentence of Section 2.1.
    - Concerning the second sentence of Section 2.2, Dave Dunkley said the water withdrawal for Metro Vancouver is not an agreement between BC Hydro and Metro. He said that MV has a water right for that withdrawal. Dave said that he would provide revised text for that sentence.
- Peter noted that for all of the options assessed in the Phase 1 study it was assumed that the Buntzen tunnel flow releases would be constrained, and that the discharge to the lower Coquitlam River was increased to 8 cms. Having these assumptions common to all options provides an equal basis from which to compare and prioritize the options.
- The increased flow downstream is not only to presumably increase attraction to the south end of the lake and through the bypass, but is also necessary to compensate for the reduced outflows through the Buntzen tunnel. Significant reductions in the Buntzen tunnel outflows would result in unacceptable rises in the reservoir water level if the releases to the lower Coquitlam River are not significantly increased.
- Brent noted that any proposed increase in flow releases to the Coquitlam River for fish passage will have to be formalized through the regulatory process - it will have to be part of the Water Use Plan – either annual approval of a variance, or a long-term issue. If the Water Use Plan is modified, the potential effects of the change will have to be evaluated. For instance, if flow releases to the Coquitlam River are increased, any potential downstream stranding risk associated with the flow changes will have to be addressed.
- Six criteria were developed to provide for a relative assessment of the options, including:
    - Proven Technology
    - Focus of Sockeye Passage
    - Effective Attraction of Migrating Smolts

- Safe and Effective Collection of Migrating Smolts
  - Safe and Effective Transport of Migrating Smolts
  - Cost

Peter summarized the fish passage options reviewed in the Phase 1 fish passage feasibility report. Options A through F were originally provided by the KSRP for consideration. Options G through J were developed by R2.

KSRP Developed Options

- Option A – The Cle Elum helix concept sized for the magnitude of flows we are looking at for Coquitlam would be too large to fit in the sluice tower forebay area. Peter showed a plan view drawing of the Cle Elum helix superimposed on the Coquitlam forebay, and noted that he had just put the drawing together the day before, and it had not yet been added to the report.
- Option B was combined with Option D and not evaluated as a stand-alone option.
- Option C – R2 assessed that the shore-based net traps and head of reservoir screw traps could never function as the long-term passage solution supporting a successful restoration, as the capture efficiency would never be adequate.
  - The MV representatives noted that the Capilano net and trap option works best during low flow years. During high flow years, such as 2017, smolt collection drops quite a bit. Nets are replaced every other year and each net is $10k-$12k. They tried a trap in the middle of the reservoir but captured few steelhead and Coho, and access and debris were problematic.
- Option D – The option calls for creating a surface overflow weir adjacent to the sluice tower, and then a second overflow weir to further drop the flow into the tower chamber upstream of gate LLO-1. This is to reduce the water level in the tower to presumably create a safer environment in the discharge tunnel. Peter noted that these would be large flows with high drops into confined spaces that would create excessive turbulence that could injure the fish. This is an unprecedented approach that would entail risk.
- Option E – This option is a bypass pipe floated out over the forebay area, with the intake end floating on a barge. Peter noted that without a source of additional attraction flow (which would make it more like an FSC as shown in Option J) this option could not pass the target 8 cms flow rate used in the options comparison. However, you could add guide nets and provide 8 cms, with 4 cms through the collector and 4 cms through the nets. The net flow would provide some velocity through the net which could enhance guidance – but flow through the nets would create a debris management concern.
- Options F1 and F2 – These are two versions of a potential spillway cut into the rock at the location of the existing high spillway. Peter noted that spillways are often used for bypass around powerhouse turbines, but generally this is a temporary route until a dedicated safe fish passage facility can be constructed. Under the right conditions, spillway can be relatively safe for fish passage; however, for Options F1 and F2, the variable reservoir level would likely cause unsafe conditions at the entrance under some conditions. Also, both of these designs would involve water plunging about 12 metres into the pool below the existing tunnel discharge. This could create an unsafe fish release condition. Norm stated that the pool below Coquitlam is deep enough – but is it large enough to capture spray so that fish will safely enter the plunge pool even in high winds? One of the participants mentioned a spillway at Seymour Reservoir (one of the 3 Metro Vancouver reservoirs) that is used for fish passage with a high plunge and water depth similar to Coquitlam, and he noted that it has a 90% survival. Peter noted that 90% survival would be unacceptable in the U.S., and that turbines with 90% survival rates have still triggered the need to construct a bypass system. Brent mentioned they have a spillway at Alouette that provides safe passage – but it is only used over a narrow operating range of reservoir water surface elevations so isn't used all of the time.

R2 Developed Options

- Option G – The drive to design a safe fish bypass system for the Coquitlam sluice tower is based on the belief that the sluice tower discharge tunnel is unsafe for fish passage, especially at higher reservoir levels. This presumption is based on the capture of dead and injured fish downstream of the project, and the observation that injuries seem to be more pronounced at higher reservoir levels. Peter showed depictions of the knife gate settings for 3 cms at reservoir levels of 151.5 m and 145 m, noting that at the higher reservoir level the shape of the gate opening is clearly not safe for fish passage, whereas at the lower reservoir level the shape appears to be somewhat safer. He questioned whether this might have actually been the source of the observed injury. LLO-1 and LLO-2 could be safe alternatives since they do not have a knife gate. Therefore, Option G is to simply continue using the existing sluice tower for passage, but transfer flow releases from the knife gate in LLO-3 to one of the other two gates, assuming that those gates are shown to be safe. Peter noted that part of the field study that Elmar will be presenting later today was designed to test whether passage through the discharge tunnel is harming fish.
    - BC Hydro noted that, the knife gate on LLO-3 was designed to provide finer flow control, so we would need to make sure we do not need fine flow control before going to another gate. It is unclear whether LLO-2 and LLO-3 gates are approved for operation at partial openings and additional research would be needed to confirm the acceptable range of openings.
    - Peter noted that if 8 cms were released through LLO-3, the knife gate would be nearly full open, depending upon the reservoir level; a fully-open knife gate is safe for fish passage.
- Option H – This is similar to Option G except that if studies can identify that there are specific features within the existing sluice tower and discharge tunnel that are harmful to the fish, then those specific items could be addressed and then the sluice tower could continue to be used for fish passage.
- Option I – This is a fixed surface collector with fish screens located adjacent to the sluice tower. The screens are used to reduce the large fish attraction flow down to a manageable flow for safe passage downstream via a dedicated bypass pipe. The screened flow would pass into the sluice tower and out thorough LLO-1. The concern with this approach is the limitation on the range of reservoir levels over which it would be able to function effectively and pass fish.
- Option J – This is a floating surface collector (FSC) with the same screen arrangement as the fixed collector in Option I. The main advantage is that the barge-mounted collector would operate over a much larger range of reservoir pool levels. The fish bypass flow would be routed downstream in a submerged flexible hose, where it would then hook up to the same bypass pipe arrangement shown for Option I. The screened flow would be returned to the reservoir and passed downstream through the Sluice Tower, presumably using LLO-3 since there would be no fish in the flow. However, this option would require guide nets to keep the fish from passing by the FSC.
    - Someone noted that if the fixed surface collector is cheaper than the floating surface collector, you could address the fixed operating range by having two fixed collectors that function over different reservoir levels. You would just switch between collectors for different reservoir level ranges. Peter noted that this could work but would likely to be more expensive than a floating surface collector.
    - Someone asked if you could have an FSC without pumps and just use gravity to drive the 8 cms attraction flow? Peter said you would not need a pumped attraction flow if: a) the entire 8 cms attraction flow were passed downstream along with the fish, or b) if the attraction flow outside the screens was somehow plumbed directly to the sluice tower or GVWD diversion for release downstream. Either way, this would be a very expensive and complicated way to operate the FSC.
- Peter suggested that consideration be given to including at least one of the last two options in the Phase 2 study, and leaned toward the FSC because it operates consistently over a full range

of reservoir levels. He also said the KSRP may want to include the first of the two spillway options. Peter suggested that the sluice tower option does not need to be part of Phase 2 engineering study since it is not an engineered option, requiring significant conceptual design or construction cost estimates.

- Alf said that he wants to keep the sluice tower passage (Option G) as an option for evaluating future options for implementation. Include it as an option and conduct minimal engineering – but do include it. Alf also said that he does not want to include any further analysis of either of the spillway options. There were no disagreements regarding the recommendation to keep sluice tower passage in the mix and to drop the spillway options.

<u>Elmar Plate – Initial Results of 2017 Study</u>
Elmar summarized some of the goals and details of the study:

- Evaluate the rate of smolt outmigration at 3 cms (low) and 8 cms (high) releases through the LLO.
- Buntzen Tunnel diversion flow was supposed to be turned off for the test period, but due to high reservoir inflows during spring 2017, the Buntzen Tunnel releases were needed to manage reservoir pool levels throughout most of the study. Therefore, a receiver was installed downstream of the Buntzen tunnel outfall, but data analysis has not yet been completed.
- The juveniles selected for the tests weighed 10 grams or more. The first 50 juveniles were handled and tagged immediately after they were transported to the reservoir; six of the tagged fish died prior to release. The next 50 fish were held for several days, allowed to acclimate, and then tags inserted - no mortalities. Two releases were conducted at 3 cms and two releases at 8 cms.
- Three release sites were used to identify the influence of localized flow nets on fish movement at the two different outflow rates:
    1. 10 meters from the dam at the boat launch,
    2. At the boom across the reservoir from the GVWD diversion tower, and
    3. An upstream release near the Buntzen Tunnel entrance.
- They placed 15 receivers in the south arm of the reservoir, upstream of the sluice tower to track fish movements. At the time of the meeting they only have results for the 8 receivers closest to the dam – additional data analysis is continuing for the additional receivers further upstream.
- LGL conducted a roving survey every 100 meters up the reservoir but detected few fish - turns out that a data filter applied by VEMCO eliminated low strength signals – but all the roving surveys were weak detection since the tags were only good out to 50 meter. LGL will reanalyze the data with a less sensitive filter.
- Fish released near the Buntzen Tunnel intake would take a day or so to migrate to the dam so the relationship between flow release and passage should be determined by what LLO release was occurring when the juveniles were detected passing the LLO and not when they were released.
- Additional releases were performed directly into the sluice tower to evaluate fish injury through the LLOs at the two flow rates. The first releases were through LLO-1 (without the knife gate), and the second releases were through LLO-3 (with the knife gate). Coho smolts (selected to be the same size as the kokanee/Sockeye juveniles) were used for some of the tests after the loss of the kokanee/Sockeye juveniles due to the power outage. Two fish release techniques were used:
    1. Upstream of trash rack – fish could go into the gatewell or back upstream, and were not necessarily committed to going downstream through the gate.
    2. Directly into the LLO gate. The release pipe itself was nearly sucked into the gate so it was assumed that all fish released through the 2nd release procedure were passed through the LLO. However, only about 11 fish were detected by the downstream receiver; however, this data is also being reanalyzed with a less sensitive filter.
- Dead juveniles were also released to see assess the ability to recover dead fish in the fyke net. Approximately 10% of the carcasses were recovered. All fish carcass release tests were done at 3 cms because the net capture efficiency was poor at 8 cms. Modifications to the testing and capture procedures would be needed to effectively evaluate 8 cms conditions.

- From release of 100 live fish directly through the LLO gates, three were recovered dead without any sign of injury; Elmar presumes that these three died for some reason upon release through the pipe and not from exposure to the discharge tunnel.
- Of the 100 adipose fin-clipped live fish released, 88 were captured in the rotary screen trap (RST). In the past, the RST capture efficiency has been estimated at 50 percent. Capture efficiency was obviously higher for the adipose fin-clipped test fish since 88 percent were recaptured. The previous RST capture efficiency estimates were based on Coho/Chinook captures which are shoreline oriented. The higher capture efficiency of the RST for the 2017 test fish could be due to better capture rates at the higher release flow of 8 cms (i.e., RST function better at higher water velocities), and/or greater capture efficiency if the test fish were not shoreline oriented.
- The operator of the RST said that they captured more wild fish this year than in any previous year so it would appear there is either higher capture efficiency due to the higher flow rate of 8 cms and/or a greater propensity for the wild fish in the reservoir to migrate out at the higher flow rate.
- It appears that fish released through LLO-3 at 3 cms had almost 100% survival. Elmar noted that the release pipe arrangement passed through the knife gate opening at the bottom, so the fish were discharged immediately downstream of the knife gate blade and not exposed to the knife gate hydraulic conditions. It is also uncertain whether fish would have similar high survival at 8 cms releases.
- It was noted that lots of dead fish were found in the RST traps a few years ago in a year when the reservoir level was up, which led to the belief that the higher pressure led to unsafe conditions in the discharge tunnel. Peter noted that if the fish were passed through the knife gate in a low flow (say around 2 cms,) with the reservoir up around 150 m or higher, then the knife gate setting would have been extremely hazardous for passage, and could have been the source of the injury and mortality witnessed.
- Based on the lack of injury found in the LGL study fish, Norm suggested that the discharge tunnel lining does not appear to be a problem and that the knife gate has probably been the source of injury all along. The overall group appeared to agree. A question was raised about the possibility that the tunnel lining may become hazardous at higher flow rates. Peter responded that at the same reservoir level, a flow of 3 cms or 8 cms should have similar survival rates associated with striking the tunnel lining because the maximum exit velocity would be the same for both 3 cms and 8 cms given the same reservoir level.

<u>Alf Leake – Summary</u>

- Alf indicated that instead of just more study, he would like to see a potential implementation plan developed that includes an adaptive approach, perhaps with short-term hatchery supplementation to jump-start restoration. An implementation plan should be presented to the FWCP at the September 19 meeting.
- Elmar to provide draft results of the analysis of the 2017 tests by September 2-5; Elmar also agreed to have LGL provide R2 with preliminary results in August as they are developed (rather than waiting for the draft report).
- Based on the results of LGL study, it appears that passing fish through one of the existing LLO gates at 8 cms seems a viable option. What are the remaining uncertainties? The following remaining uncertainties were suggested during group discussion:
    - *Can we attract the fish with the deep intakes of the existing sluice tower?* Further analysis of the LGL study data is forthcoming and may shed light on whether the increased flows do increase attraction to the deep intakes. Alf suggested that part of an adaptive management approach might be having a design in hand to add an overflow baffle in front of the sluice tower in the event that attraction is an issue. He would like to see this investigated as part of the Phase 2 study. Peter noted that this could be considered Option K.

- *Can we safely pass fish through the sluice tower at a variety of flow rates?* Although there is limited data with only a single study year, the initial results appear promising. Additional future studies would need to be conducted to validate this. The fyke net was only operated during the 3 cms releases; however, the RST downstream was operated at both flow conditions. A characterization of the fish injury condition of the fish captured in the RST during the 8 cms releases could be informative. The RST is not scheduled to be installed next year. Elmar said that LGL could install a metal frame for the fyke net next year that would allow it to be used up to 8 cms or even greater flows. It is not clear whether at these flow conditions the fyke net itself might represent an unacceptable source of fish injury for a valid sample study.
  - *Is the Buntzen Tunnel an attraction nuisance?* Conclusively determining the influence of Buntzen Tunnel releases on outmigrating Sockeye smolts may not be possible until a Sockeye run has been reestablished. Rather than trying to test the influence of the Buntzen Tunnel, another option would be to constrain Buntzen Tunnel releases during the peak of the Sockeye outmigration season and adaptively monitor the results. Such a plan would need to include an upfront assessment by BC Hydro concerning the capability and willingness by BC Hydro to constrain Buntzen Tunnel releases. The number of days the Buntzen releases could be curtailed would vary year to year and monitoring the effects of that variation would identify whether constraints could be eliminated or whether they are shown to be beneficial.
- Alf called for another KSRP meeting on September 7 to develop a plan for a September 19 presentation to the FWCP.

<u>Action Item Summary</u>

- LGL
  - LGL to provide a draft summary report of the 2017 study in early September, prior to the September 7 meeting.
  - Provide for coordination between LGL and R2 to pass along preliminary study results as they become available in August prior to the draft report in September.
  - Elmar to provide a reference pertaining to the propensity of a land-locked population of a BC system to express anadromy.
- Metro Vancouver
  - Provide revised text for Section 2.2 of the R2 Phase 1 summary report concerning the water rights associated with the MV's GVWD diversion.
  - Provide information concerning their current plans to increase and/or relocate their water diversions.
- R2
  - Revise the Phase 1 summary report reference to Port Moody in the site description to read Port Coquitlam.
  - Outline a preliminary implementation plan for Sockeye restoration at Coquitlam for presentation at the September 7 KSRP meeting.
- BC Hydro
  - Summarize the issues associated with modifying the Water Use Plan to increase the lower Coquitlam River outflows during the months of April and May, and present the information at the September 7 KSRP meeting.
  - Provide information concerning the ability to regulate higher flows (e.g., 8 cms) with the LLO-1 or LLO-2 gates.
- All
  - Review the elements of the preliminary implementation plan for Sockeye restoration to reach consensus and support of the approach for the September 19 presentation to the FWCP.

