Fisheries and Aquatic Habitat Management Plan

Site C Clean Energy Project

Revision 1: June 1, 2015

BC hydro

FOR GENERATIONS

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Revision History

Version	Date	Comments
Rev 0	05-19-2015	**Final**
Rev 1	06-01-2015	**Revision 1**

1.0 Background

1.1 The Site C Clean Energy Project

The Site C Clean Energy Project (the Project) will be the third dam and generating station on the Peace River in northeast B.C. The Project will provide 1,100 megawatts of capacity and about 5,100 gigawatt hours of energy each year to the province's integrated electricity system. The Project will be a source of clean, reliable and cost-effective electricity for BC Hydro's customers for more than 100 years.

The key components of the Project are:

- an earthfill dam, approximately 1,050 metres long and 60 metres high above the riverbed;
- an 83 kilometre long reservoir that will be, on average, two to three times the width of the current river;
- a generating station with six 183 MW generating units;
- two new 500 kilovolt AC transmission lines that will connect the Project facilities to the Peace Canyon Substation, along an existing right-of-way;
- realignment of six segments of Highway 29 over a total distance of approximately 30 kilometers; and
- construction of a berm at Hudson's Hope.

The Project will also include the construction of temporary access roads, a temporary bridge across the Peace River, and worker accommodation at the dam site.

1.2 Project Benefits

The Project will provide important benefits to British Columbia and Canada. It will serve the public interest by delivering long term, reliable electricity to meet growing demand; contribute to employment, economic development, ratepayer, taxpayer and community benefits; meet the need for electricity with lower GHG impact than other resource options; contribute to sustainability by optimizing the use of existing hydroelectric facilities, delivering approximately 35 per cent of the energy produced at the W.A.C. Bennett Dam, with only five per cent of the reservoir area; and include an honourable process of engagement with First Nations and the potential for accommodation of their interests.

1.3 Environmental Assessment Process

The environmental assessment of the Project has been carried out in accordance with the *Canadian Environmental Assessment Act, 2012* (CEAA 2012), the *BC Environmental Assessment Act* (BCEAA), and the Federal-Provincial *Agreement to Conduct a Cooperative Environmental Assessment, Including the Establishment of a Joint Review Panel of the Site C Clean Energy Project*. The assessment considered the environmental, economic, social, heritage and health effects and benefits of the Project, and included the engagement of

Aboriginal groups, the public, all levels of government, and other stakeholders in the assessment process.

Detailed findings of the environmental assessment are documented in the Site C Clean Energy Project Environmental Impact Statement (EIS), which was completed in accordance with the Environmental Impact Statement Guidelines (EIS Guidelines) issued by the Minister of Environment of Canada and the Executive Director of the Environmental Assessment Office of British Columbia. The EIS was submitted to regulatory agencies in January 2013, and amended in August 2013 following a 60 day public comment period on the assessment, including open house sessions in Fort St. John, Hudson's Hope, Dawson Creek, Chetwynd, town of Peace River (Alberta) and Prince George.

In August 2013, an independent Joint Review Panel (JRP) commenced its evaluation of the EIS, and in December 2013 and January 2014 undertook five weeks of public hearings on the Project in 11 communities in the Peace region, including six Aboriginal communities. In May 2014, the JRP provided the provincial and federal governments with a report summarizing the Panel's rationale, conclusions and recommendations relating to the environmental assessment of the Project. On completion of the JRP stage of the environmental assessment, the CEA Agency and BCEAO consulted with Aboriginal groups on the JRP report, and finalized key documents of the environmental assessment for inclusion in a Referral Package for the Provincial Ministers of Environment and Forests, Lands and Natural Resource Operations.

Construction of the Project is also subject to regulatory permits and authorizations, and other approvals. In addition, the Crown has a duty to consult and, where appropriate, accommodate Aboriginal groups.

1.4 Environmental Assessment Findings

The environmental assessment of the Project focused on 22 valued components (VCs), or aspects of the biophysical and human setting that are considered important by Aboriginal groups, the public, the scientific community, and government agencies. In the EIS, valued components were categorized under five pillars: environmental, economic, social, heritage and health. For each VC, the assessment of the potential effects of the Project components and activities during construction and operations was based on a comparison of the biophysical and human environments between the predicted future conditions with the Project, and the predicted future conditions without the Project.

Potential adverse effects on each VC are described in the EIS along with technically and economically feasible mitigation measures, their potential effectiveness, as well as specific follow-up and related commitments for implementation. If a residual effect was found on a VC, the effect was evaluated for significance. Residual effects were categorized using criteria related to direction, magnitude, geographic extent, context, level of confidence and probability, in accordance with the EIS Guidelines.

The assessment found that the effects of the Project will largely be mitigated through careful, comprehensive mitigation programs and ongoing monitoring during construction and operations. The EIS indicates that the Project is unlikely to result in a significant adverse effect for most of the valued components. However, a determination of a significant effect of the Project was found on four VCs: Fish and Fish Habitat, Wildlife Resources, Vegetation and Ecological Communities, and Current Use of Lands and Resources for Traditional Purposes.

1.5 Environmental Assessment Conclusion

On October 14, 2014, the Provincial Ministers of Environment and of Forests, Lands and Natural Resource Operation decided that the Project is in the public interest and that the benefits provided by the Project outweigh the risks of significant adverse environmental, social and heritage effects (http://www.newsroom.gov.bc.ca/2014/10/site-c-project-granted-environmental-assessment-approval.html). The Ministers have issued an Environmental Assessment Certificate setting conditions under which the Project can proceed.

Further, on November 25, 2014, The Minister of Environment of Canada issued a Decision Statement confirming that, while the Project has the potential to result in some significant adverse effects, the Federal Cabinet has concluded that those effects are justified in the circumstances. The Decision Statement sets out the conditions under which the Project can proceed.

1.6 Development of Mitigation, Management and Monitoring Plans

Mitigation, management and monitoring plans for the Project have been developed taking into account the measures proposed in the EIS, information received during the Joint Review Panel hearing process, and the Report of the Joint Review Panel on the Project. Those plans are consistent with, and meet requirements set out in, the conditions of the Environmental Assessment Certificate and of the Decision Statement issued on October 14, 2014 and November 25, 2014 respectively.