APPENDIX C
IMPLEMENTATION PLAN

Kwikwetlem Sockeye Restoration Project- Sockeye Restoration Implementation Plan
Draft Version: September 15, 2017

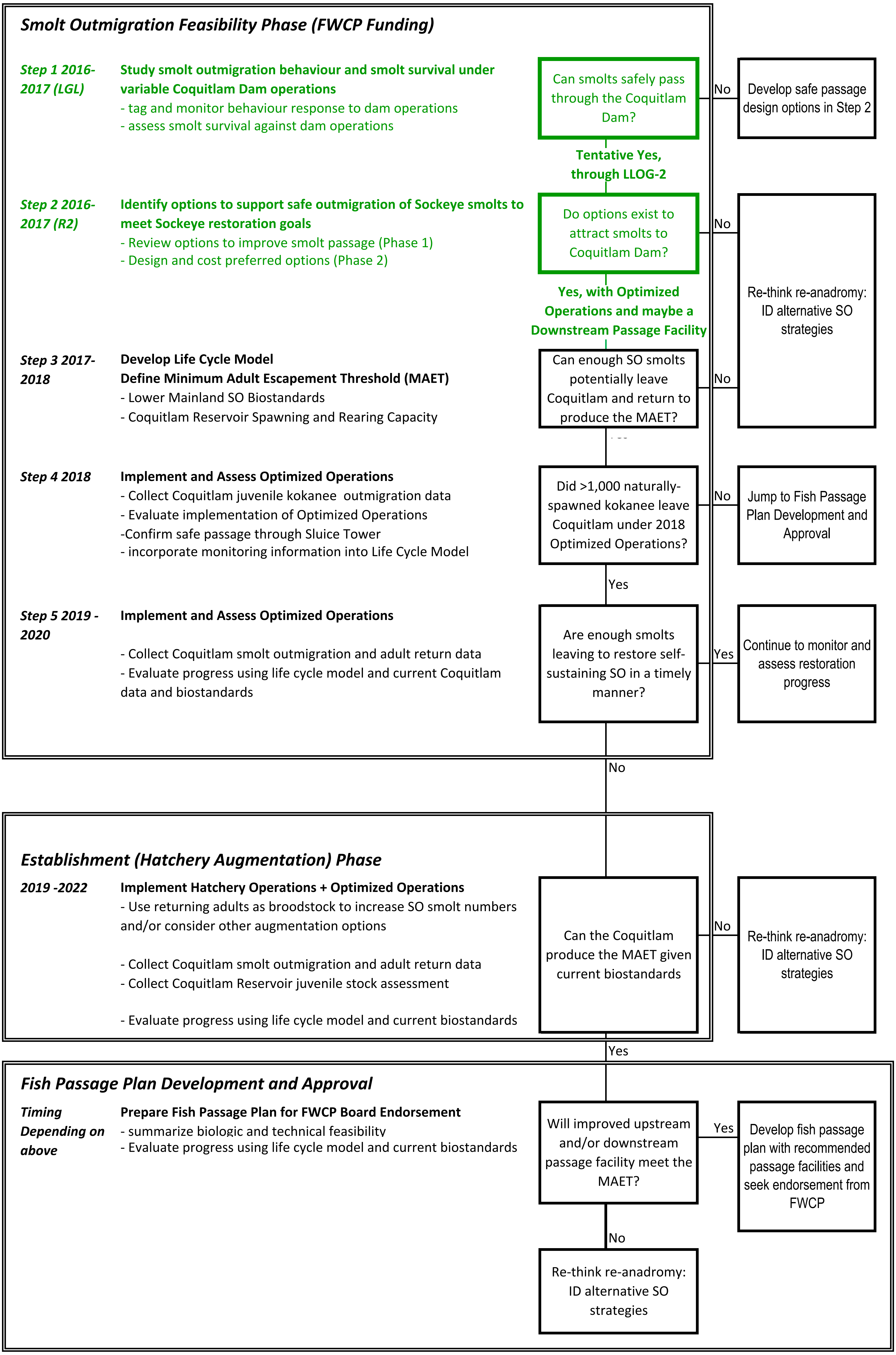
Implementation Plan

1) Based on best available information, develop a life-cycle model for the Coquitlam to calculate Sockeye returns under alternate life stage performance scenarios and identify minimum performance measures required to meet minimum adult escapement thresholds (MAET). Model results will be used to evaluate life stage metrics and whether a self-sustaining, naturally reproducing, anadromous Sockeye population can be restored under realistic life stage production and survival targets. This process will allow the KSRP to build a foundation to guide restoration efforts, and persist with restoration efforts despite annual variations in life stage production and survival. If the potential number of outmigrating Sockeye smolts and returning adults are deemed insufficient to establish a minimum self-sustaining population using reasonably expected biostandards, the KSRP will have to reconsider near-term restoration strategies. BC Hydro will fund the life-cycle analysis and is currently contracting with Dr. Eduardo Martins, UNBC to complete the analysis by June 2018.
2) Evaluate downstream fish passage facilities and develop conceptual designs and cost estimates for a Floating Surface Collector (FSC) with guide nets, and a Sluice Tower Modifications with Overflow Weir.
3) Test the kokanee outmigration response to optimized outmigration operations (*April-May 2017 - 2020)* Recommended annual operational changes, with (a.) being the highest priority.
    a. Release 8 cms through a Sluice Tower Low Level Outlet Gate (LLOG) during the Sockeye smolt outmigration period (April 1-May 30) BCH fish and Aquatic will work with internal departments (GRM and EFS) and the agencies to obtain a Water Licence variance from Comptroller of Water Rights (CWR), until such time that the WUP Order Review can consider the operational changes. LLOG-2 will be used to avoid potential issues with the Knife Gate (LLOG-3) and tunnel outcroppings.
    b. To the extent practicable, Buntzen Tunnel releases will be constrained during the peak of the Sockeye smolt outmigration period (April 1 - May 30). The number of days that releases will be shut-off will vary annually depending on the volume of reservoir inflow and releases through the LLOG and Metro Vancouver Water Intake. BC Hydro's Operations Planning Engineer (OPE) for the Coquitlam system will work with BCH Fish and Aquatics to evaluate reservoir operations and hydrologic forecasts and develop an operations plan to allow Buntzen Tunnel releases to preferable be shut off but if that is not possible due to inflows then constrained as much as possible from April 1 to May, 30 2018 while ensuring that downstream Public Safety requirements and Metro Vancouver water supply needs will be met.
    c. Attempt to hold Coquitlam Reservoir at a lower than normal operating level during Smolt outmigration window (April 1 – May 30) to encourage attraction of smolts to the LLOG. This will coincide with the Buntzen Tunnel outage and may potentially be difficult to accommodate depending on inflows.

    Immediate feedback on the effectiveness of these outmigration operations will be provided by real-time monitoring (e.g., rotary screw trap (RST) installed at or below the Sluice Tower tailrace in Reach 4, Funding request will be submitted to FWCP for 2018). Monitoring the response of naturally-reared kokanee to outmigration operations on a real-time basis, will be used to:
        i. Identify the timing and volume of releases through the Sluice Tower that optimize the rate of outmigration;
        ii. Identify the timing and degree of constraints on the Buntzen Tunnel required to optimize the rate of outmigration;
        iii. Validate the assumption that passage through LLOG-2 does not result in unacceptable injury rates;
        iv. Determine the potential contribution of the Coquitlam kokanee population to the number of outmigrating smolts; and
        v. Quantify the number of outmigrating smolts to determine smolt-to-adult survival associated with outmigrating kokanee.
4) Once the outmigration of naturally-produced, volitionally outmigrating kokanee has been quantified under outmigration operations, options to increase life stage production and survival targets can be implemented as part of an adaptive management plan to meet MAETs. If less than 1,000 naturally-produced juvenile kokanee leave Coquitlam Reservoir in spring 2018 under optimized outmigration operations, the KSRP will consider downstream

fish passage structures as part of its plan for endorsement by the FWCP Coastal Board. If more than 1,000 naturally-produced juvenile kokanee leave Coquitlam Reservoir in 2018, the KSRP will incorporate the Coquitlam data into the life cycle model to determine whether the current program will restore a self sustaining Sockeye population in a timely manner. If not, they may consider options to increase Sockeye smolt numbers including DFO supported hatchery intervention to accelerate a response. Coquitlam River fish that return to Coquitlam Dam as adult Sockeye will be used as broodstock to increase egg-to-juvenile survival, released into the reservoir, or both, based on agreements to accelerate run development.

5) Smolt-to-adult returns vary annually by system, by stock, and by size of outmigrant, and may be a primary influence in the long-term sustainability of a Sockeye population. Sockeye and kokanee differ in their salinity tolerance, seawater readiness, swimming performance, olfactory imprinting, growth, and development. LGL in their 2014 synthesis report noted that offspring from anadromous Sockeye may have a higher propensity for an anadromous life cycle than offspring from stationary kokanee. The ability to adopt an anadromous life cycle will contribute to variations in smolt-to-adult returns. The potential source of future Sockeye smolts in approximate order of expected smolt-to-adult returns (1 being highest) include:
    1) Naturally-reared Sockeye smolts that volitionally exit Coquitlam Reservoir
    2) Hatchery Sockeye juveniles released into Coquitlam Reservoir to rear and volitionally exit
    3) Naturally-reared, smolt-sized kokanee that volitionally exit Coquitlam Reservoir
    4) Hatchery smolt-sized kokanee held in Coquitlam Reservoir before release into forebay
    5) Hatchery smolt-sized kokanee released into Coquitlam River
6) If careful evaluation of a Sockeye life-cycle model and monitoring of smolt outmigration does not result in adequate smolts leaving the system BUT there is technology to support the level of outmigration success to restore a naturally-reproducing, self-sustaining anadromous Sockeye population, then the KSRP will consider downstream fish passage structures as part of its plan for endorsement by the FWCP Coastal Board. Options to increase the number of outmigrating smolts by improving fish collection efficiency through improvements in the downstream fish passage structure will include:
    a) Install a baffle at the sluice tower to increase surface-oriented attraction flows (supported by mark and recapture or biotelemetry studies of Sockeye smolts)
    b) Install a floating surface collector (FSC) with guide nets if passage efficiency is thought to be limiting efforts to meet minimum adult escapement goals
7) If improved fish passage facilities and short-term hatchery intervention will not meet the MAET within a reasonable time frame, the KSRP may have to reconsider Sockeye restoration strategies. A potential schedule of implementation actions and analyses is provided in the following flowchart.


Smolt Outmigration Feasibility Phase (FWCP Funding)
Step 1 2016-2017 (LGL)
Study smolt outmigration behaviour and smolt survival under variable Coquitlam Dam operations
- tag and monitor behaviour response to dam operations
- assess smolt survival against dam operations
Can smolts safely pass through the Coquitlam Dam?
No
Develop safe passage design options in Step 2
Tentative Yes, through LLOG-2
Step 2 2016-2017 (R2)
Identify options to support safe outmigration of Sockeye smolts to meet Sockeye restoration goals
- Review options to improve smolt passage (Phase 1)
- Design and cost preferred options (Phase 2)
Do options exist to attract smolts to Coquitlam Dam?
No
Re-think re-anadromy: ID alternative SO strategies
Yes, with Optimized Operations and maybe a Downstream Passage Facility
Step 3 2017-2018
Develop Life Cycle Model
Define Minimum Adult Escapement Threshold (MAET)
- Lower Mainland SO Biostandards
- Coquitlam Reservoir Spawning and Rearing Capacity
Can enough SO smolts potentially leave Coquitlam and return to produce the MAET?
No
Step 4 2018
Implement and Assess Optimized Operations
- Collect Coquitlam juvenile kokanee outmigration data
- Evaluate implementation of Optimized Operations
-Confirm safe passage through Sluice Tower
- incorporate monitoring information into Life Cycle Model
Did >1,000 naturally-spawned kokanee leave Coquitlam under 2018 Optimized Operations?
No
Jump to Fish Passage Plan Development and Approval
Yes
Step 5 2019 - 2020
Implement and Assess Optimized Operations
- Collect Coquitlam smolt outmigration and adult return data
- Evaluate progress using life cycle model and current Coquitlam data and biostandards
Are enough smolts leaving to restore self-sustaining SO in a timely manner?
Yes
Continue to monitor and assess restoration progress
No
Establishment (Hatchery Augmentation) Phase
2019 -2022
Implement Hatchery Operations + Optimized Operations
- Use returning adults as broodstock to increase SO smolt numbers and/or consider other augmentation options
- Collect Coquitlam smolt outmigration and adult return data
- Collect Coquitlam Reservoir juvenile stock assessment
- Evaluate progress using life cycle model and current biostandards
Can the Coquitlam produce the MAET given current biostandards
No
Re-think re-anadromy: ID alternative SO strategies
Yes
Fish Passage Plan Development and Approval
Timing Depending on above
Prepare Fish Passage Plan for FWCP Board Endorsement
- summarize biologic and technical feasibility
- Evaluate progress using life cycle model and current biostandards
Will improved upstream and/or downstream passage facility meet the MAET?
Yes
Develop fish passage plan with recommended passage facilities and seek endorsement from FWCP
No
Re-think re-anadromy: ID alternative SO strategies

APPENDIX D
DESIGN CRITERIA TECHNICAL MEMO

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Technical Memorandum

Date: March 8, 2018 Project Number: 2168.01/TM-001

To: Alf Leake and Alexis Hall (BC Hydro)

From: Peter Christensen (R2)

Project: Coquitlam Sockeye Downstream Passage Alternatives

Subject: Conceptual Design Criteria

cc: Phil Hilgert

Background

This memorandum provides the design criteria used to develop the two alternative design concepts provided in the Coquitlam Smolt Outmigration Phase 2 Concept Development Report. This document is not intended to describe the fish passage alternatives themselves, or the background and decisions that led to the choice of the alternatives; rather, it is only to provide the design criteria used in the development of the alternatives. Descriptions of the alternatives, and the restoration plans and goals that led to the choice of those alternatives are provided in the Phase 2 summary report. The sections below provide the specific criteria, and the source of the criteria and/or the particular data that was used to develop the criteria. This memorandum will be included as an attachment to the Phase 2 summary report.

Migration Season

Based on the outmigration season for Sockeye smolts in other regional watersheds in the U.S. northwest and southern British Columbia it is assumed that the Sockeye smolt outmigration season at the Coquitlam Reservoir would be during the months of ***April and May***. Although there may be early migrants in late March, and that there was some indication during the 2017 monitoring of traps downstream that outmigration of resident kokanee smolts out of the Coquitlam Reservoir appears to extend into early June, any future decision to expand the timeframe of operations associated with the downstream Sockeye passage program would not impact the design features of the collection and passage alternatives.

Flow Rate

During the 2017 biological field study performed at the Coquitlam Reservoir by LGL Limited, acoustic tagged Sockeye/kokanee smolt were released upstream of the reservoir outlet sluice tower during the months of April and May, and monitored for movement and passage through the sluice tower to the lower Coquitlam River downstream. In addition, traps were monitored in the lower river downstream of the outlet to identify the magnitude and timing of the outmigration of resident kokanee smolts from the reservoir. During the study, two flow rates were passed through the outlet sluice tower on an alternating basis with each flow rate being maintained for approximately one week. The low flow rate of 3 cubic metres per second (cms) approximates the typical historic outlet flows through the sluice tower during the months of April and May. The high flow rate of 8 cms was chosen to investigate the impact on outmigration of a significant increase in the flow rate, while staying within the safe operating conditions of the downstream fish traps.

Results of the LGL study, and the downstream fish trapping, revealed a significant increase in the rate of outmigration during the periods of operation at 8 cms. As a result, BC Hydro and the Kwikwetlem Salmon Restoration Program (KSRP) agreed to increase the reservoir outflow rate through the sluice tower to 8 cms continuously during the Sockeye smolt outmigration season. Therefore, the concept alternatives are developed to accommodate a flow rate of ***8.0 cms***.

Reservoir Elevation

BC Hydro provided daily operations data for the Coquitlam Reservoir from February 2, 2003 through August 15, 2017. This data included daily reservoir water surface elevations. An analysis of this data for the months of April and May revealed a significant shift in operations starting in 2009. This coincides with the completion of the seismic upgrades to the dam and the installation of the knife gate in LLO-3 in the sluice tower, which were both completed in late 2008. For the 61-day period (April/May) during the years of 2003 to 2008 the minimum reservoir elevation was 143.0 (May 12, 2004) and the maximum was 147.8 (April 15, 2008). After the seismic upgrades, the April/May reservoir level rose significantly, with a minimum elevation of 144.5 (April 9, 2012) and a maximum elevation of 152.1 (May 31, 2016).

Based on the analysis of the data provided by BC Hydro, the more recent post seismic upgrade operations were considered, and an 8-metre range of operating reservoir elevations from ***144.5 to 152.5*** were used as the design range for the design of the passage alternatives.

Capture Velocity

The concept alternatives will be designed to include a capture location where the velocity is high enough that once a Sockeye Smolt passes through the capture location it will no longer be able to swim back upstream and leave the facility. Based on R2 experience with similar facilities in operation in the Northwest U.S., the design minimum velocity for capture is **2.1 m/s** (7.0 ft/s)

Fish Screens

The most comprehensive list of juvenile fish screen design criteria is the document "Anadromous Salmonid Passage Facility Design", published by the U.S. National Marine Fisheries Service (NMFS 2011). Table 1 provides a list of the fish screen design criteria used in the development of the concept alternatives, taken from NMFS 2011.

Table 1 – Salmonid Fish Screen Design Criteria (NMFS 2011)

Criteria	Design Value	Paragraph	Notes
Maximum Screen Approach Velocity	0.4 fps (0.12 m/s)	11.6.1.1	Average velocity perpendicular to screen
Uniformity of Approach Velocity	Peak point velocity <110% max. design average	11.6.1.4 & 15.2	Use baffles to ensure even flow distribution on screen
Minimum Sweeping Velocity	Greater than approach velocity	11.6.1.5	Velocity of flow parallel to the screen face
Maximum Rate of Velocity Increase	0.2 fps/ft (0.02 m/s/m)	11.9.1.8	Also, do not decelerate upstream of capture
Maximum Screen Exposure Time	60 seconds	11.9.1.2	Assume fish moving at the velocity of sweeping flow
Maximum Slotted Screen Opening Size	1.75 mm	11.7.1.2 & 11.1.7.1	3/32 inches (2.4 mm) holes for perforated plate
Screen Material	Corrosion Resistant	11.7.1.4	Sufficiently durable to maintain smooth surface
Minimum Open Area	27%	11.7.1.6	
Screen Cleaning	Automatic Screen Cleaning	11.10.1.2	Required for Active Screen Design Criteria
Trashrack Bar Spacing	8 inches clear (0.203 m)	4.8.2.5	Fish ladder exit rack for adult fish salmonids

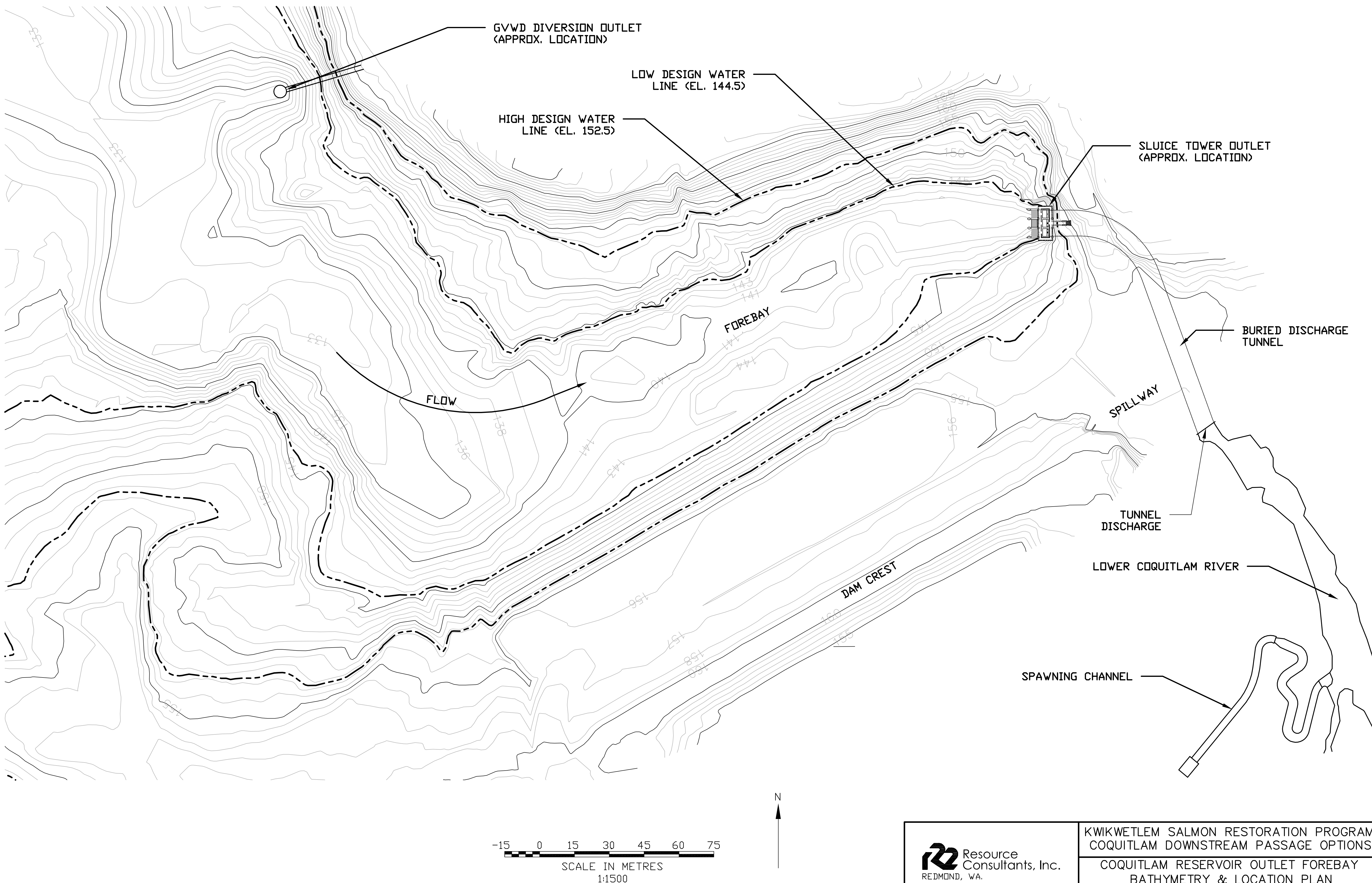
Bypass Pipe

If fish are to be bypassed around the sluice tower to a discharge location in the lower Coquitlam River, the bypass conduit will be designed to meet the bypass pipe design criteria cited in NMFS 2011, as provided in Table 2 below.

Table 2 – Salmonid Bypass Pipeline and Outfall Design Criteria (NMFS 2011)

Criteria	Design Value	Paragraph	Notes
Flow Velocity	6 to 12 fps (1.83 to 3.66 m/s)	11.9.3.8	For given flow and pipe size velocity controlled by slope
Minimum Pipe Diameter	15 inches (0.38 m)	6.4.1.4	Uses fish distribution flume criterion
Minimum Bend Radius	5 times pipe diameter	11.9.3.4	Install facilities to minimize debris if bends are present
Minimum Depth of Flow	40% of Pipe Diameter	11.9.3.9	
Hydraulic Jumps	Avoid hydraulic jumps	11.9.3.12	There shall be no hydraulic jumps in the bypass pipe
Internal Conditions	Smooth conditions throughout pipe	11.9.3.1	Minimize turbulence, risk of catching debris, and potential for fish injury.
River Velocity at Outfall Location	Greater than 4 fps (1.2 m/s)	11.9.4.1	If not practical choose location with goal of minimizing predation
River Depth at Outfall Location	Adequate to ensure no bottom impact	11.9.4.1	
Maximum Outfall Impact Velocity	25 fps (7.6 m/s)	11.9.4.2	

APPENDIX E
CONCEPT DRAWINGS



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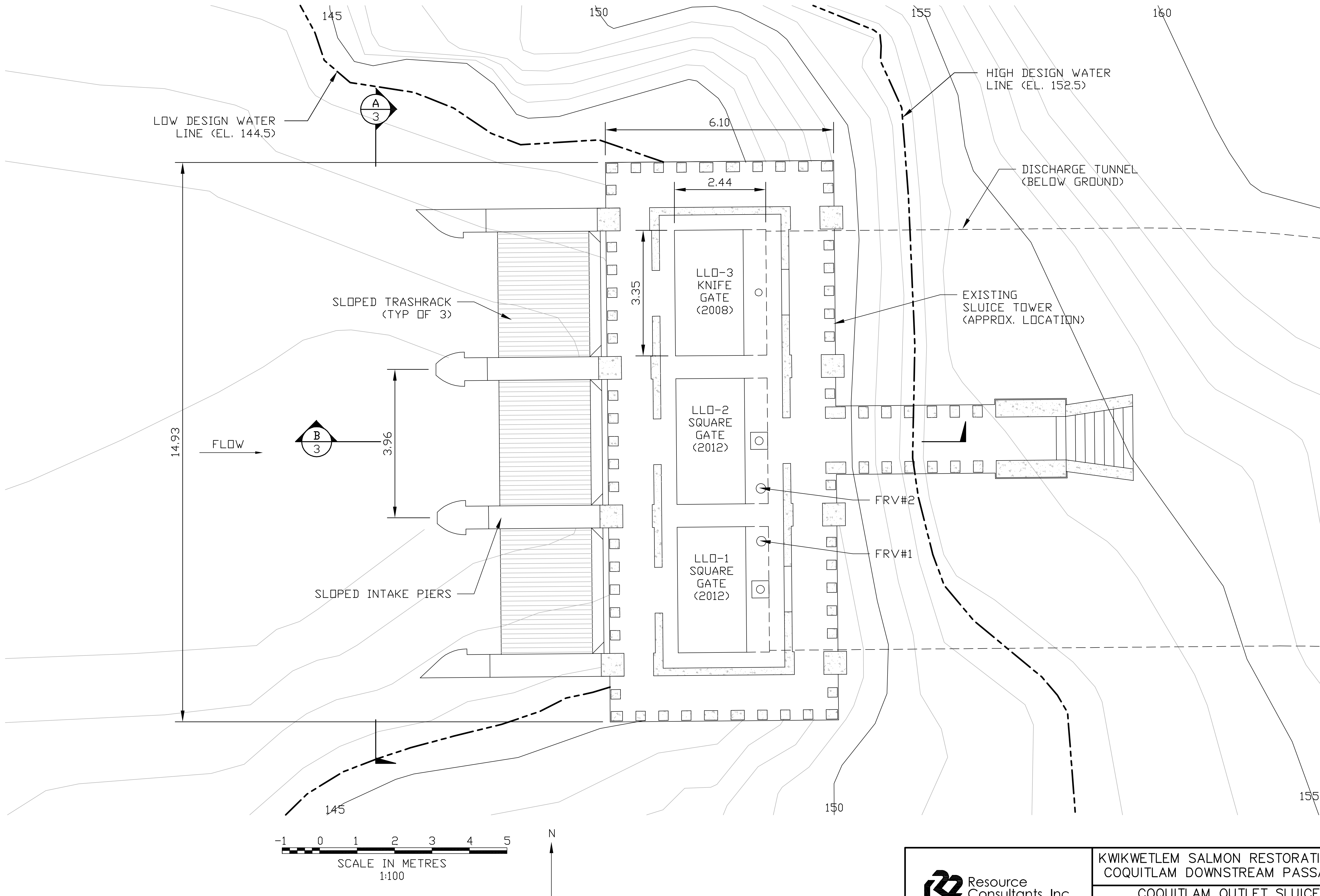
KWIKWETLEM SALMON RESTORATION PROGRAM
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

COQUITLAM RESERVOIR OUTLET FOREBAY
BATHYMETRY & LOCATION PLAN
DRAWING 1



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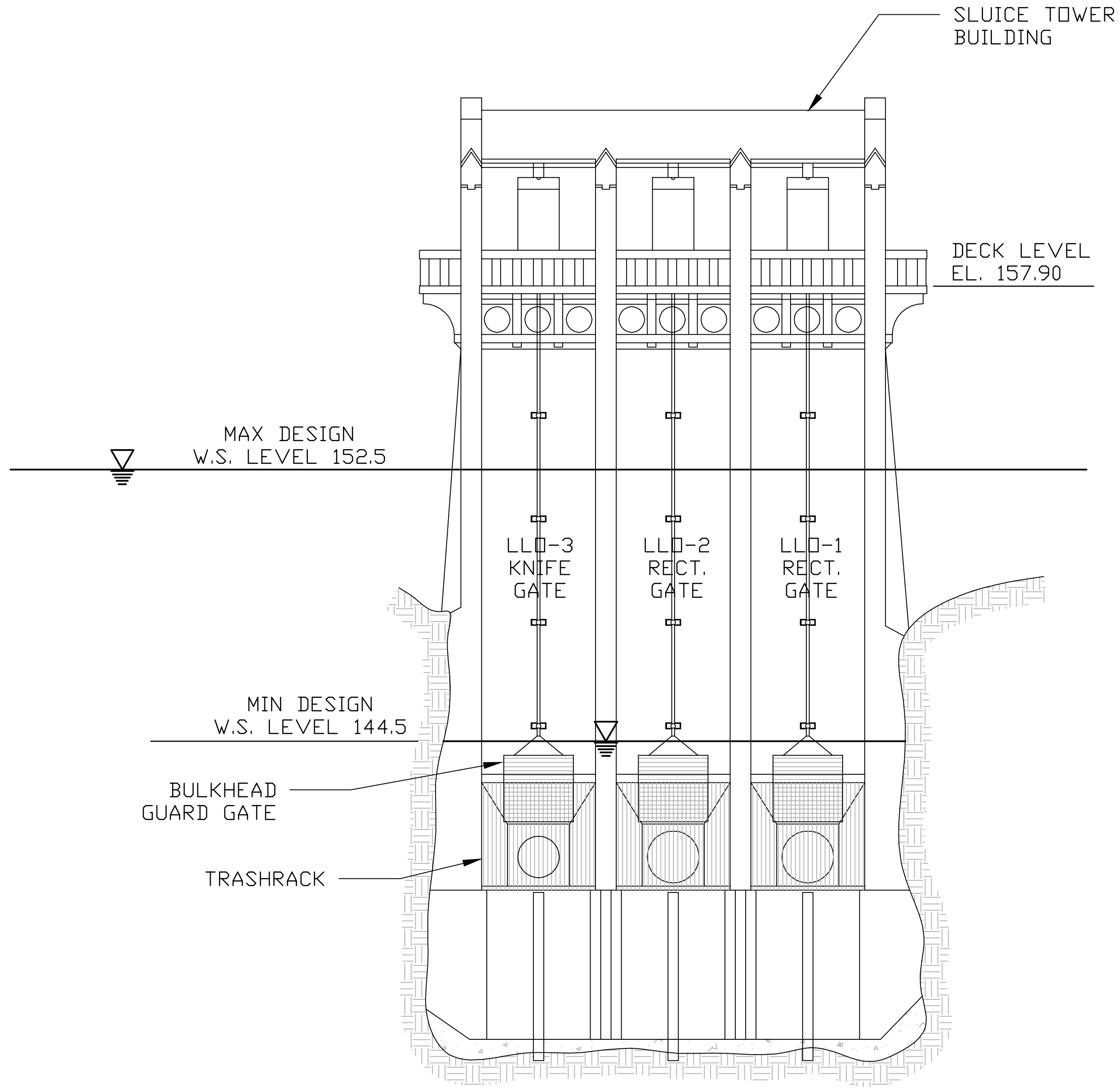
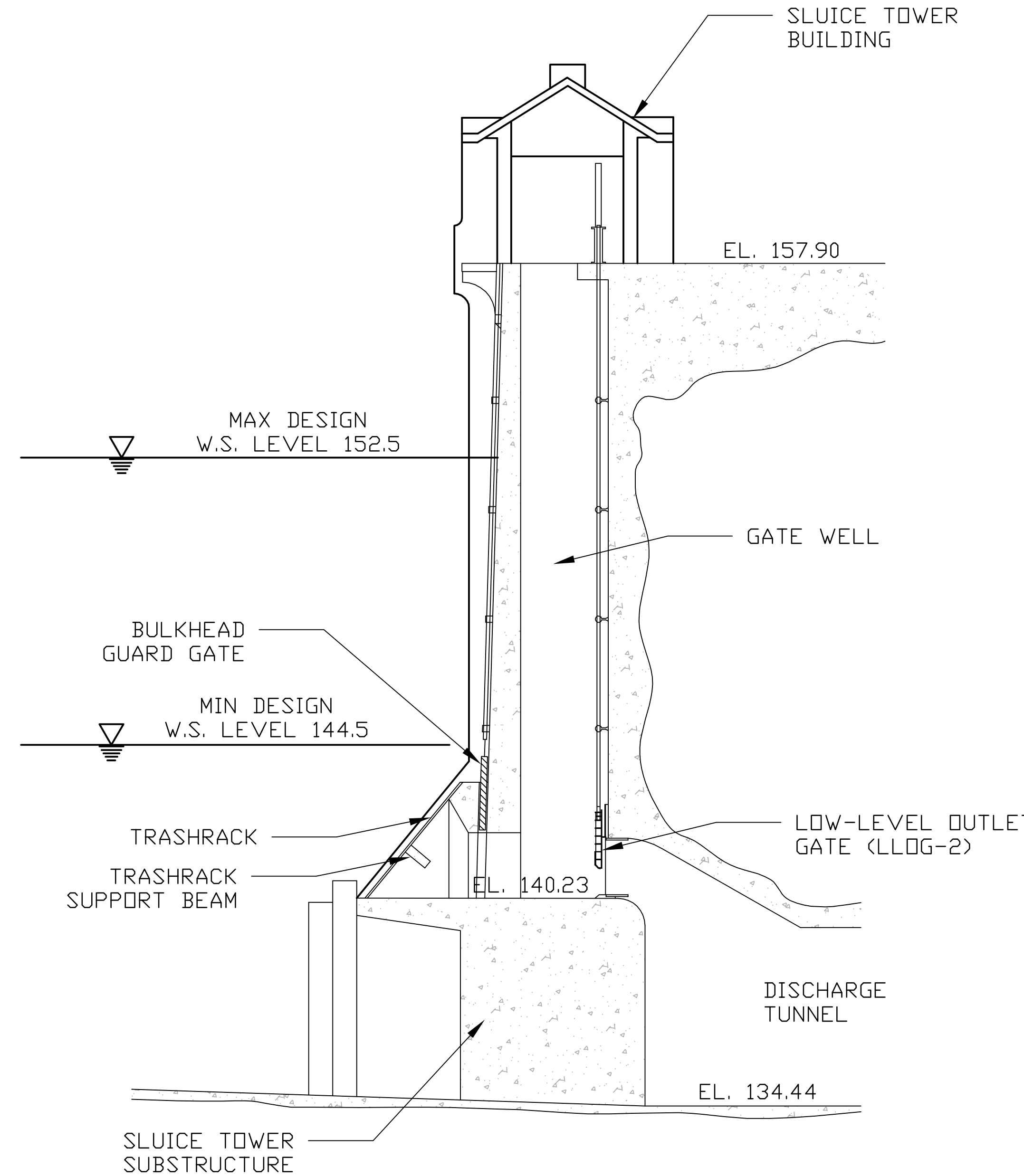
KWIKWETLEM SALMON RESTORATION PROGRAM
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

COQUITLAM OUTLET SLUICE TOWER
EXISTING CONDITIONS – PLAN VIEW
DRAWING 2



ELEVATION VIEW (A/2)
(FROM FOREBAY)



SECTION VIEW (B/2)
(THROUGH LLO-2)

-2 0 2 4 6 8 10
SCALE IN METRES
1:200

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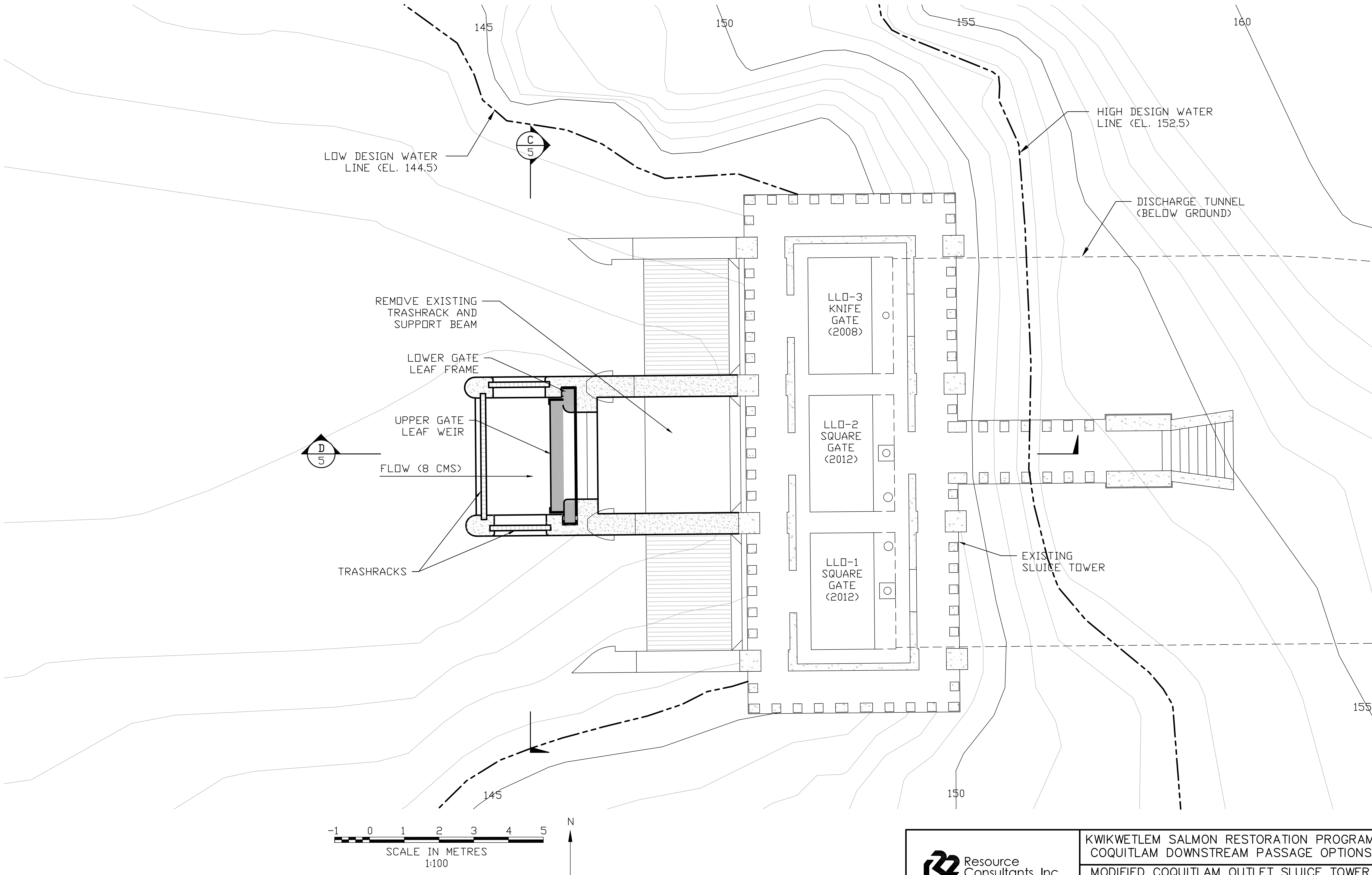
KWIKWETLEM SALMON RESTORATION PROGRAM
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