1.7 Fish and Fish Habitat

Section 12 of the EIS, as amended (July 2013) describes the assessment of potential effects of the Project on fish and fish habitat including the following:

- Changes in Fish Habitat: Quality and quantity of fish habitats, habitat availability, water depth, velocity, water temperature, sedimentation, water quality, ice regime, aquatic productivity, food resources, and competition for food and habitat
- Changes in Fish Health and Survival: Species diversity; fish population distribution, fish population relative abundance, fish population biomass, sedimentation, stranding, fish entrainment, and total dissolved gas
- Changes in Fish Movement: Fish species population, movement patterns and general life history parameters (i.e., access to habitats), swim speeds, and fish entrainment

The Local Assessment Area for fish and fish habitat includes the following:

- The Peace River in the proposed reservoir area;
- Tributaries entering the proposed reservoir;
- Peace River downstream of the proposed Site C Dam to the Many Islands Area, Alberta;

- Watercourses and water bodies within the transmission line and roadway rights-of-way;
- Watercourses and water bodies within the Project activity zone; and
- Riparian areas adjacent to identified watercourses and water bodies;

Mitigation measures were proposed in the EIS to avoid, reduce, or compensate for the potential adverse effects on fish and fish habitat of construction and operation of the Project. These included standard mitigation measures to be implemented during construction activities, and other mitigation measures such as specific features in the design of the Project, and habitat works at the dam site or in the Local Assessment Area. After implementation of mitigation measures, the EIS predicted a significant adverse effect on the fish and fish habitat as a result of the potential for the loss of indigenous fish populations or distinct groups of fish.

2.0 Objective and Scope

2.1 Objective

The objective of the Fisheries and Aquatic Habitat Management Plan (FAHMP) is to describe the measures that will be used to mitigate the adverse effects of the Project on fish and fish habitat during the construction and operation phases. The plan has been developed in accordance with the conditions of the Environmental Assessment Certificate (EAC) and Federal Decision Statement (FDS), as indicated below. FDS conditions 8.3 to 8.7 refer to “a fish and fish habitat management plan”, while the EAC condition 4 refers to “a Fisheries and Aquatic Habitat Management Plan”. Each refers to similar requirements for fish. For simplicity, BC Hydro developed one plan, entitled “Fisheries and Aquatic Habitat Management Plan.” Note that additional information for some of the conditions below will be addressed in plans to be submitted under a separate cover.

EAC Condition	Condition	Plan Reference
FISH AND FISH HABITAT		
4	The EAC Holder must manage harmful Project effects on fish and fish habitats during the construction and operation phases by implementing mitigation measures detailed in a Fisheries and Aquatic Habitat Management Plan.	
	The Fisheries and Aquatic Habitat Management Plan must be developed by a QEP	This condition is addressed in FAHMP Section 8.0 Qualified Professionals
	The Fisheries and Aquatic Habitat Management Plan must include at least the following:	

EAC Condition	Condition	Plan Reference
	• Remove temporary structures as soon as they are no longer required.	These conditions are addressed in Construction Environmental Management Plan (CEMP) Section 4.5, Fisheries and Aquatic Habitat Management.
	• Maintain a 15 m machine free zone adjacent to watercourses during reservoir clearing (as measured from the Ordinary High Water Mark).	
	• Place material relocation sites (R5a, R5b, and R6) 15 m back from the mainstem to avoid affecting Peace River fish habitat.	
	• Contour mainstream bars to reduce potential for fish stranding, as advised by FLNR.	This condition is addressed in FAHMP Section 6.2.1.1, Peace River Channel Contouring and Side Channel Enhancement.
	• Incorporate fish habitat features into the final capping of material relocation sites upstream of the dam.	This condition is addressed in FAHMP Section 6.2.3.4, Dam Site Material Relocation Site Enhancement.
	• Contour and cap with gravels and cobble substrate the spoil area between elevations 455 m and 461 m to provide a productive fish habitat that will be available to fish during the operation phase.	This condition is addressed in FAHMP Section 6.2.3.4, Dam Site Material Relocation Site Enhancement.
	• Include fish habitat features (e.g., shears, large riprap point bars, etc.) in the final design of the north bank haul road bed material that would be placed in the Peace River.	This condition is addressed in FAHMP Section 6.2.1.2, River Road Habitat Enhancement.
	• Incorporate fish habitat features into the final design of the Highway 29 roadway that would border the reservoir, east of Lynx Creek.	This condition is addressed in FAHMP Section 6.2.3.2, Highway 29 Realignment Fish Habitat.
	• Construct the Hudson‘s Hope shoreline protection with large material that will provide replacement fish habitat.	This condition is addressed in FAHMP Section 6.2.3.3, Hudson’s Hope Shoreline Protection Fish Habitat.
	• Incorporate additional fish habitat	This condition is addressed in FAHMP

EAC Condition	Condition	Plan Reference
	features (e.g., shear zones and point bars) into the final design of the Hudson's Hope shoreline protection.	Section 6.2.3.3, Hudson's Hope Shoreline Protection Fish Habitat.
	• Contour Highway 29 borrow sites prior to decommissioning to provide littoral fish habitat in the reservoir.	This condition is addressed in FAHMP Section 6.2.3.1, Site C Reservoir Shoreline Enhancement.
	• Cap material repositioning areas with gravel and cobble, and contour to enhance fish habitat conditions.	This condition is addressed in FAHMP Section 6.2.3.4, Dam Site Material Relocation Site Enhancement.
	• Plant a 15 m wide riparian area along the reservoir shoreline adjacent to BC Hydro-owned farmland where necessary to provide riparian habitat and bank stabilization except as approved by the onsite environmental monitor.	This condition is addressed in FAHMP Section 6.2.3.5, Reservoir Shoreline Riparian Planting.
	• Increase wetted habitat by creating new wetted channels and restoring back channels on the south bank island downstream of the dam.	This condition is addressed in FAHMP Section 6.2.1.1, Peace River Channel Contouring and Side Channel Enhancement.
	• Enhance side channel complexes between the dam site and the confluence of the Peace and Pine rivers during low flows.	This condition is addressed in FAHMP Section 6.2.1.1, Peace River Channel Contouring and Side Channel Enhancement.
	• Manage reservoir fluctuation within a 1.8 m maximum normal operating range from the maximum operating level of 461.8 m.	
	• If the reservoir deviates from the normal operating range, the EAC Holder must report the event in accordance with water licence requirements.	
	The EAC Holder must manage construction footprints to reduce the harmful Project effects on fish and fish habitat, in accordance with the conditions of the applicable *Fisheries Act* authorization(s) and direction provided by FLNR.	

EAC Condition	Condition	Plan Reference
	This draft Fisheries and Aquatic Habitat Management Plan must be provided to FLNR, MOE and Aboriginal Groups for review a minimum of 90 days prior to commencement of construction.	This condition is addressed in FAHMP Section 2.3 Consultation
	The EAC Holder must file the Final Fisheries and Aquatic Habitat Management Plan with EAO, FLNR, MOE and Aboriginal Groups a minimum of 30 days prior to commencement of construction.	
	The EAC Holder must develop, implement and adhere to the Final Fisheries and Aquatic Habitat Management Plan, and any amendments, to the satisfaction of EAO.	