COQUITLAM OUTLET SLUICE TOWER
EXISTING CONDITIONS–ELEVATION & SECTION
DRAWING 3



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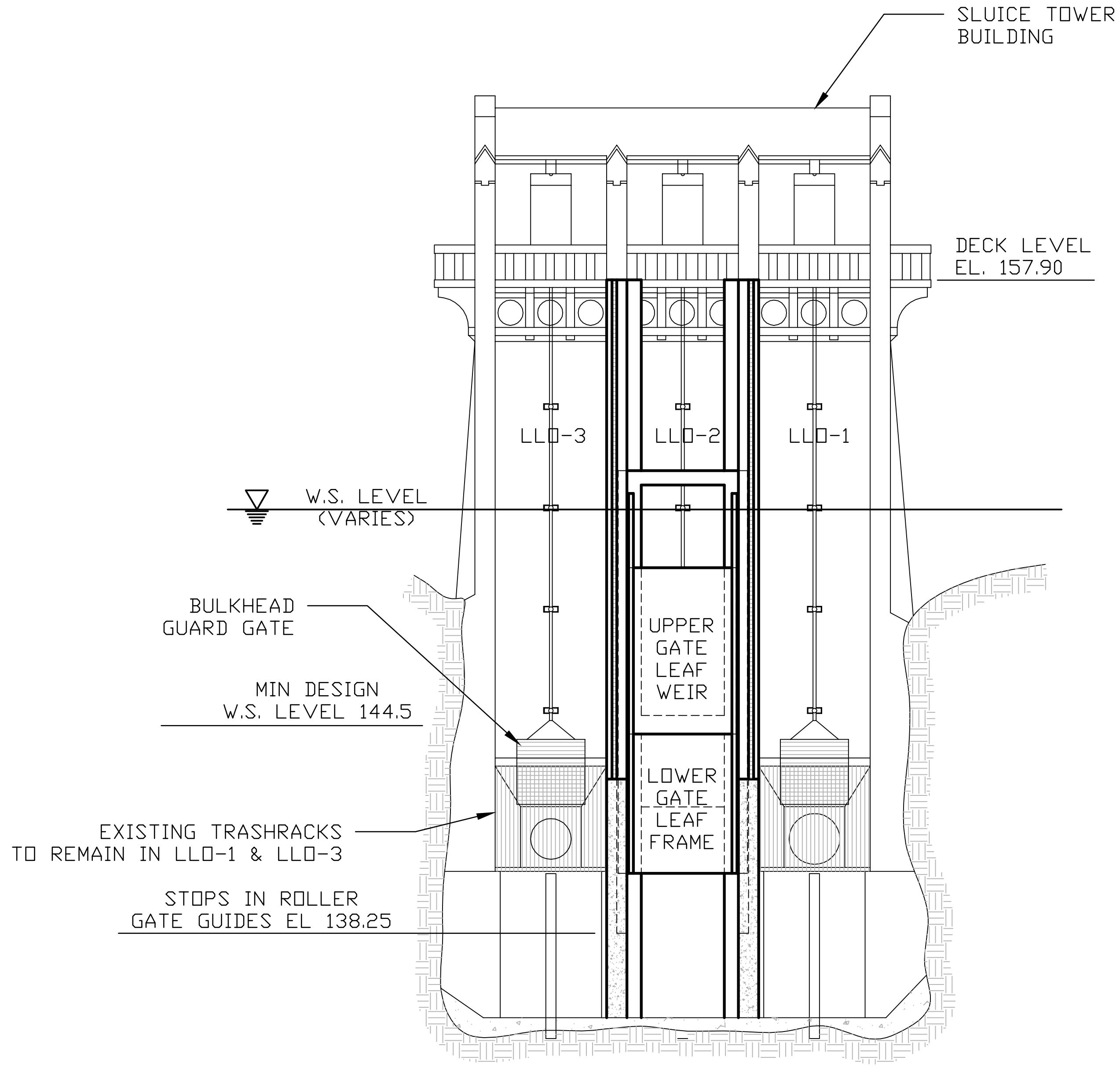
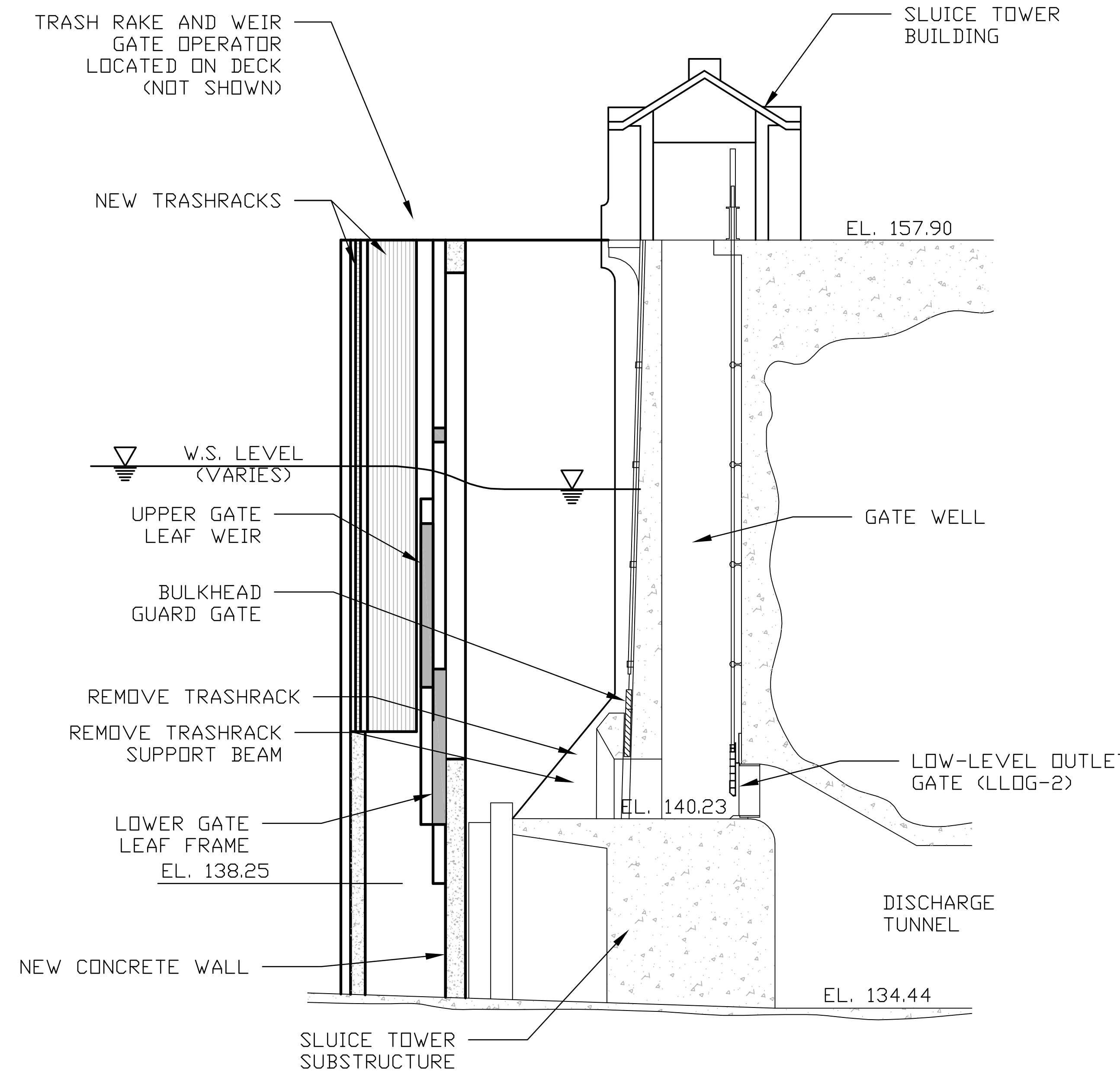
KWIKWETLEM SALMON RESTORATION PROGRAM
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

MODIFIED COQUITLAM OUTLET SLUICE TOWER
ALTERNATIVE 1 – PLAN VIEW
DRAWING 4



ELEVATION VIEW (FROM FOREBAY) C/4



SECTION VIEW (THROUGH LLO-2) D/4

-2 0 2 4 6 8 10

SCALE IN METRES
1:200

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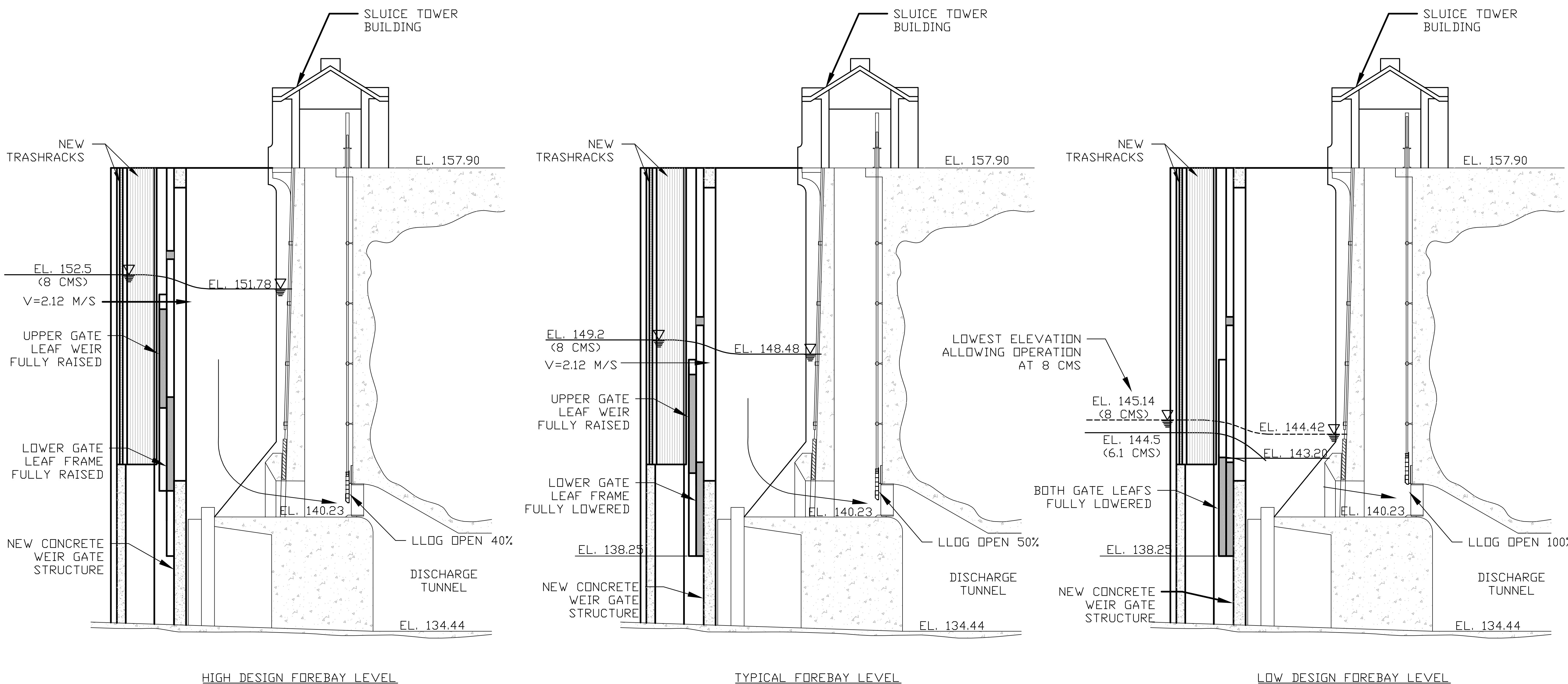
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

MODIFIED COQUITLAM OUTLET SLUICE TOWER
ALTERNATIVE 1—ELEVATION & SECTION
DRAWING 5

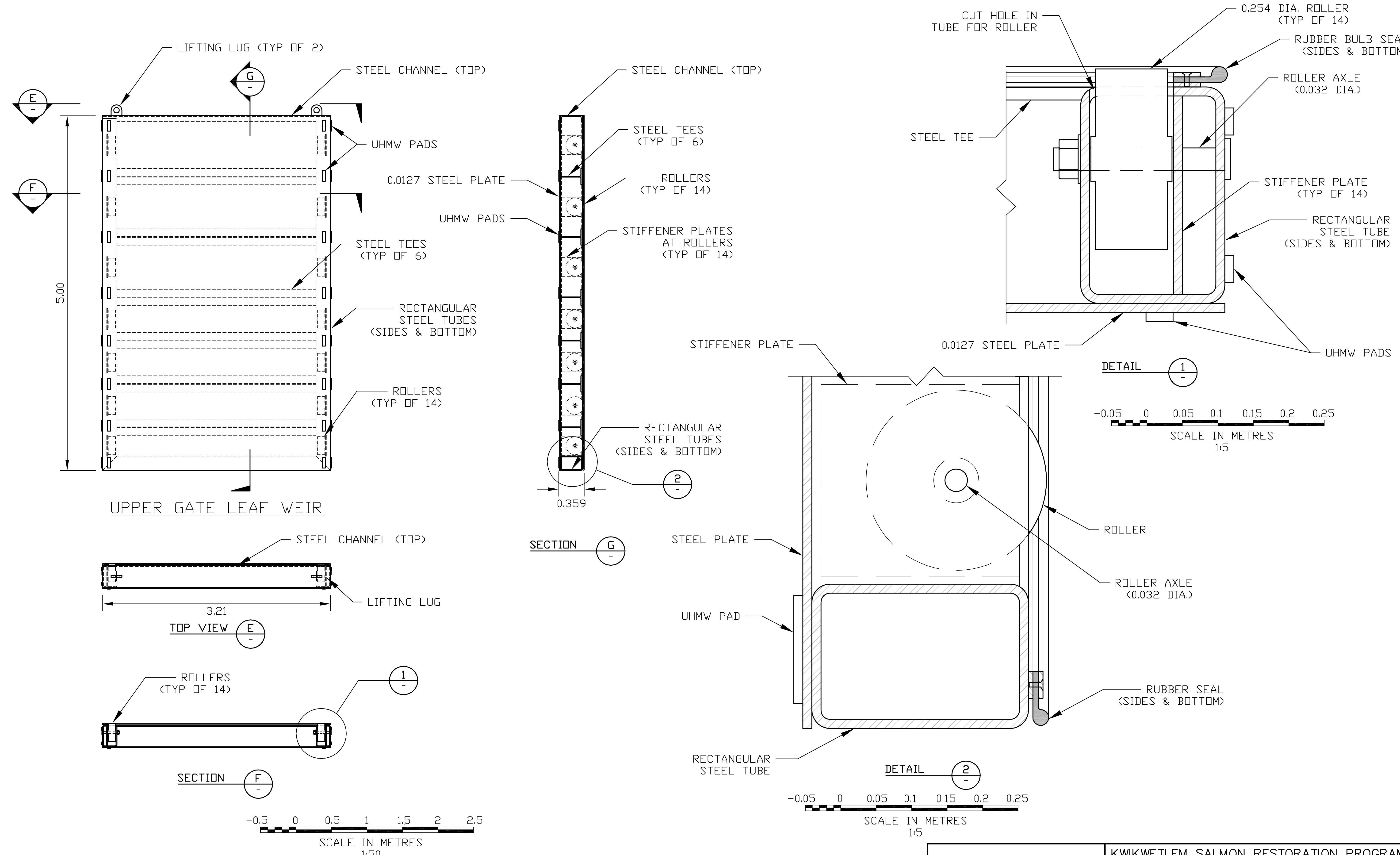


OPERATION OF WEIR GATE AND LLOG AT VARIOUS FOREBAY LEVELS

-2 0 2 4 6 8 10

SCALE IN METRES
1:200

Resource Consultants, Inc. REDMOND, WA.	KWIKWETLEM SALMON RESTORATION PROGRAM COQUITLAM DOWNSTREAM PASSAGE OPTIONS
	MODIFIED COQUITLAM OUTLET SLUICE TOWER ALTERNATIVE 1 – OPERATIONAL ELEVATIONS DRAWING 6



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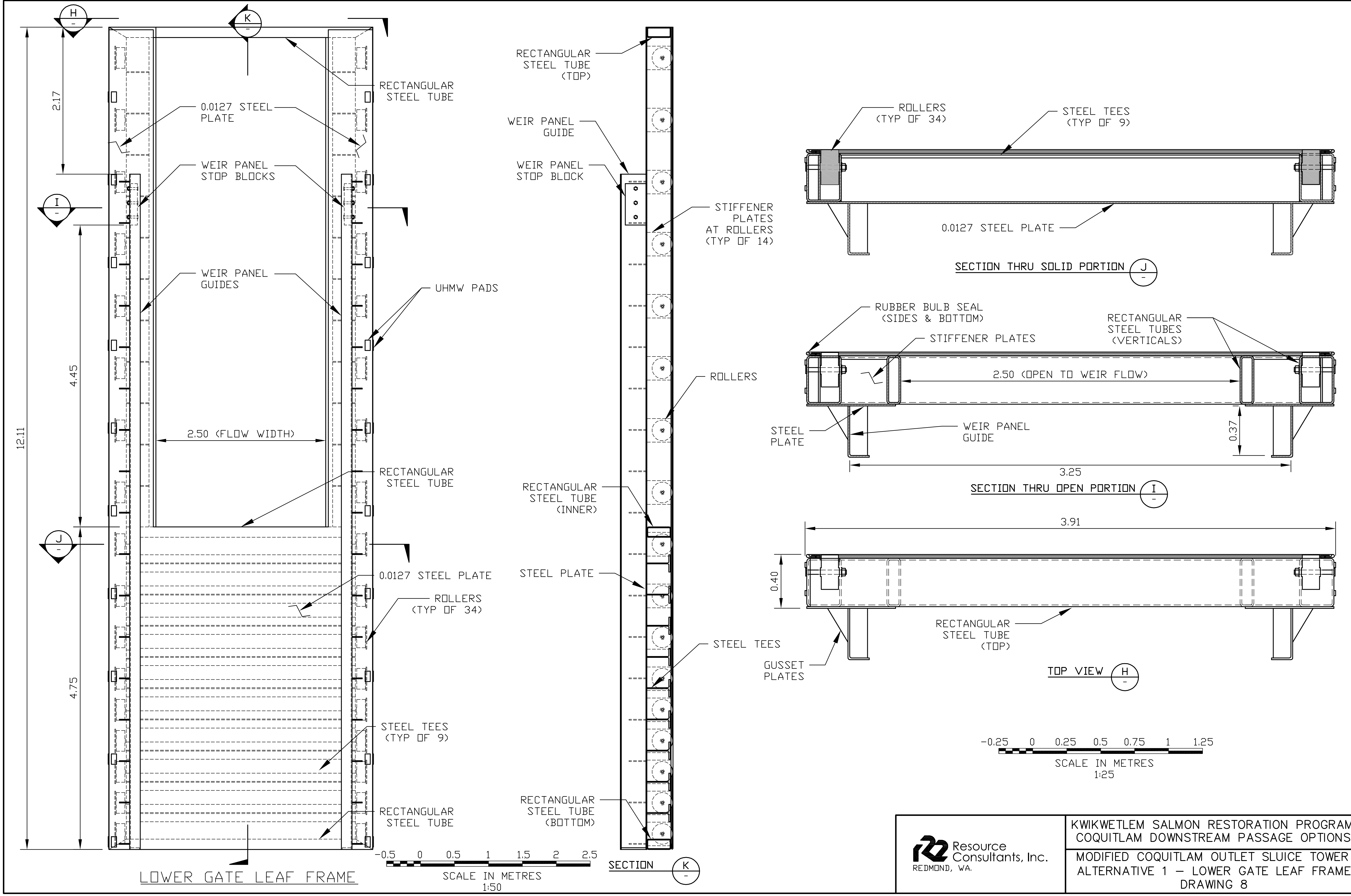
KWIKWETLEM SALMON RESTORATION PROGRAM
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

MODIFIED COQUITLAM OUTLET SLUICE TOWER
ALTERNATIVE 1 – UPPER GATE LEAF WEIR
DRAWING 7



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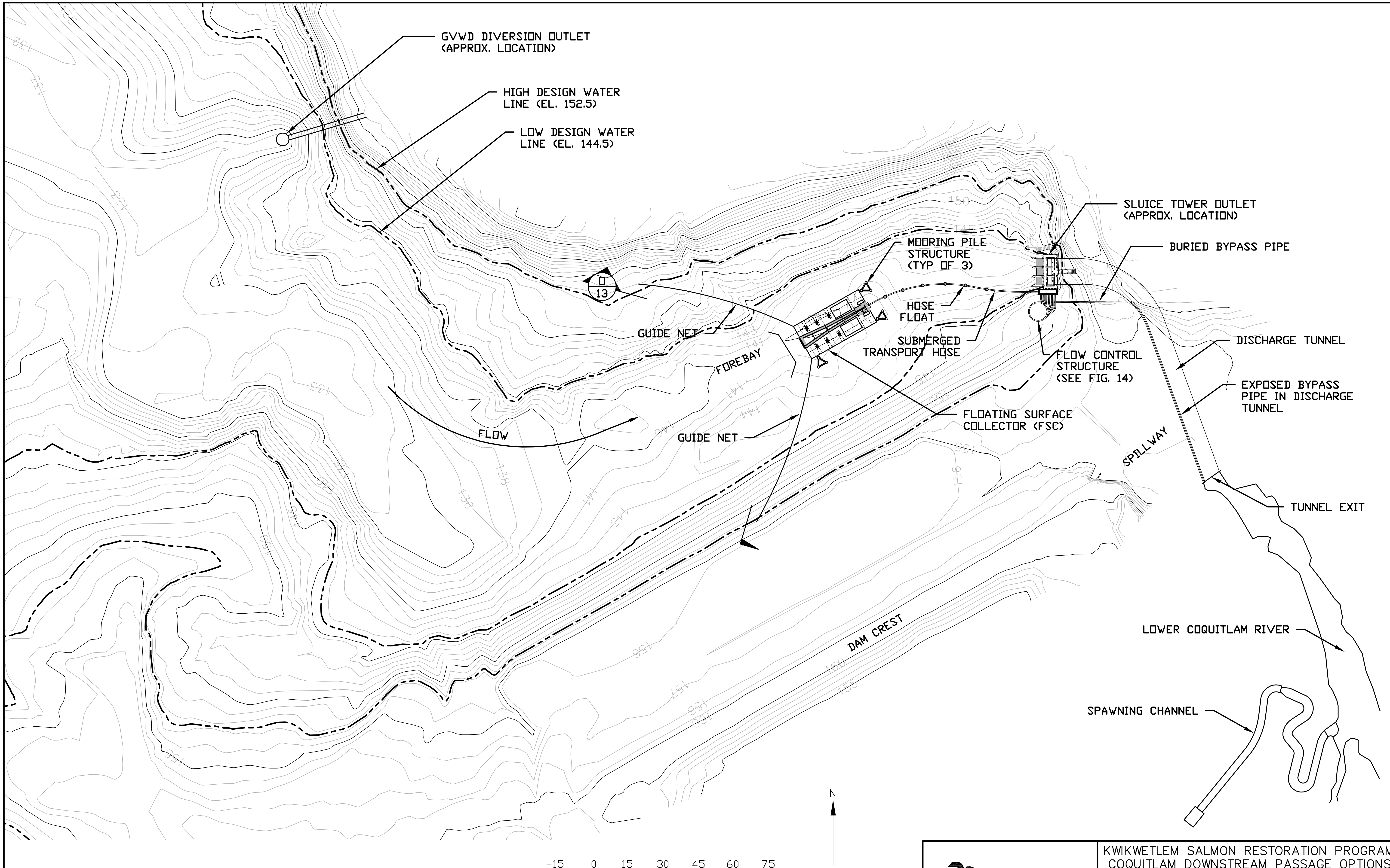
KWIKWETLEM SALMON RESTORATION PROGRAM
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

MODIFIED COQUITLAM OUTLET SLUICE TOWER
ALTERNATIVE 1 – LOWER GATE LEAF FRAME
DRAWING 8



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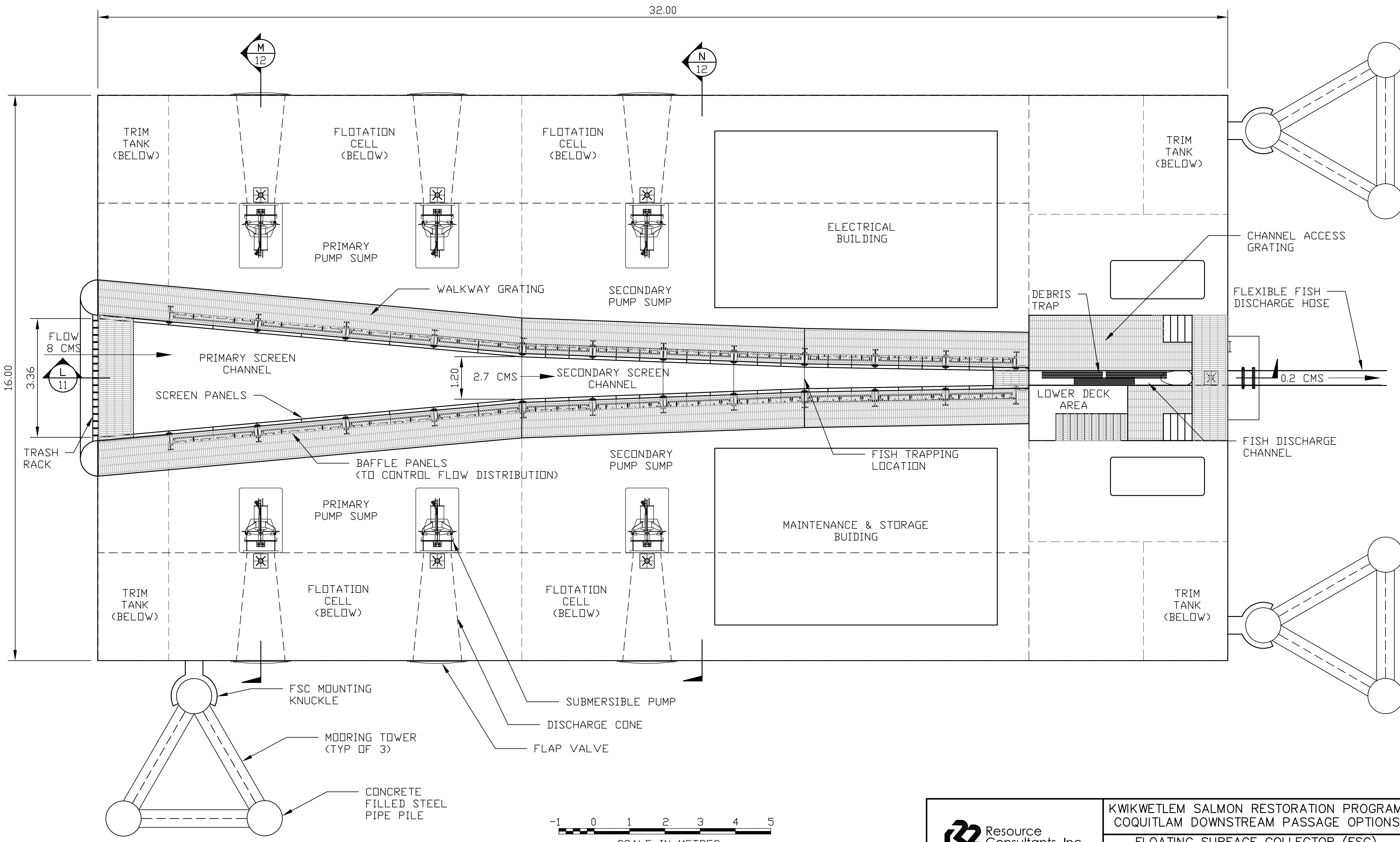
KWIKWETLEM SALMON RESTORATION PROGRAM
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

FLOATING SURFACE COLLECTOR (FSC)
ALTERNATIVE 2 – OVERALL FOREBAY PLAN
DRAWING 9



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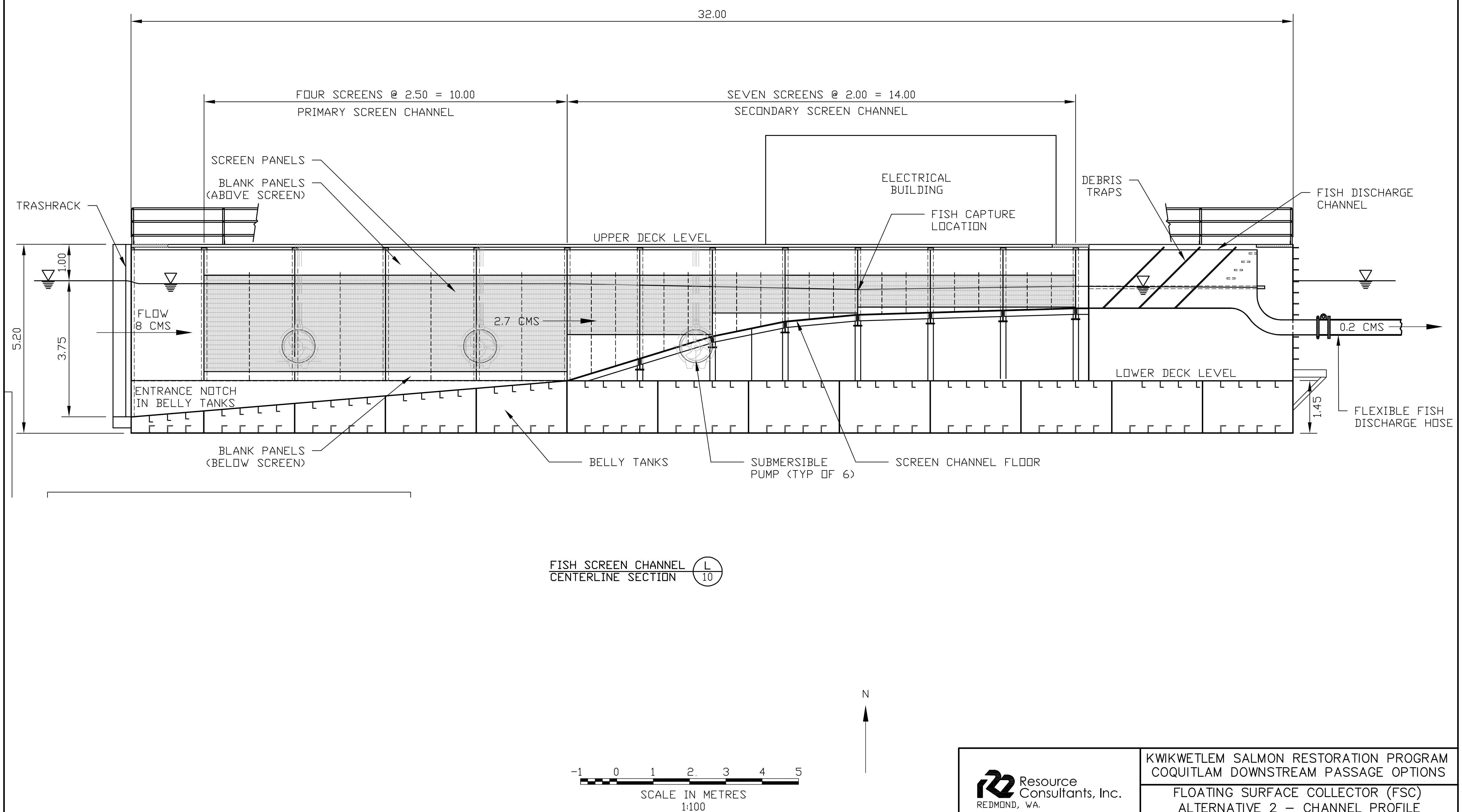
KWIKWETLEM SALMON RESTORATION PROGRAM
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

FLOATING SURFACE COLLECTOR (FSC)
ALTERNATIVE 2 – UPPER DECK PLAN VIEW
DRAWING 10



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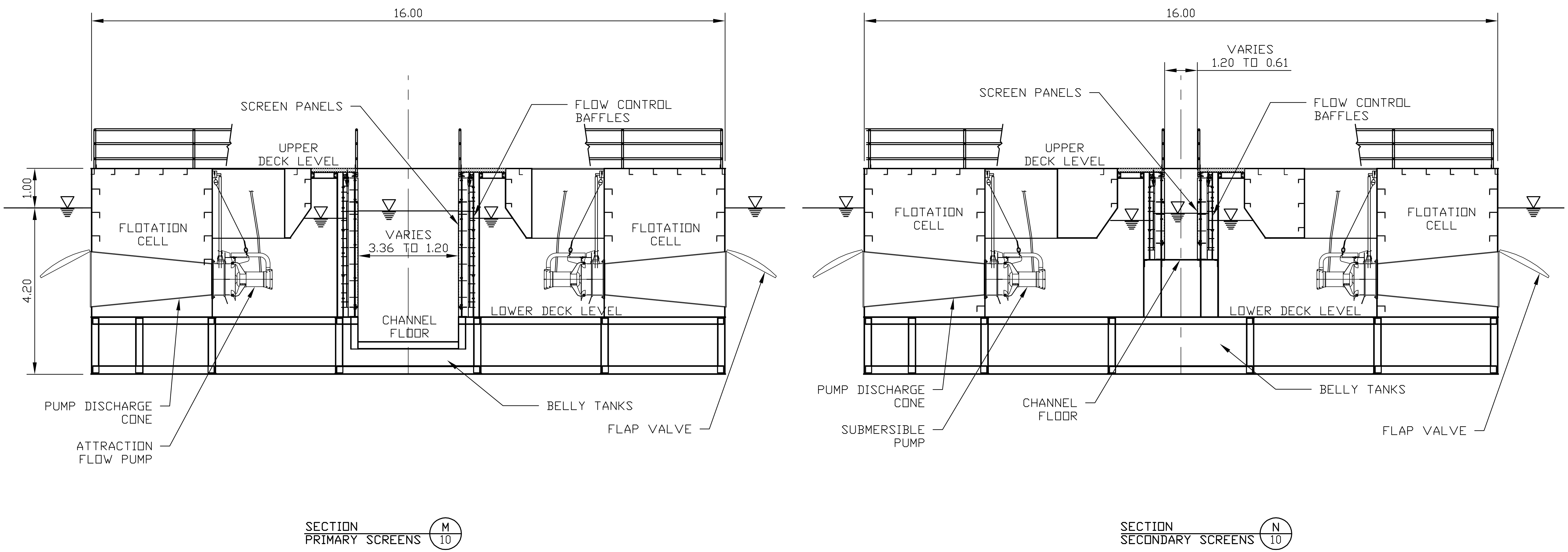
KWIKWETLEM SALMON RESTORATION PROGRAM
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