FDS Condition	Condition	Plan Reference
8.	**Fish and Fish Habitat**	
8.1	The Proponent shall undertake efforts to avoid or minimize adverse impacts to fish and fish habitat to ensure the continued availability of fisheries resources in the Local Assessment Area.	
8.2	The Proponent shall prepare and submit to the Agency an annual schedule identifying the location and timing of construction activities that may impact fish or fish habitat 90 days prior to such activities occurring.	Submitted under separate cover.
8.3.	The Proponent shall prepare, in consultation with Fisheries and Oceans Canada, Reservoir Area Aboriginal groups and Immediate Downstream Aboriginal groups, a fish and fish habitat management plan.	These conditions are addressed in the Fisheries and Aquatic Habitat Management Plan (FAHMP).

FDS Condition	Condition	Plan Reference
8.4	The Plan shall include:	
8.4.1.	Identification of baseline conditions for fish and fish habitat in the Local Assessment Area;	This condition is addressed in FAHMP Section 4.0, Fish and Fish Habitat Baseline Conditions.
8.4.2.	Measures to mitigate potential effects on fish and fish habitat during construction and operation of the Designated Project including:	This condition is addressed in FAHMP Section 6.0, Fish and Fish Habitat Mitigation.
8.4.2.1.	Erosion and sediment control measures, riparian zone avoidance measures, best practices for watercourse crossings, in-stream work guidelines, and in-stream work timing windows;	These conditions are addressed in CEMP Section 4.5, Fisheries and Aquatic Habitat Management.
8.4.2.2.	Measures to avoid or reduce fish stranding;	This condition is addressed in CEMP Section 4.5, Fisheries and Aquatic Habitat Management. See also FAHMP 6.2.1.1, Peace River Channel Contouring and Side Channel Enhancement.
8.4.2.3.	Operational practices, technologies and design features that minimize downstream fish entrainment past the dam site;	This condition is addressed in FAHMP Section 6.2.2.1, Fish Entrainment.
8.4.2.4.	Measures to mitigate the effects of Total Dissolved Gas concentrations in tailwater on fish; and	This condition is addressed in FAHMP Section 6.2.2.3, Mitigation of Total Dissolved Gas.
8.4.2.5.	Measures to mitigate obstructed upstream fish passage for bull trout and, as appropriate and feasible, other migrating fish species;	This condition is addressed in FAHMP Section 6.2.2.2, Upstream Fish Passage.
8.4.3.	An approach to monitor changes to fish and fish habitat baseline conditions in the Local Assessment Area;	The approach is summarized in FAHMP Section 2.2, Scope as well in the monitoring programs listed in Appendix D. Further information on monitoring will be provided in the Fisheries and Aquatic

FDS Condition	Condition	Plan Reference
		Habitat Monitoring and Follow-up Program.
8.4.4.	An approach to monitor and evaluate the effectiveness of mitigation or offsetting measures and to verify the accuracy of the predictions made during the environmental assessment on fish and fish habitat; and	The approach is summarized in FAHMP Section 2.2, Scope as well in the monitoring programs listed in Appendix D. Further information on monitoring will be provided in the Fisheries and Aquatic Habitat Monitoring and Follow-up Program.
8.4.5.	Any other requirements identified by Fisheries and Oceans Canada in support of its application for an authorization under the *Fisheries Act*.	To date, Fisheries and Oceans Canada has not identified other requirements in support of an application for an authorization under the *Fisheries Act*. Should DFO identify other requirements, these will be taken into account in amendments to the plan, as described in condition 8.7
8.5.	The Proponent shall submit a draft copy of the plan to the Agency, Fisheries and Oceans Canada, Reservoir Area Aboriginal groups and Immediate Downstream Aboriginal groups 90 days prior to submitting its application for authorization under the *Fisheries Act*.	This condition is addressed in FAHMP Section 2.3 Consultation
8.6.	The Proponent shall submit to the Agency the final plan a minimum of 30 days prior to submitting its application for authorization under the Fisheries Act. When submitting the final plan, the Proponent shall provide to the Agency an analysis that demonstrates how it has appropriately considered the input, views or information received from Fisheries and Oceans Canada, Reservoir Area Aboriginal groups and Immediate Downstream Aboriginal groups and shall describe how it has taken the plan into consideration as part of its application for an authorization under the Fisheries Act.	Submitted under separate cover.
8.7.	The Proponent shall implement the plan and provide to the Agency an analysis and summary of the implementation of the plan, as well as any amendments made to the plan in response to the results, on an annual basis during construction and for the first ten years of operation and once every five years for the	This condition is addressed in FAHMP Section 7 Reporting

FDS Condition	Condition	Plan Reference
	next 20 years.	
8.8	The Proponent shall develop an offsetting plan, in consultation with Fisheries and Oceans Canada, to offset residual serious harm to fish and monitor the effectiveness of offsets.	Offsetting plans are submitted as a component of the application for authorization under the Fisheries Act. Information from offsetting plans will be submitted to CEAA as described under FDS Condition 8.9.
8.9	The Proponent shall conduct an analysis for any physical fish habitat offsets proposed in the offsetting plan, in consultation with Transport Canada, Environment Canada, Reservoir Area Aboriginal groups and Immediate Downstream Aboriginal groups, that includes:	These conditions will be met in a separate analysis.
8.9.1	the effects on migratory birds and their habitats;	
8.9.2	the effects on terrestrial species and their habitats;	
8.9.3	the effects on species at risk and species at risk habitat;	
8.9.4	the effects on current use of lands and resources for traditional purposes by Aboriginal peoples;	
8.9.5	identification of navigation impacts; and	
8.9.6	identification of potential sources of contamination (e.g. mercury).	

FDS Condition	Condition	Plan Reference
8.10	The Proponent shall submit to the Agency the results of the analysis in condition 8.9, including a description of how the input, views or information received have been taken into account in finalizing its fish habitat offsetting plan.	This condition will be met in a stand-alone document that is expected to be submitted to CEAA prior to implementing the offsetting plan.

2.2 Scope

The project will be constructed in accordance with the EAC and FDS conditions, which will be achieved during construction and operations by the implementation of:

- Standard mitigation measures (e.g., erosion and sediment control measures) described in the CEMP
- Project-specific mitigation measures (e.g. reservoir shoreline habitat enhancement works and capping of dam site material relocation site with fish habitat features) described in the FAHMP

The FAHMP includes five sections supported by BC Hydro's EIS: 1) introduction; 2) regulatory context; 3) description of fish and fish habitat baseline conditions; 4) summary of predicted effects on fish and fish habitat; and 5) fish and fish habitat mitigation measures. Section 5 describes the mitigation measures that will be implemented in accordance with the EAC and FDS conditions, including standard measures and Project-specific measures.