FLOATING SURFACE COLLECTOR (FSC)
ALTERNATIVE 2 – CHANNEL PROFILE
DRAWING 11



-1 0 1 2 3 4 5

SCALE IN METRES 1:100

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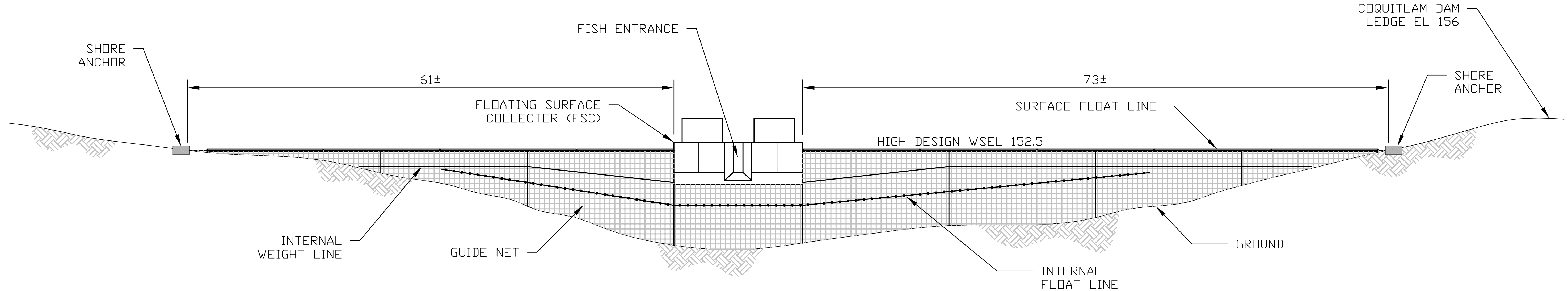
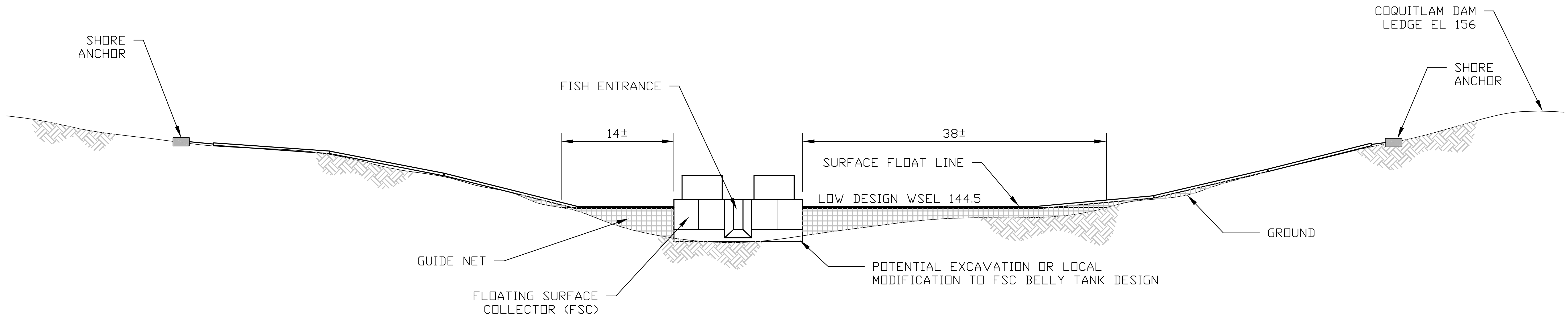
KWIKWETLEM SALMON RESTORATION PROGRAM
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

FLOATING SURFACE COLLECTOR (FSC)
ALTERNATIVE 2 – CHANNEL SECTIONS
DRAWING 12



GUIDE NET ELEVATION
AT HIGH DESIGN WSEL 152.5 (D/9)



GUIDE NET ELEVATION
AT LOW DESIGN WSEL 144.5 (D/9)

-5 0 5 10 15 20 25
SCALE IN METRES
1:500

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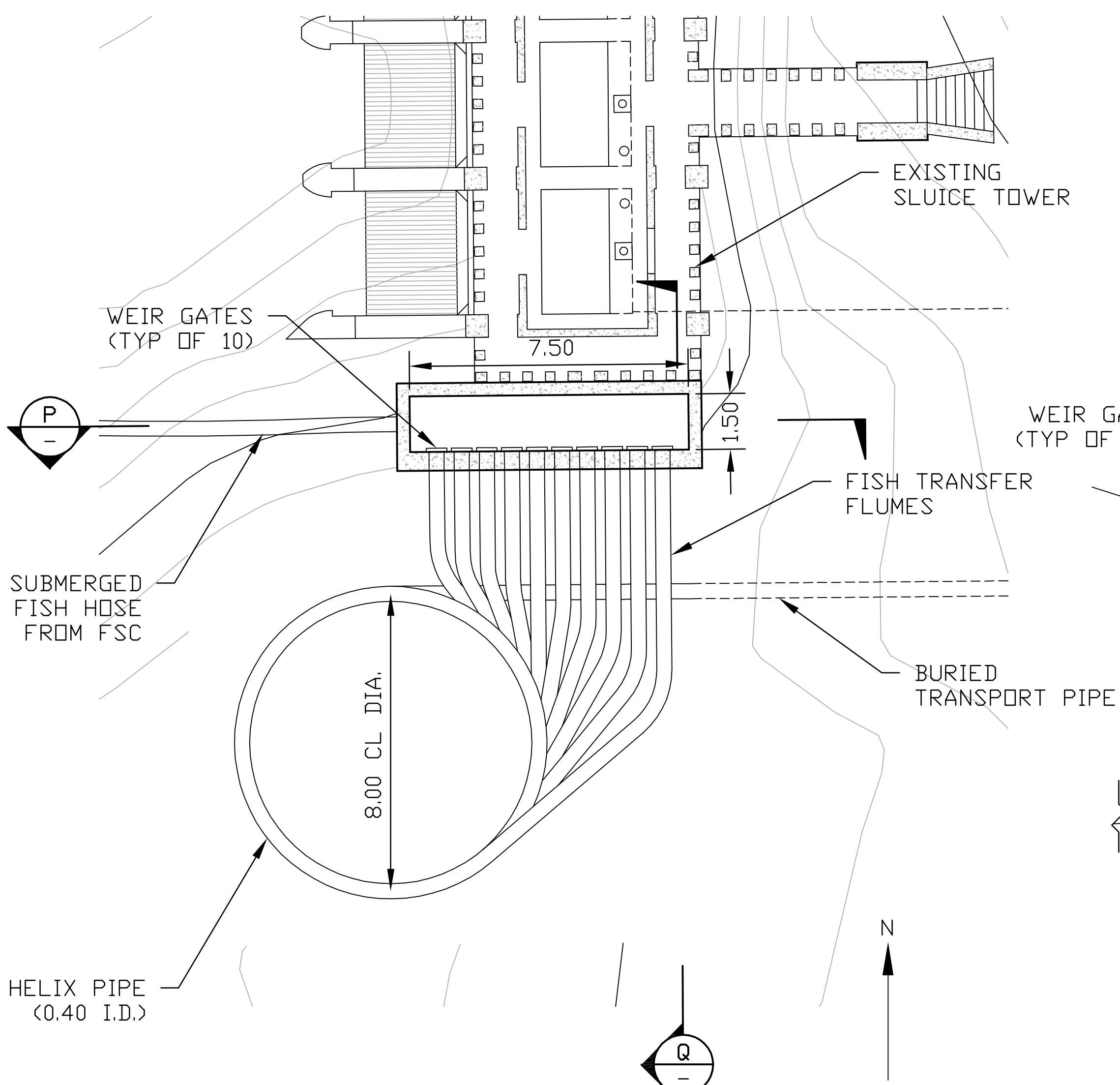
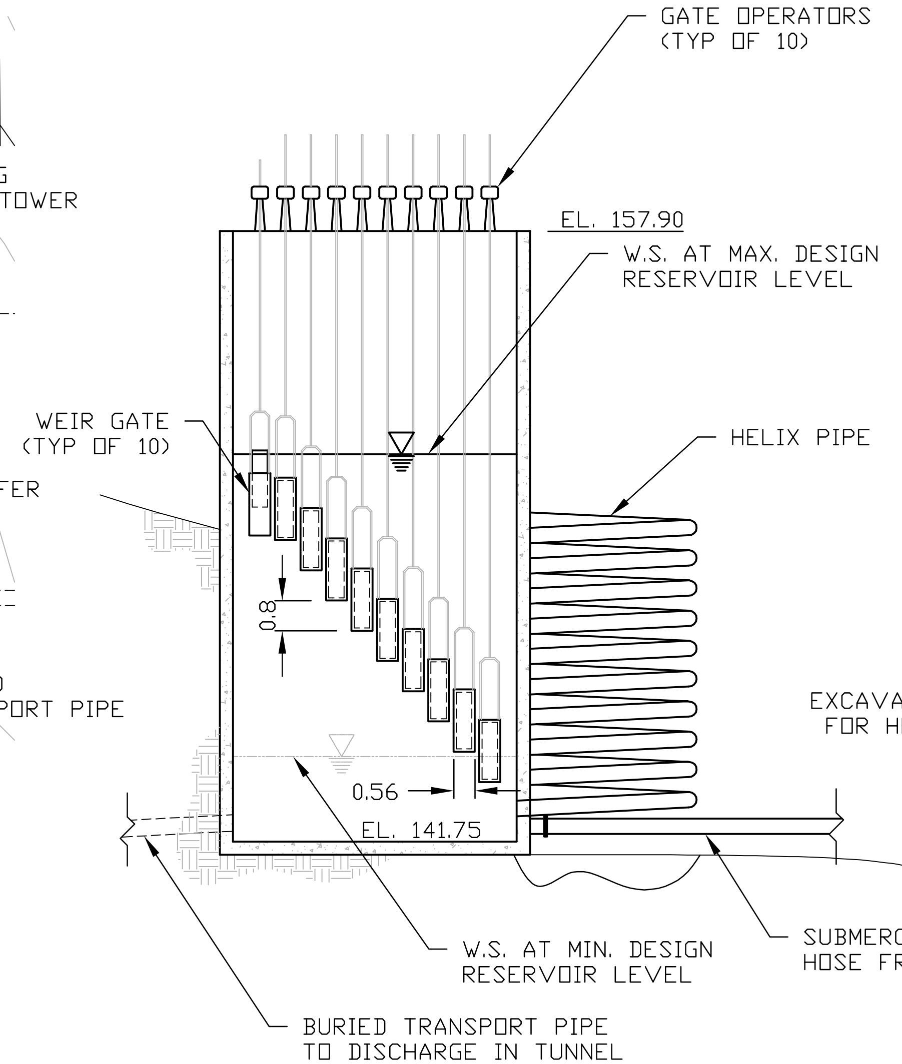
KWIKWETLEM SALMON RESTORATION PROGRAM
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

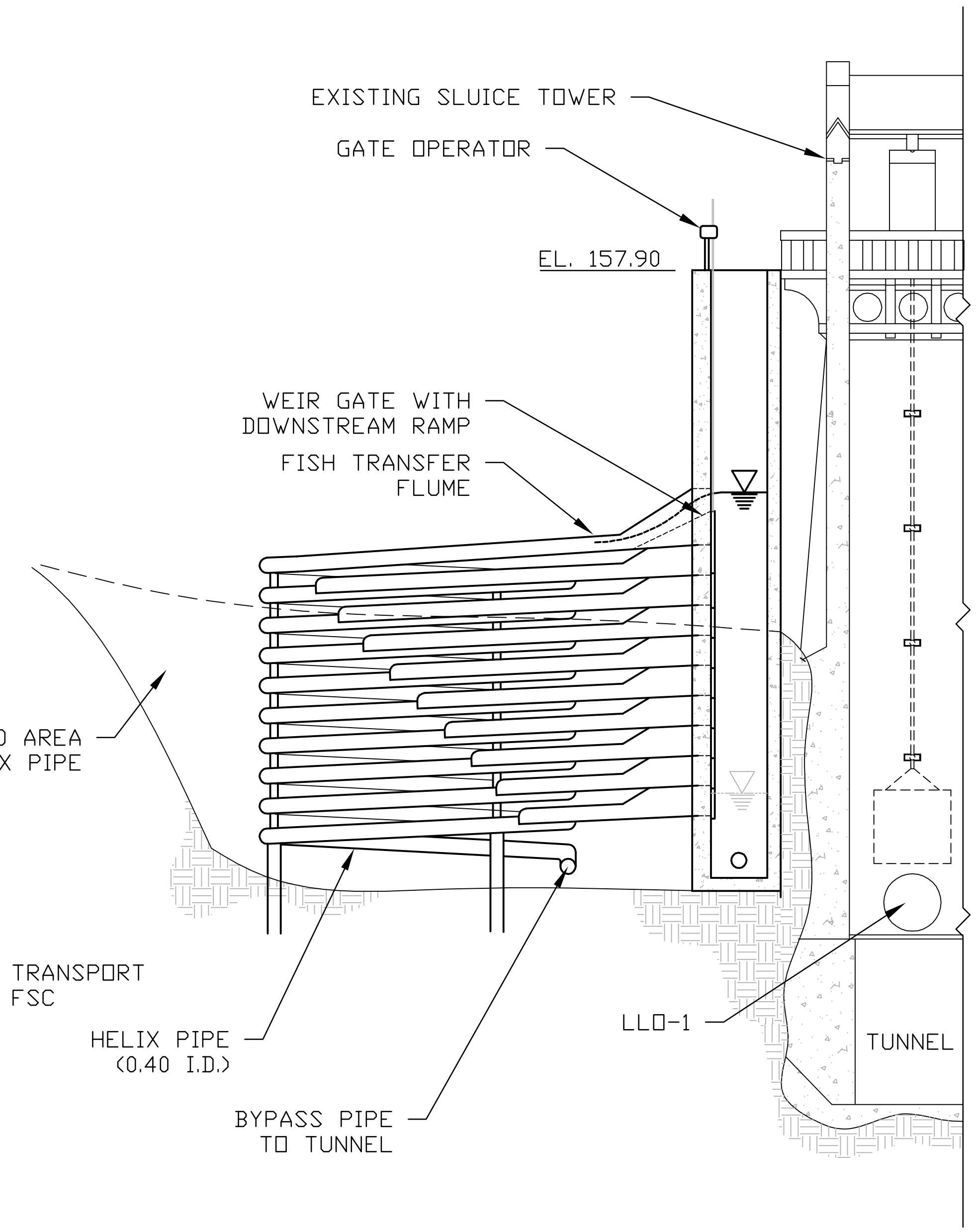
FLOATING SURFACE COLLECTOR (FSC)
ALTERNATIVE 2 – GUIDE NET ELEVATIONS
DRAWING 13



FLOW CONTROL STUCTURE
(SEE PLAN FIG. 9)



SECTION P
FLOW CONTROL WEIR GATES



SECTION Q
SPIRAL PIPE STRUCTURE

-2 0 2 4 6 8 10
SCALE IN METRES
1:200

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KWIKWETLEM SALMON RESTORATION PROGRAM
COQUITLAM DOWNSTREAM PASSAGE OPTIONS

FLOATING SURFACE COLLECTOR (FSC)
ALTERNATIVE 2 – FLOW CONTROL STRUCTURE
DRAWING 14

APPENDIX F
RESERVOIR OUTLET OPERATIONS AND WATER LEVELS FOR MONTHS OF APRIL AND MAY 2009-2017

	All releases in cms						All elevations in m
Date	GVRD withdrawals	Knife Gate (To Coquitlam River Started in October 2008)	Other LLO (Spill To Coquitlam River in addition to Knife Gate)	Tunnel Gate flow to Buntzen	Lake Buntzen Turbine Flow	Lake Buntzen Spill (Non power release)	Coquitlam Reservoir Elevation (m)
4/1/2009	2.063	5.262	0	0	0	0	145.091
4/2/2009	2.832	5.02	0	0	0	0	145.122
4/3/2009	2.504	5.024	0	0	0	0	145.129
4/4/2009	2.647	5.025	0	0	0	0	145.129
4/5/2009	2.691	5.023	0	0	0	0	145.126
4/6/2009	2.622	5.033	0	0	14.808	0	145.143
4/7/2009	2.433	5.075	0	0	0	0	145.211
4/8/2009	2.291	5.149	0	0	0	0	145.328
4/9/2009	2.171	5.235	0	8.9	8.626	0	145.407
4/10/2009	2.424	5.262	0	33.509	37.389	0	145.275
4/11/2009	2.28	5.154	0	33.382	37.492	0	145.112
4/12/2009	2.674	5.152	0	33.379	37.539	0	145.116
4/13/2009	2.84	5.267	0	33.515	37.597	0	145.287
4/14/2009	2.636	5.193	0	21.919	23.716	0	145.173
4/15/2009	2.553	5.193	0	0	0	0	145.175
4/16/2009	2.386	5.22	0	0	0	0	145.217
4/17/2009	2.26	5.311	0	0	0	0	145.359
4/18/2009	2.457	5.43	0	0	0	0	145.542
4/19/2009	2.683	5.483	0	0	0	0	145.626
4/20/2009	2.572	5.537	0	0	0	0	145.715
4/21/2009	2.571	5.642	0	0	0	0	145.887
4/22/2009	2.407	5.664	0	0	0	0	146.11
4/23/2009	2.569	5.636	0	0	0	0	146.239
4/24/2009	2.539	5.667	0	0	0	0	146.295
4/25/2009	2.578	5.687	0	0	0	0	146.33
4/26/2009	2.797	5.7	0	0	0	0	146.353
4/27/2009	2.875	5.714	0	0	0	0	146.378
4/28/2009	3.027	5.729	0	0	0	0	146.405
4/29/2009	2.993	5.714	0	0	0	0	146.378
4/30/2009	3.068	5.729	0	0	0	0	146.404
5/1/2009	3.745	5.463	0	0	0	0	146.454
5/2/2009	2.644	5.262	0	0	0	0	146.54
5/3/2009	2.761	5.362	0	0	0	0	146.752
5/4/2009	2.644	5.43	0	0	0	0	146.893
5/5/2009	2.567	5.556	0	17.188	13.232	0	147.17
5/6/2009	2.675	5.605	0	35.005	37.44	0	147.27
5/7/2009	3.167	5.577	0	34.96	37.436	0	147.209
5/8/2009	4.567	5.536	0	34.894	37.485	0	147.117
5/9/2009	6.95	5.454	0	34.762	37.545	0	146.937
5/10/2009	6.862	5.366	0	34.625	37.586	0	146.753
5/11/2009	6.873	5.326	0	15.392	13.648	0	146.673
5/12/2009	4.404	5.4	0	0	0	0	146.831
5/13/2009	3.039	5.443	0	5.147	0	0	146.919
5/14/2009	3.19	5.434	0	12.239	0	0	146.898
5/15/2009	3.247	5.449	0	0	4.872	0	146.932
5/16/2009	2.9	5.48	0	0	0	0	146.998
5/17/2009	2.94	5.527	0	0	0	0	147.103
5/18/2009	2.665	5.609	0	0	0	0	147.283
5/19/2009	2.952	5.702	0	0	0	0	147.487
5/20/2009	2.852	5.759	0	0	0	0	147.614
5/21/2009	3.394	5.789	0	0	0	0	147.681
5/22/2009	3.484	5.819	0	0	0	0	147.751
5/23/2009	3.99	5.859	0	0	0	0	147.843
5/24/2009	3.825	5.904	0	0	0	0	147.946
5/25/2009	3.119	5.801	0	0	0	0	148.058
5/26/2009	3.313	5.699	0	0	0	0	148.259
5/27/2009	4.127	5.791	0	0.776	0	0	148.487
5/28/2009	4.764	5.83	0	0	0	0	148.589
5/29/2009	5.608	5.869	0	0	0	0	148.691
5/30/2009	6.004	5.924	0	0	0	0	148.834
5/31/2009	6.431	5.971	0	0	0	0	148.956

	All releases in cms						All elevations in m
Date	GVRD withdrawals	Knife Gate (To Coquitlam River Started in October 2008)	Other LLO (Spill To Coquitlam River in addition to Knife Gate)	Tunnel Gate flow to Buntzen	Lake Buntzen Turbine Flow	Lake Buntzen Spill (Non power release)	Coquitlam Reservoir Elevation (m)
4/1/2010	4.306	3.204	0	0	0	0	144.71
4/2/2010	4.173	3.243	0	0	0	0	144.807
4/3/2010	3.588	3.358	0	0	0	0	145.088
4/4/2010	3.79	3.406	0	0	0	0	145.206
4/5/2010	4.373	3.429	0	0	0	0	145.265
4/6/2010	4.1	3.454	0	0	0	0	145.329
4/7/2010	4.231	3.502	0	0	0	0	145.454
4/8/2010	4.457	3.61	0	0	0	0	145.739
4/9/2010	4.327	3.649	0	0	0	0	145.841
4/10/2010	4.421	3.66	0	0	0	0	145.871
4/11/2010	4.413	3.663	0	0	0	0	145.877
4/12/2010	4.765	3.661	0	0	0	0	145.873
4/13/2010	4.459	3.666	0	0	0	0	145.887
4/14/2010	5.019	3.673	0	0	0	0	145.907
4/15/2010	4.839	3.691	0	0	0	0	145.954
4/16/2010	4.833	3.723	0	0	0	0	146.042
4/17/2010	4.292	3.774	0	0	0	0	146.187
4/18/2010	4.393	3.858	0	0	0	0	146.425
4/19/2010	4.84	3.927	0	0	0	0	146.623
4/20/2010	4.538	3.985	0	0	0	0	146.794
4/21/2010	4.18	4.037	0	0	0	0	146.948
4/22/2010	4.758	3.618	0	0	0	0	147.093
4/23/2010	4.473	3.257	0	0	0	0	147.181
4/24/2010	4.391	3.283	0	0	0	0	147.286
4/25/2010	4.242	3.318	0	0	0	0	147.425
4/26/2010	4.542	3.338	0	0	0	0	147.501
4/27/2010	3.374	3.415	0	0	0	0	147.828
4/28/2010	2.665	3.515	0	0	0	0	148.239
4/29/2010	3.114	3.554	0	0	0	0	148.402
4/30/2010	2.565	3.196	0	0	0	0	148.493
5/1/2010	2.582	2.893	0	0	0	0	148.575
5/2/2010	2.693	2.909	0	0	0	0	148.662
5/3/2010	2.535	2.968	0	0	0	0.259	148.995
5/4/2010	2.866	3.002	0	4.266	0	1.926	149.177
5/5/2010	2.939	3.003	0	10.003	0	7.673	149.183
5/6/2010	2.609	2.998	0	9.997	0	10.695	149.151
5/7/2010	2.797	2.99	0	9.989	0	11.314	149.111
5/8/2010	2.901	2.983	0	9.98	0	11.477	149.067
5/9/2010	3.417	2.973	0	9.969	0	11.452	149.011
5/10/2010	3.596	2.965	0	9.961	0	11.401	148.965
5/11/2010	3.493	2.958	0	9.953	0	11.441	148.929
5/12/2010	3.533	4.512	0	9.951	0	11.455	148.915
5/13/2010	3.92	6.044	0	9.948	0	11.443	148.901
5/14/2010	4.047	6.037	0	9.944	0	11.458	148.884
5/15/2010	3.924	6.039	0	9.946	0	11.482	148.889
5/16/2010	4.219	6.042	0	9.947	0	11.525	148.898
5/17/2010	3.917	6.047	0	9.949	0	11.564	148.909
5/18/2010	3.322	6.067	0	9.959	0	11.747	148.962
5/19/2010	3.418	4.708	0	5.597	0	11.022	149.063
5/20/2010	3.215	2.817	0	0	0	6.335	149.36
5/21/2010	3.227	2.852	0	0	0	4.167	149.578
5/22/2010	3.383	2.867	0	0	0	3.19	149.668
5/23/2010	3.133	2.876	0	0	0	2.694	149.729
5/24/2010	3.536	2.886	0	0	0	2.492	149.787
5/25/2010	3.563	2.892	0	3.053	0	2.664	149.825
5/26/2010	3.335	2.892	0	9.921	0	7.17	149.822
5/27/2010	3.516	2.895	0	9.925	0	10.154	149.842
5/28/2010	3.192	2.903	0	9.935	0	11.057	149.898
5/29/2010	2.798	2.913	0	9.948	0	11.291	149.962
5/30/2010	2.912	2.925	0	9.962	0	11.477	150.038
5/31/2010	3.067	1.918	0	9.975	0	11.973	150.112

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4/1/2011	2.489	3.857	0	15.339	0	21.518	148.764
4/2/2011	2.736	3.548	0	15.352	0	19.019	148.806
4/3/2011	2.804	3.543	0	15.345	0	17.646	148.782
4/4/2011	2.397	3.543	0	15.345	0	18.294	148.782
4/5/2011	2.762	3.545	0	15.347	0	19.497	148.791
4/6/2011	2.918	3.552	0	15.357	0	19.114	148.821
4/7/2011	2.885	3.543	0	15.345	0	18.09	148.782
4/8/2011	3.066	3.526	0	15.322	0	17.306	148.705
4/9/2011	2.617	3.508	0	15.297	0	16.892	148.621
4/10/2011	2.452	3.503	0	15.29	0	17.212	148.603
4/11/2011	2.887	3.625	0	21.035	0	19.926	148.802
4/12/2011	2.934	3.73	0	30.365	0	30.512	148.73
4/13/2011	2.691	3.694	0	30.273	0	34.428	148.576
4/14/2011	3.028	3.663	0	30.195	0	35.43	148.446
4/15/2011	3.76	3.624	0	30.1	0	35.413	148.286
4/16/2011	2.597	3.578	0	29.987	0	35.124	148.096
4/17/2011	3.054	3.528	0	29.863	0	34.465	147.892
4/18/2011	3.103	3.473	0	29.728	0	34.008	147.675
4/19/2011	4.186	3.416	0	29.585	0	33.721	147.446
4/20/2011	2.801	3.356	0	29.443	0	33.271	147.217
4/21/2011	2.985	3.298	0	29.304	0	33.118	146.994
4/22/2011	2.929	3.237	0	29.164	0	32.805	146.769
4/23/2011	2.775	3.175	0	29.023	0	32.497	146.543
4/24/2011	2.714	3.115	0	28.89	0	32.421	146.329
4/25/2011	2.874	3.07	0	28.789	0	32.793	146.169
4/26/2011	3.195	3.034	0	28.711	0	33.423	146.044
4/27/2011	3.241	4.765	0	20.534	0	31.184	145.977
4/28/2011	2.792	6.062	0	14.496	0	21.666	146.051
4/29/2011	2.917	6.057	0	14.493	0	18.084	146.04
4/30/2011	2.569	6.014	0	14.471	0	16.417	145.972
5/1/2011	2.638	5.958	0	14.444	0	15.614	145.887
5/2/2011	3.144	5.916	0	14.423	0	15.507	145.824
5/3/2011	3.617	5.924	0	14.427	0	15.806	145.838
5/4/2011	3.175	4.145	0	7.362	0	13.94	145.83
5/5/2011	2.905	2.996	0	0	0	6.551	145.92
5/6/2011	2.818	3.038	0	0	0	4.343	146.064
5/7/2011	2.649	3.108	0	0	4.284	3.331	146.315
5/8/2011	2.96	3.173	0	0	0	3.109	146.542
5/9/2011	3.326	3.204	0	0	7.196	1.462	146.655
5/10/2011	3.256	3.229	0	0	5.844	0	146.746
5/11/2011	3.067	5.173	0	0	2.938	0	146.959
5/12/2011	3.175	6.227	0	0	0	0	147.357
5/13/2011	3.124	6.311	0	0	0	0	147.518
5/14/2011	2.727	6.371	0	0	8.434	0	147.643
5/15/2011	2.705	6.504	0	0	0	0	147.917
5/16/2011	2.967	6.666	0	0	0	0	148.256
5/17/2011	3.072	6.801	0	0	14.552	0	148.538
5/18/2011	3.852	4.342	0	9.87	11.122	0	148.663
5/19/2011	3.564	2.809	0	8.838	0.882	0	148.684
5/20/2011	3.87	2.833	0	0	0	0	148.823
5/21/2011	2.981	2.872	0	0	0	0.138	149.048
5/22/2011	2.791	2.909	0	0	0	0.888	149.264
5/23/2011	3.341	2.937	0	0	0	1.433	149.427
5/24/2011	3.616	2.959	0	0	0	1.695	149.557
5/25/2011	4.028	2.979	0	0	0	1.856	149.678
5/26/2011	4.064	3.019	0	6.217	0	3.099	149.925
5/27/2011	3.735	3.04	0	19.777	0	13.582	150.047
5/28/2011	4.12	3.041	0	19.781	0	20.409	150.056
5/29/2011	4.148	3.036	0	19.768	0	22.177	150.021
5/30/2011	3.794	3.036	0	19.769	0	22.495	150.025
5/31/2011	4.158	1.795	0	19.773	0	22.713	150.036

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4/1/2012	3.024	3.292	0	14.029	16.273	0	144.627
4/2/2012	2.91	3.273	0	14.014	16.199	0	144.581
4/3/2012	2.825	3.258	0	14.004	18.309	0	144.55
4/4/2012	3.188	3.271	0	9.007	0	0	144.578
4/5/2012	2.918	3.274	0	5.048	16.076	0	144.587
4/6/2012	2.93	3.271	0	5.048	0	0	144.579
4/7/2012	2.833	3.261	0	5.045	0	0	144.556
4/8/2012	2.592	3.251	0	5.043	0	0	144.533
4/9/2012	2.981	3.243	0	5.04	12.723	0	144.515
4/10/2012	3.052	3.257	0	5.044	11.474	0	144.548
4/11/2012	3.031	3.293	0	5.054	0	0	144.632
4/12/2012	3.071	3.342	0	5.067	0	0	144.745
4/13/2012	3.234	3.388	0	5.079	12.778	0	144.848
4/14/2012	2.812	3.417	0	5.087	10.657	0	144.914
4/15/2012	2.969	3.433	0	5.092	0	0	144.951
4/16/2012	3.073	3.448	0	5.096	22.736	0	144.986
4/17/2012	3.143	3.477	0	5.104	9.85	0	145.056
4/18/2012	2.881	3.501	0	5.111	0	0	145.114
4/19/2012	2.668	3.525	0	5.118	13.49	0	145.172
4/20/2012	2.298	3.608	0	5.142	0	0	145.378
4/21/2012	2.451	3.674	0	5.161	0	0	145.539
4/22/2012	2.889	3.71	0	5.172	0	0	145.631
4/23/2012	2.627	1.663	0	5.196	11.547	0	145.838
4/24/2012	2.457	1.957	0	5.23	0	0	146.123
4/25/2012	3.107	3.475	0	5.297	13.889	0	146.737
4/26/2012	4.471	3.772	0	5.416	5.328	0	147.785
4/27/2012	4.831	3.901	0	5.469	29.173	0	148.25
4/28/2012	4.67	3.938	0	5.484	0	0	148.389
4/29/2012	4.4	3.955	0	5.491	0	0	148.452
4/30/2012	4.625	3.394	0	11.774	11.81	0	148.599
5/1/2012	5.097	2.93	0	19.294	22.661	0	148.776
5/2/2012	4.967	2.938	0	19.312	21.985	0	148.819
5/3/2012	4.831	2.929	0	19.294	32.038	0	148.772
5/4/2012	4.651	2.92	0	19.275	21.332	0	148.721
5/5/2012	4.268	2.912	0	19.256	26.18	0	148.674
5/6/2012	4.734	2.899	0	19.23	22.335	0	148.603
5/7/2012	5.175	2.884	0	19.199	19.775	0	148.521
5/8/2012	5.232	2.874	0	19.179	20.302	0	148.469
5/9/2012	5.357	2.869	0	19.169	23.106	0	148.443
5/10/2012	4.437	2.859	0	19.149	26.764	0	148.389
5/11/2012	3.436	2.843	0	19.116	25.222	0	148.303
5/12/2012	3.545	2.826	0	19.082	16.93	0	148.213
5/13/2012	3.633	2.818	0	19.065	18.429	0	148.171
5/14/2012	3.939	2.824	0	19.078	14.505	0	148.207
5/15/2012	4.182	2.842	0	19.113	11.417	0	148.299
5/16/2012	4.285	2.856	0	19.142	26.173	0	148.373
5/17/2012	4.105	2.857	0	19.145	18.937	0	148.379
5/18/2012	3.451	2.849	0	19.128	23.338	0	148.336
5/19/2012	4.113	2.835	0	19.1	18.575	0	148.261
5/20/2012	3.096	2.822	0	19.074	20.203	0	148.195
5/21/2012	3.082	2.852	0	19.133	22.251	0	148.36
5/22/2012	3.163	2.929	0	19.294	25.167	0	148.777
5/23/2012	3.976	2.944	0	19.323	20.746	0	148.852
5/24/2012	4.37	2.952	0	29.175	31.618	0	148.897
5/25/2012	4.275	2.934	0	36.109	39.582	0	148.794
5/26/2012	4.258	2.917	0	36.044	34.785	0	148.703
5/27/2012	3.913	2.902	0	35.985	37.739	0	148.62
5/28/2012	3.691	1.766	0	35.9	34.39	0	148.499
5/29/2012	3.867	0.76	0	35.82	36.402	0	148.387
5/30/2012	3.707	0.753	0	35.72	38.301	0	148.245
5/31/2012	3.537	0.748	0	35.64	33.459	0	148.134

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4/1/2013	4.078	4.085	0	36.523	39.026	0	149.378
4/2/2013	3.397	3.869	0	36.46	38.962	0	149.29
4/3/2013	3.284	3.726	0	36.363	39	0	149.152
4/4/2013	3.052	3.695	0	36.262	39.068	0	149.012
4/5/2013	2.773	3.798	0	23.634	26.986	0	149.501
4/6/2013	2.897	3.966	0	0	0	0	150.283
4/7/2013	2.745	4.045	0	0	0	0	150.657
4/8/2013	2.966	4.076	0	0	0	0	150.805
4/9/2013	3.676	3.89	0	0	1.048	0	150.888
4/10/2013	3.334	3.714	0	0	24.364	0	151.294
4/11/2013	3.434	3.788	0	17.739	37.136	0	151.703
4/12/2013	3.089	3.774	0	38.072	41.39	0	151.62
4/13/2013	2.958	3.748	0	37.969	40.06	0	151.468
4/14/2013	2.916	3.714	0	37.837	37.063	0	151.274
4/15/2013	3.381	3.675	0	37.683	39.598	0	151.05
4/16/2013	4.04	3.631	0	37.519	28.049	0	150.809
4/17/2013	3.252	3.586	0	37.348	45.548	0	150.558
4/18/2013	3.272	3.542	0	37.183	44.459	0	150.318
4/19/2013	3.287	3.508	0	37.059	38.484	0	150.138
4/20/2013	3.058	3.479	0	36.95	30.898	0	149.981
4/21/2013	2.891	3.449	0	36.838	33.201	0	149.821
4/22/2013	3.535	3.413	0	36.705	39.27	0	149.633
4/23/2013	3.652	3.37	0	36.547	36.494	0	149.41
4/24/2013	3.849	3.328	0	36.392	37.662	0	149.192
4/25/2013	4.01	3.289	0	36.254	37.238	0	148.997
4/26/2013	3.763	3.255	0	36.134	36.521	0	148.828
4/27/2013	3.164	3.231	0	36.05	36.222	0	148.713
4/28/2013	3.119	3.234	0	36.06	35.682	0	148.727
4/29/2013	3.453	3.225	0	36.027	41.437	0	148.679
4/30/2013	3.804	3.195	0	35.923	41.794	0	148.531
5/1/2013	4.399	3.03	0	35.774	56.13	0	148.32
5/2/2013	4.09	2.905	0	35.617	14.41	0	148.098
5/3/2013	4.553	2.87	0	17.459	25.453	0	147.928
5/4/2013	3.963	2.888	0	0	0	0	148.021
5/5/2013	3.902	2.931	0	0	0	0	148.241
5/6/2013	4.221	2.989	0	0	0	0	148.54
5/7/2013	3.581	3.049	0	0	0	0	148.856
5/8/2013	3.692	3.103	0	0	2.599	0	149.149
5/9/2013	4.102	3.152	0	0	5.728	0	149.414
5/10/2013	3.681	3.19	0	21.718	26.375	0	149.625
5/11/2013	3.514	3.192	0	36.702	28.544	0	149.632
5/12/2013	3.03	3.215	0	36.796	37.502	0	149.771
5/13/2013	3.056	3.124	0	36.961	50.796	0	150.002
5/14/2013	3.105	3.051	0	37.043	29.797	0	150.119
5/15/2013	3.44	3.041	0	37.003	32.941	0	150.056
5/16/2013	3.588	3.017	0	36.896	36.465	0	149.903
5/17/2013	3.222	2.991	0	36.785	37.77	0	149.747
5/18/2013	2.971	2.971	0	36.7	35.15	0	149.629
5/19/2013	3.162	2.952	0	36.616	37.563	0	149.509
5/20/2013	3.868	2.923	0	36.498	40.527	0	149.341
5/21/2013	3.3	2.897	0	36.386	35.542	0	149.185
5/22/2013	3.47	2.875	0	36.298	37.853	0	149.06
5/23/2013	3.199	2.851	0	36.196	35.814	0	148.916
5/24/2013	3.175	2.824	0	29.119	30.956	0	148.763
5/25/2013	3.353	2.801	0	25.123	28.387	0	148.636
5/26/2013	3.428	2.778	0	25.056	31.256	0	148.501
5/27/2013	3.182	2.754	0	24.991	29.211	0	148.371
5/28/2013	2.78	2.778	0	9.899	11.921	0	148.515
5/29/2013	2.805	2.848	0	0	0	0	148.909
5/30/2013	2.868	2.895	0	8.408	21.77	0	149.181
5/31/2013	2.811	2.902	0	24.912	26.207	0	149.219