The fish and fish habitat mitigation measures for the Project are those proposed in the EIS, as well as the EAC and the FDS conditions. The FAHMP has been developed in accordance with these conditions described in the table above. Two plans that closely relate to the FAHMP are the Fisheries and Aquatic Habitat Monitoring and Follow-up Program (FAHMFP) and Fish Passage Management Plan. These two plans will be prepared and submitted separately, as described below.

Following FDS Condition 8.4 the FAHMFP includes:

- "An approach to monitor changes to fish and fish habitat baseline conditions in the Local Assessment Area" (FDS Condition 8.4.3)
- "An approach to monitor and evaluate the effectiveness of mitigation or offsetting measures and to verify the accuracy of the predictions made during the environmental assessment on fish and fish habitat" (FDS Condition 8.4.4)

The general monitoring approach will be to monitor changes in baseline conditions in the Local Assessment Area for physical habitat, lower trophic levels, fish abundance, and community composition. This information will be used to evaluate the effectiveness of Project mitigation or offsetting measures and verify the accuracy of predictions made during the Environmental Assessment. The monitoring programs will be designed to address specific Management Questions and impact hypotheses as defined in the EIS. Many of the baseline studies for the Project were developed with future monitoring in mind such that the sample sites and methodologies could be repeated to monitor potential changes to fish and fish habitat during construction and operation of the project. A summary of proposed follow-up monitoring programs is included as Appendix D.

The future compensation procedure will follow an adaptive process to implement future mitigation and compensation options during Project operations, as informed by results of the follow-up monitoring. The draft FAHMFP will be submitted to FLNR, MOE, and Aboriginal Groups for review within 90 days following the commencement of construction as described in EAC Condition 7.

The Fish Passage Management Plan included in the EIS (Volume 2 Appendix Q) describes the approach to manage fish passage and included as Appendix E in this plan. Following EAC condition 6, a Fish Passage Management Plan, which will include updates since submission of the EIS, will be prepared by QEPs and submitted prior to Project activities that may affect upstream fish passage. The EIS (Volume 2 Section 12) identified the river diversion phase of construction as the first Project activity that is expected to affect upstream fish passage. Additional information on this plan is described in Section 6.2.2.2 Upstream Fish Passage of this plan.

2.3 Consultation

BC Hydro began consultation on the Project in late 2007, before any decision to advance the Project to an environmental assessment. BC Hydro's consultation with the public, stakeholders, regional and local governments, regulatory agencies, and Aboriginal groups is described in EIS Section 9, Information Distribution and Consultation. Additional information on the consultation process and a summary of issues and concerns raised during consultation are provided in:

- EIS, Volume 1, Appendix G, Public Information Distribution and Consulting Supporting Documentation
- EIS, Volume 1, Appendix H, Aboriginal Information Distribution and Consultation Supporting Documentation
- EIS, Volume 1, Appendix I, Government Agency Information Distribution and Consultation Supporting Documentation
- EIS, Volume 5, Appendix A01 to A29, Parts 2 and 2A, Aboriginal Consultation Summaries
- Technical Memo: Aboriginal Consultation

In accordance with EAC Condition 4 and FDS Condition 8.5, the draft Fisheries and Aquatic Habitat Management Plan was submitted to the Canadian Environmental Assessment Agency, Fisheries and Oceans Canada, Ministry of Forests, Lands and Natural Resource Operations, BC Ministry of Environment, and Aboriginal groups named in the EAC and FDS conditions for review and comment on October 17, 2014.

BC Hydro is committed to ongoing consultation on fisheries and aquatic habitat management during construction of the Project, and will continue to consider input received in the future development of the plan.

2.4 Revisions to the Plan

The FAHMP provides information on mitigation measures that will be developed and implemented at different times during construction. For example, fish habitat features will be built into River Road, which will be built at the start of construction. Consequently, detailed design has been completed. For other mitigation measures that would be constructed later during construction, such as contouring Highway 29 borrow sites prior to decommissioning to provide littoral fish habitat in the reservoir, preliminary designs are available and included in the FAHMP. Detailed design will be completed in coordination with the detailed design of the associated project components (i.e., Highway 29).

Further information will become available as detailed design progresses and as the results of pre-construction surveys are received. Further input may also be received from contractors, Aboriginal Groups, the public and regulatory agencies that need to be taken into account in the design. It will be beneficial to take this information into account in a revision of the FAHMP.

When the FAHMP is revised, BC Hydro expects to provide the revised plan for review and comment to the executive director of the Environmental Assessment Office (the "Executive Director"), ii) the President of the Canadian Environmental Assessment Agency (the "President of the Agency"), iii) BC Ministry of Environment, BC Ministry of Forests Lands and Natural Resource Operations, Fisheries and Oceans Canada, and iv) Aboriginal Groups who would potentially be affected by the revised plan.

The period of time provided for review and comment on a proposed material revision will depend on the nature or urgency of the revision and the relative interests or jurisdiction of government agencies and of the rights and relative interests of potentially affected Aboriginal group, and any legal requirement to consult.

3.0 Regulatory Context

In constructing and operating the Project, BC Hydro and its contractors must comply with laws, regulations, and standards of general applicability, as well as Project-specific conditions of approvals, permits, other authorizations, guidelines and protocols that are relevant to the design and implementation of mitigation programs. The following subsections explain how this FAHMP considers and integrates regulatory requirements that pertain to the protection and management of fish and fish habitat.

3.1 Federal

Federal legislation for the *Fisheries Act* and *Species at Risk Act* provided guidance to the fish and fish habitat effects assessment, including determination of the following significance criteria described in EIS Section 12.6.2:

a) The loss of an indigenous fish species, sub-species, populations, or distinct groups or,

b) a reduction in the long-term average standing stock biomass of the fish community relative to the existing baseline condition

The FAHMP takes into account recent amendments to the *Fisheries Act* and follows the guidance provided in the Fisheries Protection Policy Statement (DFO 2013a). More specific guidance is provided in the Fisheries Productivity Investment Policy (DFO 2013b) to undertake effective measures to offset serious harm to fish that are part of, or support a commercial, recreation or Aboriginal fishery, consistent with the Fisheries Protection provisions of Canada's *Fisheries Act*.

Construction and operation of the Project will require authorizations under the *Fisheries Act* for those project components that result in "serious harm to fish". The applications for authorization will an offsetting plan to counterbalance unavoidable residual losses to fisheries productivity and with the goal of providing for the ongoing productivity of recreational and Aboriginal fisheries. BC Hydro has reviewed construction activities with Fisheries and Oceans Canada (DFO), proposed the sequence of applications for authorization, and has submitted an application for authorization for Site Preparation activities.

3.2 Provincial

As described in Section 12.1.1 of the EIS, British Columbia is responsible for regulation of non-salmon freshwater fisheries, including management, conservation, and recreation. The Ministry of Environment and Ministry of Forests, Lands and Natural Resource Operations provide regulatory oversight for the fisheries in the Project area. Development of the FAHMP took into account relevant provincial Plans and Policies[1], as well as the Draft Fish, Wildlife and Ecosystem Resources and Objectives for the Lower Peace River Watershed Site C Project Area (B.C. Government 2011).

The standard fish and fish habitat mitigation measures described in this plan and included in the CEMP support the provincial permitting for the Project, such as the Section 9 Water Act approvals for Project components involving in-stream works.

4.0 Fish and Fish Habitat Baseline Conditions

This section has been developed in accordance with FDS Condition 8.4.1: The Plan shall include: identification of baseline conditions for fish and fish habitat in the Local Assessment Area.

The baseline conditions for fish and fish habitat are described in terms of the following (from EIS, Section 12.3 with amendment as required):

- Fish ecology, including description of fish communities, identification of species composition, distribution, relative abundance, migration and movement patterns, and general life history parameters;
- Fish habitats, including an evaluation of the quality and quantity of fish habitats in the Local Assessment Area. These include critical or sensitive areas such as spawning, rearing, and overwintering habitats and migration routes; and
- Changes in environmental factors (e.g., food, water temperature, sediment transport).

In total, 32 fish species have been recorded in the Fish and Fish Habitat Local Assessment Area. None of the species are officially listed as endangered, threatened, or a special concern under Schedule 1 of the Species at Risk Act (SARA), or are being considered for official listing under Schedule 2 or 3 of SARA.

[1] Relevant provincial Plans and Policies include the B.C. Freshwater Fisheries Program Plan (BCMOE 2007) and Conservation Framework (BCMOE 2009), and alignment with the goals of federal regulatory direction on conservation of fish species and protection of the productivity of fish, fish habitat and fisheries through the *Species at Risk Act*, and the *Fisheries Act*

In British Columbia, one species is listed as “red” (endangered or threatened): spottail shiner; and three are listed as “blue” (special concern): bull trout, goldeye, and pearl dace. The remaining species are designated as “yellow”, described as secure and not at risk of extinction.

In Alberta, two species are identified as “may be at risk” -- pygmy whitefish and spoonhead sculpin. A total of six species have “sensitive” designations, including bull trout, Arctic grayling, lake trout, brook stickleback, northern pikeminnow, and northern redbelly dace. The rainbow trout designation as “at risk” refers to the Athabasca River population. The remaining fish species are “secure”, “not assessed”, or “not determined”.

Table 1. Fish Species Recorded by Baseline Studies in the Local Assessment Area

Group	**Species**		**Provincial Status**	
	Common Name	**Latin Name**	**B.C.**	**AB**
Sport fish	Arctic grayling	*Thymallus arcticus*	Yellow	Sensitive
	Bull trout	*Salvelinus confluentus*	Blue	Sensitive
	Brook trout	*Salvelinus fontinalis*	Exotic	Exotic
	Burbot	*Lota lota*	Yellow	Secure
	Goldeye	*Hiodon alosoides*	Blue	Secure
	Kokanee	*Oncorhynchus nerka*	Yellow	Not assessed
	Lake whitefish	*Coregonus clupeaformis*	Yellow	Secure
	Lake trout	*Salvelinus namaycush*	Yellow	Sensitive
	Mountain whitefish	*Prosopium williamsoni*	Yellow	Secure
	Northern pike	*Esox lucius*	Yellow	Secure
	Pygmy whitefish	*Prosopium coulteri*	Yellow	May be at risk
	Rainbow trout	*Oncorhynchus mykiss*	Yellow	At risk
	Yellow perch	*Perca flavescens*	Yellow	Secure
	Walleye	*Sander vitreus*	Yellow	Secure
Suckers	Largescale sucker	*Catostomus macrocheilus*	Yellow	Sensitive

Group	Species		Provincial Status	
	Common Name	**Latin Name**	**B.C.**	**AB**
	Longnose sucker	*Catostomus catostomus*	Yellow	Secure
	White sucker	*Catostomus commersoni*	Yellow	Secure
Minnows	Brook stickleback	*Culea inconstans*	Yellow	Secure
	Finescale dace	*Chourosomus neogaeus*	Unknown	Undetermined
	Flathead chub	*Platygobio gracilis*	Yellow	Secure
	Lake chub	*Couesius plumbeus*	Yellow	Secure
	Longnose dace	*Rhinichthys cataractae*	Yellow	Secure
	Northern pikeminnow	*Ptychocheilus oregonensis*	Yellow	Sensitive
	Northern redbelly dace	*Phoxinus eos*	Unknown	Sensitive
	Peamouth	*Mylcheilus caurinus*	Yellow	Not rated
	Pearl dace	*Margariscus margarita*	Blue	Undetermined
	Redside shiner	*Richardsonius balteatus*	Yellow	Secure
	Spottail shiner	*Notropis hudsonius*	Red	Secure
	Trout-perch	*Percopsis omiscomaycus*	Yellow	Secure
Sculpins	Prickly sculpin	*Cottus asper*	Yellow	Not assessed
	Slimy sculpin	*Cottus cognatus*	Yellow	Secure
	Spoonhead sculpin	*Cottus ricei*	Yellow	May be at risk

Fish species listed in Table 1 may have traditional use, recreational use, or management value. All fish species listed in Table 1 have ecological function value and have the potential to be affected by the Project.

Fish habitat is defined as any spawning ground and nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly to carry out their life processes (Fisheries and Oceans Canada 1998). A distinction is made for important habitat, which is defined as habitat that is essential for the maintenance of a self-sustaining fish population. Removal of important habitat from production by alteration, destruction, or elimination of access might reduce the sustainability of the population.

Important habitats are present throughout the LAA (EIS, Volume 2, Appendix O Fish and Fish Habitat Technical Data Report) and Appendix F of this plan. Depending on the species, important habitats are located in the Peace River upstream and downstream of the Site C Dam site, and in Peace River tributaries within and outside of the inundation zone of the Site C reservoir. In general, the lower sections of Peace River tributaries provide important spawning and early rearing habitats for suckers and minnows. Important spawning and rearing habitats for sport fish have been recorded only in upstream areas of large tributaries.

The upper Halfway River watershed provides spawning and rearing habitats for the Peace River bull trout population. The Moberly River provides spawning and rearing habitats for the Peace River Arctic grayling population. Maurice Creek provides spawning and rearing habitats for the Peace River rainbow trout population. The Halfway River, Moberly River, and Pine River provide spawning habitats for the Peace River mountain whitefish population. The Beatton River provides spawning and rearing habitats for walleye and goldeye. All tributaries to the Peace River provide spawning and rearing habitats for suckers, minnows, and sculpins. The Peace River downstream of the Halfway River confluence provides rearing habitat for mountain whitefish. Side channels provide habitats for several fish species, in particular northern pike, yellow perch, and spottail shiner. Finally, the mainstem Peace River is a migration area for several species by providing an upstream and/or downstream movement corridor between habitats. Several species require the Peace River as a movement corridor including Arctic grayling, bull trout, mountain whitefish, burbot, goldeye, walleye, largescale sucker, and longnose sucker.