	All releases in cms						All elevations in m
Date	GVRD withdrawals	Knife Gate (To Coquitlam River Started in October 2008)	Other LLO (Spill To Coquitlam River in addition to Knife Gate)	Tunnel Gate flow to Buntzen	Lake Buntzen Turbine Flow	Lake Buntzen Spill (Non power release)	Coquitlam Reservoir Elevation (m)
4/1/2014	3.497	4.138	0	37.911	42.777	0	151.383
4/2/2014	3.371	3.694	0	37.76	42.942	0	151.162
4/3/2014	3.122	3.654	0	37.604	42.966	0	150.934
4/4/2014	3.537	3.644	0	37.568	42.984	0	150.885
4/5/2014	3.032	3.627	0	37.502	43.083	0	150.787
4/6/2014	2.947	3.608	0	37.432	24.48	0	150.685
4/7/2014	3.422	3.586	0	37.349	44.646	0	150.562
4/8/2014	3.134	3.579	0	37.322	44.679	0	150.527
4/9/2014	3.307	3.577	0	37.315	44.82	0	150.513
4/10/2014	3.418	3.548	0	37.206	44.917	0	150.352
4/11/2014	3.639	3.509	0	37.063	45.053	0	150.143
4/12/2014	3.516	3.467	0	36.906	45.19	0	149.916
4/13/2014	3.989	3.424	0	36.744	15.868	0	149.688
4/14/2014	3.678	3.379	0	36.579	31.383	0	149.455
4/15/2014	3.42	3.338	0	36.43	32.335	0	149.245
4/16/2014	2.888	3.305	0	36.31	44.923	0	149.079
4/17/2014	2.879	3.331	0	36.405	44.938	0	149.221
4/18/2014	2.872	3.39	0	36.618	45.138	0	149.515
4/19/2014	2.578	3.376	0	36.567	42.084	0	149.441
4/20/2014	3.016	3.373	0	36.557	7.368	0.004	149.428
4/21/2014	3.213	3.348	0	36.467	51.044	0.203	149.298
4/22/2014	3.577	3.315	0	36.345	46.658	0	149.126
4/23/2014	3.633	3.282	0	36.227	46.841	0	148.96
4/24/2014	2.956	3.255	0	36.135	47.019	0	148.831
4/25/2014	3.187	3.235	0	36.064	47.126	0	148.729
4/26/2014	3.087	3.199	0	35.936	14.773	0	148.548
4/27/2014	3.116	3.165	0	35.819	46.866	0	148.385
4/28/2014	4.189	3.129	0	35.699	47.014	0	148.215
4/29/2014	3.449	3.358	0	35.55	27.897	0	148.005
4/30/2014	4.215	3.598	0	35.403	31.802	0	147.805
5/1/2014	4.559	3.119	0	35.318	35.006	0	147.693
5/2/2014	3.669	2.815	0	35.286	35.547	0	147.65
5/3/2014	3.1	2.808	0	35.259	29.463	0	147.614
5/4/2014	3.17	2.812	0	35.277	33.661	0	147.64
5/5/2014	3.176	2.818	0	35.299	35.276	0	147.666
5/6/2014	3.437	2.795	0	35.213	46.484	0	147.548
5/7/2014	3.971	2.762	0	35.096	37.864	0	147.39
5/8/2014	3.623	2.729	0	32.737	38.551	0	147.23
5/9/2014	3.459	2.731	0	20.515	41.118	0	147.246
5/10/2014	2.794	2.772	0	0	0	0	147.441
5/11/2014	3.535	2.795	0	0	0	0	147.555
5/12/2014	4.189	2.816	0	0	0	0	147.658
5/13/2014	4.563	2.835	0	10.56	0	0	147.753
5/14/2014	5.31	2.834	0	12.76	0	0	147.75
5/15/2014	4.994	2.864	0	0	0	0	147.899
5/16/2014	4.723	2.895	0	4.181	6.731	0	148.054
5/17/2014	4.231	2.906	0	12.495	10.281	0	148.11
5/18/2014	3.692	2.906	0	12.495	17.068	0	148.107
5/19/2014	4.114	2.902	0	12.49	11.988	0	148.09
5/20/2014	5.032	2.898	0	12.485	10.344	0	148.066
5/21/2014	5.392	2.891	0	12.476	12.602	0	148.031
5/22/2014	5.561	2.886	0	12.469	10.905	0	148.003
5/23/2014	4.225	2.904	0	12.493	15.7	0	148.105
5/24/2014	4.346	2.939	0	12.537	13.268	0	148.278
5/25/2014	3.939	2.943	0	12.542	12.306	0	148.297
5/26/2014	4.219	2.959	0	12.563	13.442	0	148.383
5/27/2014	4.532	2.976	0	12.584	17.176	0	148.466
5/28/2014	3.994	2.973	0	12.581	11.657	0	148.452
5/29/2014	3.372	2.974	0	12.582	15.107	0	148.456
5/30/2014	3.22	2.982	0	12.592	12	0	148.497
5/31/2014	3.955	2.982	0	12.591	12.612	0	148.495

	All releases in cms						All elevations in m
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4/1/2015	3.677	4.077	0	22.242	0	22.508	152.084
4/2/2015	3.367	3.721	0	25.111	0	27.022	151.958
4/3/2015	3.175	3.696	0	25.044	0	28.371	151.809
4/4/2015	2.936	3.674	0	24.986	0	28.536	151.68
4/5/2015	3.065	3.649	0	24.917	0	28.341	151.526
4/6/2015	3.746	3.619	0	24.841	0	28.05	151.354
4/7/2015	3.967	3.588	0	24.759	0	27.498	151.171
4/8/2015	3.88	3.556	0	24.674	0	27.528	150.982
4/9/2015	3.832	3.521	0	24.586	0.115	27.399	150.786
4/10/2015	3.039	3.488	0	22.538	28.716	18.479	150.6
4/11/2015	2.792	3.467	0	19.936	54.79	0.046	150.479
4/12/2015	2.98	3.443	0	19.888	6.718	0	150.347
4/13/2015	3.587	3.42	0	19.841	33.282	0	150.219
4/14/2015	3.196	3.404	0	19.807	28.024	0	150.127
4/15/2015	3.409	3.382	0	19.761	20.79	0	150.001
4/16/2015	3.263	3.357	0	11.023	14.588	0	149.871
4/17/2015	4.209	3.356	0	0	0	0	149.865
4/18/2015	4.473	3.358	0	0	0	0	149.879
4/19/2015	4.193	3.361	0	0	0	0	149.893
4/20/2015	4.575	3.362	0	0	0	0	149.895
4/21/2015	4.483	3.361	0	0	0	0	149.893
4/22/2015	4.259	3.364	0	0	0	0	149.911
4/23/2015	4.364	2.557	0.809	0	0	0	149.919
4/24/2015	3.52	3.36	0	0	0	0	149.95
4/25/2015	3.679	3.371	0	0	0	0	150.007
4/26/2015	3.687	3.376	0	0	0	0	150.038
4/27/2015	3.505	3.388	0	0	0	0	150.106
4/28/2015	3.815	3.412	0	0	0	0	150.239
4/29/2015	3.565	3.43	0	0	0.16	0	150.344
4/30/2015	3.513	3.443	0	0	0	0	150.411
5/1/2015	4.15	3.129	0	0	0	0	150.458
5/2/2015	3.712	2.879	0	0	0	0	150.49
5/3/2015	4.132	2.882	0	0	0	0	150.506
5/4/2015	4	2.876	0	0	0	0	150.507
5/5/2015	3.499	2.884	0	0	0	0	150.522
5/6/2015	3.694	2.884	0	0	0	0	150.537
5/7/2015	4.881	2.886	0	0	0	0	150.536
5/8/2015	5.245	2.884	0	0	0	0	150.522
5/9/2015	5.852	2.881	0	0	0	0	150.499
5/10/2015	5.093	2.878	0	0	0	0	150.478
5/11/2015	5.015	2.875	0	0	0	0	150.457
5/12/2015	5.523	2.873	0	0	0	0	150.445
5/13/2015	4.577	2.871	0	0	0	0	150.43
5/14/2015	5.633	2.867	0	7.502	0	0	150.407
5/15/2015	5.325	2.847	0	10.361	0	0	150.267
5/16/2015	5.364	2.841	0	0	0	0	150.226
5/17/2015	5.239	2.838	0	0	0	0	150.206
5/18/2015	6.301	2.834	0	0	0	0	150.185
5/19/2015	6.895	2.83	0	0	0	0	150.153
5/20/2015	6.595	2.825	0	0	0	0	150.122
5/21/2015	7.02	2.82	0	0	0	0	150.089
5/22/2015	6.44	2.815	0	0	0	0	150.054
5/23/2015	5.635	2.81	0	0	0	0	150.018
5/24/2015	6.165	2.806	0	0	0	0	149.992
5/25/2015	5.605	2.801	0	0	0	0	149.963
5/26/2015	5.585	2.798	0	0	0	0	149.936
5/27/2015	5.901	2.792	0	0	0	0	149.902
5/28/2015	6.765	2.785	0	5.499	0.118	0	149.856
5/29/2015	6.918	2.766	0	10.305	10.484	0	149.729
5/30/2015	7.202	2.755	0	0	0	0	149.652
5/31/2015	7.07	2.747	0	0	0	0	149.599

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4/1/2016	3.148	4.081	0	15.111	34.833	0	151.01
4/2/2016	2.862	3.566	0	15.113	11.713	0	151.017
4/3/2016	3.194	3.564	0	15.109	12.992	0	151.002
4/4/2016	2.875	3.574	0	15.125	17.878	0	151.063
4/5/2016	3.014	3.583	0	15.139	19.238	0	151.112
4/6/2016	2.914	3.588	0	15.146	19.679	0	151.141
4/7/2016	3.035	3.589	0	15.149	13.822	0	151.148
4/8/2016	3.139	3.593	0	15.154	14.614	0	151.17
4/9/2016	3.125	3.599	0	15.164	44.922	0	151.206
4/10/2016	2.849	3.598	0	15.162	0	0	151.198
4/11/2016	3.297	3.592	0	15.153	21.987	0	151.162
4/12/2016	2.934	3.586	0	15.144	26.673	0	151.131
4/13/2016	3.057	3.59	0	15.151	21.809	0	151.155
4/14/2016	2.896	3.582	0	15.138	21.716	0	151.107
4/15/2016	3.946	3.568	0	15.115	14.154	0	151.024
4/16/2016	4.072	3.551	0	15.089	9.855	0	150.927
4/17/2016	4.396	3.533	0	15.061	0	0	150.827
4/18/2016	5.389	3.521	0	15.042	20.158	0	150.757
4/19/2016	5.724	3.517	0	15.036	26.558	0	150.737
4/20/2016	5.606	3.519	0	15.039	21.647	0	150.749
4/21/2016	5.18	3.522	0	15.043	14.995	0	150.765
4/22/2016	4.786	3.523	0	15.045	29.362	0	150.772
4/23/2016	4.025	3.529	0	15.054	0	0	150.803
4/24/2016	4.54	3.538	0	15.069	6.105	0	150.859
4/25/2016	5.203	3.536	0	15.065	35.857	0	150.843
4/26/2016	4.684	3.524	0	8.757	21.532	0	150.774
4/27/2016	5.041	3.523	0	0	0	0	150.771
4/28/2016	4.625	3.524	0	0	0	0	150.776
4/29/2016	4.36	3.526	0	0	0	0	150.787
4/30/2016	4.664	3.528	0	0	0	0	150.799
5/1/2016	5.009	3.182	0	0	0	0	150.818
5/2/2016	5.608	2.959	0	0	0	0	150.854
5/3/2016	5.463	2.967	0	0	0	0	150.916
5/4/2016	5.184	2.973	0	19.17	0	0	150.949
5/5/2016	6.054	2.957	0	11.217	0	0	150.842
5/6/2016	5.875	2.96	0	0	0	0	150.862
5/7/2016	4.973	2.966	0	0	0	0	150.905
5/8/2016	5.956	2.973	0	0	0	0	150.953
5/9/2016	5.453	2.977	0	0	0	0	150.981
5/10/2016	5.882	2.979	0	0	0	0	150.992
5/11/2016	6.096	2.979	0	0	0	0	150.996
5/12/2016	6.674	2.98	0	0	0	0	151.004
5/13/2016	6.86	2.981	0	0	0	0	151.009
5/14/2016	6.797	2.984	0	0	0	0	151.027
5/15/2016	5.428	2.989	0	0	0	0	151.066
5/16/2016	5.625	2.993	0	0	0	0	151.089
5/17/2016	6.24	2.994	0	0	0	0	151.103
5/18/2016	5.814	2.996	0	0	0	0	151.11
5/19/2016	5.599	2.999	0	0	0	0	151.13
5/20/2016	5.092	3	0	0	0	0	151.144
5/21/2016	5.088	3.001	0	0	0	0	151.147
5/22/2016	5.168	3.001	0	0	0	0	151.148
5/23/2016	4.936	3.001	0	0	0	0	151.149
5/24/2016	5.364	3.001	0	0	0	0	151.15
5/25/2016	5.993	3.001	0	0	0	0	151.151
5/26/2016	5.14	3.002	0	0	0	0	151.154
5/27/2016	5.084	3.009	0	0	0	0	151.206
5/28/2016	4.564	3.029	0	0	6.878	0	151.354
5/29/2016	4.904	3.112	0	0	0	0	151.941
5/30/2016	5.477	3.134	0	0	0	0	152.091
5/31/2016	5.751	3.14	0	0	0	0	152.138

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4/1/2017	2.617	4.102	0	37.931	48.827	0	151.414
4/2/2017	2.774	3.663	0	37.837	39.936	0	151.276
4/3/2017	2.844	3.631	0	37.714	35.865	0	151.095
4/4/2017	2.692	3.594	0	37.569	34.928	0	150.883
4/5/2017	2.552	3.581	0	37.521	35.036	0	150.82
4/6/2017	2.608	3.608	0	37.622	42.463	0	150.967
4/7/2017	2.454	3.624	0	37.684	39.198	0	151.058
4/8/2017	2.6	3.68	0	37.903	41.61	0	151.383
4/9/2017	2.833	3.705	0	38.004	49.958	0	151.523
4/10/2017	2.818	3.689	0	37.938	39.37	0	151.426
4/11/2017	2.852	3.677	0	37.892	46.245	0	151.357
4/12/2017	2.667	3.653	0	37.799	36.946	0	151.221
4/13/2017	2.514	3.641	0	37.752	49.181	0	151.154
4/14/2017	2.585	3.631	0	37.714	38.54	0	151.097
4/15/2017	2.587	3.618	0	37.66	39.275	0	151.019
4/16/2017	2.394	3.598	0	37.585	38.809	0	150.907
4/17/2017	2.615	3.567	0	37.466	39.044	0	150.733
4/18/2017	2.743	1.523	1.676	18.269	23.691	0	150.747
4/19/2017	2.715	0	2.978	0	4.402	0	150.997
4/20/2017	2.925	0	3.008	0	0	0	151.205
4/21/2017	2.979	0	3.032	0	0	0	151.371
4/22/2017	2.893	0	3.053	0	0	0	151.514
4/23/2017	2.808	0	5.359	0	0	0	151.787
4/24/2017	3.053	0	8.126	14.531	34.404	0	152.075
4/25/2017	3.256	0	8.116	38.358	37.728	0	152.039
4/26/2017	3.091	0	8.08	38.286	35.663	0	151.933
4/27/2017	3.172	0	8.036	38.198	39.011	0	151.804
4/28/2017	3.149	0	7.97	38.068	41.948	0	151.612
4/29/2017	3.019	0	7.896	37.923	38.517	0	151.401
4/30/2017	3.23	0	7.847	37.829	41.655	0	151.264
5/1/2017	3.841	0	7.786	37.712	38.967	0	151.092
5/2/2017	3.734	0	7.715	37.578	40.594	0	150.896
5/3/2017	3.5	0	5.432	37.508	39.974	0	150.799
5/4/2017	3.106	1.182	1.972	37.616	52.297	0	150.96
5/5/2017	2.722	3.198	0	37.826	48.583	0	151.271
5/6/2017	3.001	3.241	0	38.021	37.797	0	151.55
5/7/2017	3.022	3.235	0	37.995	37.499	0	151.508
5/8/2017	3.156	4.847	0	37.899	33.989	0	151.366
5/9/2017	3.148	7.921	0	37.765	38.26	0	151.169
5/10/2017	2.89	7.847	0	37.638	35.608	0	150.985
5/11/2017	2.878	7.838	0	37.624	39.307	0	150.972
5/12/2017	2.847	7.937	0	37.793	52.218	0	151.217
5/13/2017	2.894	5.528	0	37.782	45.579	0	151.198
5/14/2017	3.141	3.029	0	37.698	26.041	0	151.073
5/15/2017	3.029	3.007	0	37.595	33.217	0	150.923
5/16/2017	3.023	2.997	0	37.549	38.138	0	150.857
5/17/2017	3.006	2.98	0	37.469	39.763	0	150.738
5/18/2017	2.957	2.954	0	37.35	42.786	0	150.564
5/19/2017	3.065	2.929	0	37.234	38.803	0	150.395
5/20/2017	3.339	2.908	0	37.141	36.778	0	150.26
5/21/2017	3.255	2.898	0	37.097	41.748	0	150.196
5/22/2017	3.679	2.897	0	37.092	40.493	0	150.19
5/23/2017	3.498	2.9	0	37.107	29.728	0	150.212
5/24/2017	3.59	2.9	0	37.108	44.98	0	150.212
5/25/2017	3.683	2.882	0	37.027	38.51	0	150.092
5/26/2017	3.608	2.865	0	36.948	36.836	0	149.979
5/27/2017	4.116	2.857	0	36.914	39.43	0	149.932
5/28/2017	4.552	2.857	0	36.911	34.96	0	149.928
5/29/2017	4.294	2.867	0	14.624	20.144	0	150.001
5/30/2017	3.562	2.909	0	0	0	0	150.276
5/31/2017	3.531	2.95	0	0	0	0	150.546