The complete description of fish and fish habitat baseline conditions is found is Appendix F of this plan:

5.0 Potential Effects of the Project on Fish and Fish Habitat

The following is a summary of the effects assessment for Fish and Fish Habitat (EIS, Section 12).

The assessment of the potential effects of the Project on fish and fish habitat was conducted in accordance with the methodology required by the EIS Guidelines. This methodology provided a structured approach to assess and communicate results of the assessment by category of effects for each project component during construction and operations of the Project. An initial step was to assess the potential for interactions between project components or activities, and fish and fish habitat (EIS, Volume 2, Appendix A, Table 2). From this exercise, interactions that may result in an adverse effect were assessed in EIS, Section 12 Fish and Fish Habitat Effects Assessment. Interactions were not carried forward into the effects assessment if standard mitigation measures to avoid or reduce the potential effects are available during construction and well understood to be effective. The implementation of the standard mitigation measures is described in the CEMP.

EIS, Sections 12.1 to 12.2 introduce the assessment approach, and describe the use of models as part of a weight of evidence approach to predictions:

> "The effects assessment of fish and fish habitat uses a first principles approach that includes computer modelling of water quality, water temperature and ice regime, fluvial geomorphology, sediment transport, aquatic productivity, and fish population dynamics. Modelling was used as a tool to inform and support information collected by baseline studies. This combined approach was used to support the prediction of potential effects to fish and fish habitat caused by the Project."

An important component of the assessment was a quantitative ecosystem approach to analyze the range of possible changes in fish and fish habitat, both upstream and downstream of the proposed Site C Dam (Volume 2, Appendix P Part 3 Future Conditions in the Peace River). The methods used are centred on a weight of evidence approach based on multiple performance measures and analyses to assess a range of possible changes in aquatic habitat and fish biomass that may result from operation of the Project. The modelling examined the pathways of effect and ecosystem interactions illustrated in Figure 12.2 of Section 12. The following key metrics were evaluated:

- Total habitat area before and after construction, and during operation of the Project
- Primary production (biomass and production of phytoplankton and periphyton)
- Secondary production (biomass and production of benthos and zooplankton)
- Fish production and biomass (total, as well as by species groups)
- Fish harvest

This approach was informed by discussions with DFO and MOE staff, allowing the approach and specific methodologies, including modeling and metrics, to address emerging directions in fish habitat assessment, and anticipated changes in the approach to regulation. As a result of this work, the assessment in the EIS is consistent with DFO's Fisheries Protection Policy Statement, which states that "very large-scale impacts that are likely to result in ecosystem transformation which require the most detailed estimates of impacts to productivity, likely involving quantitative fish population models." The above-listed metrics of fisheries productivity are consistent with those recommended in DFO's conceptual framework for a science-based interpretation of ongoing productivity of fisheries (DFO 2013a; Randall et al. 2013).

The potential effects of the project on fish and fish habitat were organized into three categories of effects: changes to fish habitat, changes to fish health and fish survival, and changes to fish movement. Potential effects that could occur during construction and operation phases of the Project were grouped as follows (Section 12.4):

Table 2. Potential Effects of the Project by Categories of Effects during Construction and Operations of the Project.

Category of Effect	Construction Phase	Operation Phase
Change in Fish Habitat	• Change in fish habitat due to the construction of the dam and generating station, Highway 29 and Hudson's Hope Shoreline Protection	• Transformation of reservoir habitat during reservoir operations

Category of Effect	Construction Phase	Operation Phase
	• Change in habitat due to construction headpond and reservoir filling	• Downstream habitat changes
Fish Health and Survival	• Sediment inputs from the construction of the dam and generating station, Highway 29 and Hudson's Hope shoreline protection • Sediment inputs from construction headpond and reservoir filling • Stranding of fish • Fish entrainment • Total dissolved gas supersaturation	• Stranding of fish • Fish entrainment • Total dissolved gas supersaturation
Fish Movement	• Hindered fish movement	• Hindered fish movement

Section 12.5 of the EIS addressed the following:

- Assessment of potential effects before mitigation
- Identification of potential mitigation activities
- Assessment of whether there would likely be a potential residual effect after mitigation

A summary of the residual effects of the Project on fish and fish habitat are (from pages 12-37 to 12-39 of the EIS) as follows:

- The reservoir will eliminate 28.0 km^2 of habitat in the Peace River mainstem (predominantly deep run/glide habitat) and 1.63 km^2 of tributary habitat (a mix of pool, riffles, runs and other habitat types). These habitat losses will be offset by the creation of 93 km^2 of reservoir habitat, of which 9.42 km^2 will be littoral habitat (< 6 m deep), and 83.57 km^2 will be limnetic habitat. The total area will increase by 3.3-fold as the river is converted to a reservoir. [pg. 12-37 to 12-38 of EIS]
- Phytoplankton biomass densities ($t \bullet km^{-2}$ or $g \bullet m^{-2}$) are expected to increase about 30X relative to current biomass densities, in both the early and long term. Average periphyton densities in the reservoir are expected to decrease to 5% of their current value in both the early and long term, as only the littoral zone of the Site C reservoir (10.1% of the

area) will grow periphyton, and periphyton production per unit area is expected to be less than in the Peace River. When future conditions are compared to current conditions, it is expected that there will be about a 2.7-fold increase in algal biomass (tonnes of periphyton plus phytoplankton) and a 1.8-fold increase in primary production (t/year of primary production). [pg 12-38 of EIS]

- Total secondary production in the Site C reservoir (i.e., littoral and profundal benthic production plus pelagic zooplankton production) is expected to be very similar to the total current rates of benthic production in both the mainstem Peace River and the area of tributaries that will be flooded when the reservoir is created. Overall reservoir secondary production is estimated to be 89% to 121% of current Peace River secondary production. The form of secondary production will change from being 100% benthic in the current system to a mix of benthic (74% to 81%) and zooplankton production (19% to 26%) in the reservoir. [pg 12-38 of EIS]
- Results for the most likely fish community scenario indicate about a 1.8-fold increase in total biomass of harvestable fish in the Site C reservoir relative to what currently exists in the Peace River, though with a very different species composition. Group 1 fish (burbot, lake trout, rainbow trout, walleye, northern pike) are expected to increase in their overall biomass, as increases in burbot, lake trout, northern pike, and rainbow trout offset decreases in walleye. The total biomass of group 2 passage-sensitive species (Arctic grayling, mountain whitefish, bull trout) is expected to decline, due to declines in the biomass of mountain whitefish and Arctic grayling. Bull trout are expected to increase in the reservoir over the longer term under two of the three fish community scenarios (maximum, most likely), and decline under the minimum scenario. The changes in overall biomass are driven most strongly by a substantial increase in group 3 planktivorous fish species (kokanee and lake whitefish) over both the near and long term.

Residual effects were characterized and a determination of significance was made, as described in EIS, Section 12.6 as follows:

> The project is predicted to have a significant adverse effect on the fish and fish habitat VC as a result of the potential for the loss of indigenous fish populations or distinct groups of fish. The three distinct groups of fish that may be lost are the adfluvial component of the Moberly River Arctic grayling, migratory (adfluvial) bull trout that spawn in the Halfway River, and mountain whitefish that rear in the Peace River and spawn in tributaries of the Peace River or the Peace River mainstem upstream of the Site C Dam site. The loss of these distinct groups occurs because of loss of river habitat, reduced fish health and survival during construction and reservoir filling, and hindered fish movement. Although these distinct groups will be affected, the species as a whole of Arctic grayling, bull trout and mountain whitefish will continue to be present in Peace River tributaries and downstream of the reservoir and may persist in the reservoir.[2]

The EIS described the uncertainty associated with these predictions. In accordance with Section 12.8 of the EIS and to be included as a component of the FAHMFP, follow up monitoring programs will be implemented to verify the accuracy of the predictions and effectiveness of the mitigation measures.

[2] EIS, Section 12.6.3.2, pp. 19-24

6.0 Fish and Fish Habitat Mitigation

FDS Condition 8.4.2 sets out the requirements for measures to mitigate potential effects on fish and fish habitat during construction and operation of the Designated Project. The requirements for this condition are described below.

In developing these plans for measures to mitigate the potential adverse effects of the Project on Fish and Fish Habitat, an objective is to provide for ongoing productivity of fish ecosystems while following relevant guidance provided in applicable regulations and standards, and through dialogue and consultation with appropriate regulatory authorities and Aboriginal groups. Mitigation measures were considered based on values associated with the conservation and utilization of BC Freshwater Fisheries Program[3] and BC Conservation Framework[4] that articulates three conservation goals: 1) Contribute to global efforts for species and ecosystem conservation, 2) Prevent species and ecosystems from becoming at risk and 3) Maintain the diversity of native species and ecosystems. As described in DFO's Fisheries Productivity Investment Policy (DFO 2013b) central to the mitigation measures will be avoidance, reduction and, where necessary, offsets (or compensation) for adverse effects to fish and fish habitat that may result from the construction and operation of the Project. Information on key standard and Project-specific mitigation measures are described in the following sections.

6.1 Construction Environmental Management Plan

This section has been developed in accordance with:

- FDS Condition 8.4.2.1: erosion and sediment control measures, riparian zone avoidance measures, best practices for watercourse crossings, instream work guidelines, and in-stream working timing windows
- FDS Condition 8.4.4.: measures to avoid or reduce fish stranding
- EAC Condition 4:
    - Remove temporary structures as soon as they are no longer required
    - Maintain a 15 m machine free zone adjacent to watercourses during reservoir clearing (as measured from the Ordinary High Water Mark)
    - Place material relocation sites (R5a, R5b, and R6) 15 m back from the Peace River mainstem to avoid affecting Peace River fish habitat
    - Develop a feasible strategy for the salvage and relocation of stranded fish in habitats that are at risk of dewatering

The CEMP describes the mitigation measures that will be implemented during construction of the Project. All construction must be conducted in compliance with the project's Environmental Requirements:

- The Environmental Specifications described in Section 4 of the CEMP
- The conditions included in the EAC for the Project (BC Environmental Assessment Office, 2014)
- The conditions included in the decision statement issued by the Minister of Environment of Canada (CEAA, 2014)

[3] http://www.env.gov.bc.ca/esd/documents/ff_program_plan.pdf
[4] http://www.env.gov.bc.ca/conservationframework

- The permits, authorizations and approvals for the Project issued by regulatory agencies Statutory requirements

The CEMP outlines the requirements for Environmental Protection Plans (EPPs), which will be prepared and implemented by BC Hydro's contractors.

Contractor(s) will be required to retain a Qualified Environmental Professional and qualified Environmental Monitors who will monitor construction activities with respect to compliance with applicable EPPs. The environmental management roles and responsibilities are described in Sections 2 of the CEMP.

Standard mitigation measures and environmental requirements for fish and fish habitat are addressed under the following sections of the CEMP: Fisheries and Aquatic Habitat Management (Section 4.5), Erosion Prevention and Sediment and Control Management (Section 4.4), and Surface Water Quality Management (Section 4.14). CEMP standard mitigation measures and associated environmental requirements for fish and fish habitat addressing EAC Condition 4 are summarized in Table 3.

Table 3. EAC Condition 4 Standard Mitigation for Fish and Fish Habitat Addressed in CEMP

EAC Condition	**CEMP Section**
"Remove temporary structures as soon as they are no longer required"	CEMP Section 4.5
"Maintain a 15 m machine free zone adjacent to watercourses during reservoir clearing (as measured from the Ordinary High Water Mark)"	CEMP Section 4.5
"Place material relocation sites (R5a, R5b, and R6) 15 m back from the Peace River mainstem to avoid affecting Peace River fish habitat.	CEMP Section 4.5
"Develop a feasible strategy for the salvage and relocation of stranded fish in habitats that are at risk of dewatering"	CEMP Section 4.5

CEMP standard mitigation measures and associated environmental requirements for fish and fish habitat addressing FDS Condition 8.4.2.1 and 8.4.2.2 are summarized in Table 4.

Table 4. FDS Condition 8.4.2.1 Standard Mitigation for Fish and Fish Habitat Addressed in CEMP

FDS Condition	**CEMP Section**
"Erosion and sediment control measures"	CEMP Section 4.4
"Riparian zone avoidance measures"	CEMP Section 4.5
"Best practices for watercourse crossings"	CEMP Section 4.5
"In-stream work guidelines"	CEMP Section 4.5

"In-stream work timing windows"	CEMP Section 4.5
"Measures to avoid or reduce fish stranding"	CEMP Section 4.5

6.2 Project-specific Mitigation Measures

The following sections provide descriptions of key mitigation measures in accordance with the EAC and FDS conditions and are organized by geographic location: 1) downstream of the Site C dam site, 2) at the dam site, and 3) within the Site C reservoir area.

6.2.1 Mitigation Measures Downstream of Site C Dam Site

BC Hydro will undertake a number of physical works to enhance fish habitat in the Peace River downstream of the Site C dam site to mitigate 1) altered fish habitat due to the construction of the River Road[5], 2) altered fish habitat downstream of Site C Dam during operations, and 3) potential effects associated with reduced fish health and survival due to stranding during construction and operations (following the categories of effects listed in the EIS Volume 2 Section 12).

6.2.1.1 Peace River Channel Contouring and Side Channel Enhancement

EAC Condition 4

a) "Contour mainstream bars to reduce potential for fish stranding, as advised by FLNR."
b) "Increase wetted habitat by creating new wetted channels and restoring back channels on the south bank island downstream of the dam."
c) "Enhance side channel complexes between the dam site and the confluence of the Peace and Pine rivers during low flows."

FDS Condition 8.4.2

a) "Measures to avoid or reduce fish stranding." (FDS Condition 8.4.2.2)
b) "Measures to mitigate the effects of Total Dissolved Gas concentrations in tailwater on fish." (FDS Condition 8.4.2.3)

BC Hydro will enhance habitat in Peace River side channels and contour mainstem bars between the dam and the confluence with the Pine River to mitigate potential effects of the operation of the Project (EIS, Table 12.19). Side channels provide unique physical habitat characteristics relative to the Peace River mainstem, provide habitats for smaller-sized fish species and younger age-classes of large-fish species and provide refuge during high river flows and during periods of fry emergence (see EIS Section 12.3.2.6). These mitigation works are focused on: a) reducing the extent of dewatering of shallow habitats to reduce the risk of fish stranding, b) maintaining wetted channel areas by maintaining side-channel connectivity, c) providing a suitable compensation depth for refuge from areas of high total dissolved gas, d) providing stable wetted aquatic habitat across the range of Site C operational flows, and e) providing suitable cover and substrates to support various life stages. The general approach is to use a 'cut and fill' excavation and deposition approach in shallow water habitats that are at risk of being dewatered during operations along a 4 km long area downstream of the Site C dam site (Figure 1). Shallow habitats farther from shore are excavated to below the water elevation

[5] The River Level Road, or River Road, is described as the north bank haul road in the Site C EIS.

that occurs at low flows, and this material is used to 'fill' shallow habitats that are at risk of dewatering near shore.

The main channel and side channel areas targeted by these enhancement sites are currently used for rearing and feeding by several fish species, including mountain whitefish, bull Trout, Arctic grayling, rainbow trout and walleye. Fish use of the enhanced areas is expected to increase for these species with the proposed work. The increased wetted surface area and wetted duration of the habitat is also expected to result in an overall increase in primary and secondary productivity. The effectiveness of these measures will be monitored, and will be described in the FAHMFP.

Two side channel and Peace River channel contouring habitat enhancement sites were selected for preliminary design; these are referred to as sites 108R and 109L (Appendix A Peace River Channel Contouring and Side Channel Enhancement). Hydraulic modelling estimates that these preliminary designs reduce dewatered areas between Site C and the Pine River and that the side channels remain open under the range of operational flows. A complete description of the proposed channel habitat enhancement sites is provided in Appendix A.

Detailed design for these sites is ongoing. The design will also take into: 1) opportunities for side channel complexing including boulder placement, 2) foreshore private property boundaries and input from property owners near the channels, and 3) reviewing the high flow design criteria to reduce changes from the contouring at channel elevations that are wetted less frequently and where grasses and other vegetation occurs and may provide habitat for wildlife.

6.2.1.2 River Road Habitat Enhancement

EAC Condition 4 – "Include fish habitat features (e.g., shears, large riprap point bars, etc.) in the final design of the north bank haul road bed material that would be placed in the Peace River"

Habitat will be enhanced along the River Road by incorporating fish habitat features (e.g., shears, large riprap point bars) in the final design (Figure 1). Designs were completed for the construction of twenty 15 m x 4 m riprap spurs aligned perpendicular to Peace River flows (Appendix B Rock Spurs for Fish Habitat along River Level Road). Modelling results indicate the spurs provide a diversity of shoreline flow velocities during the range of Site C operational flows. This diversity of hydraulic habitat and the backwater habitat created by the spurs provide shoreline habitat conditions (e.g., rearing and feeding) that are expected to support resident and migratory fish species.

6.2.2 Mitigation Measures at the Site C Dam Site

BC Hydro will undertake mitigation at the Site C dam site to mitigate 1) reduced fish health and survival due to fish entrainment during construction and operations, 2) hindered fish movement due to obstruction to fish passage during construction and operations, and 3) reduced fish health and survival due to total dissolved gas during construction and operations (following the categories of effects listed in the EIS Volume 2 Section 12).

6.2.2.1 Fish Entrainment

FDS Condition 8.4.2.3 - "Operational practices, technologies and design features that minimize downstream fish entrainment past the dam site"

Measures to manage fish entrainment during construction and operations will be taken into account in the design and operation of the diversion works, spillway and generating station as described in EIS Volume 2, Appendix Q Fish Passage Management Plan and included as

Appendix E of this plan. The specific mitigation measures to increase the survival of fish that are entrained are:

River Diversion Phase of Project Construction

- Utilize large diameter diversion tunnels and associated hydraulics that provide low risk of fish mortality.
- Incorporate smooth and gradual transitions from the round tunnels to the square exits.
- Complete tunnel linings with a smooth concrete surface finish.
- Reduce any obstructions (e.g., boulders) in the tunnel tailrace area.
- Operate the modified diversion tunnel for a short duration, as described in EIS, Volume 1 Appendix B, Reservoir Filling Plan.

Operations

- Use large, slow rotating Francis turbines to increase entrainment survival.
- Design smooth and gradual transitions at the approach channel and penstock entrances and tailrace exit structures into the final design.
- Design the orientation and size of openings and exits to reduce hydraulic turbulence to reduce fish injury.
- Ensure smooth surface finishing on linings of spillways.
- Reduce obstructions (e.g., boulders) from spillway and tailrace areas.

6.2.2.2 Upstream Fish Passage

EAC Condition 6 – "The Fish Passage Management Plan must include at least the following:"

- "Establish a periodic capture data base/protocol/methodology for small-fish species to assess genetic exchange between upstream and downstream fish populations. Data must be provided annually to the relevant federal and provincial agencies."
- "Address genetic differences exceeding beyond a pre-defined threshold (to be determined through discussion with the agencies) by implementing a translocation program."
- "Design the installation and use of a trap and haul facility."

"A draft Fish Passage Management Plan will be submitted to FLNR, MOE and Aboriginal Groups for review a minimum of 90 days prior to Project activities that may impact upstream fish passage."

FDS Condition 8.4.2.5 - "Measures to mitigate obstructed upstream fish passage for bull trout and, as appropriate and feasible, other migrating fish species."

The following measures are proposed to support mitigation of effects resulting from change in fish movement, and will be described in the documents listed below:

- Upstream fish passage during construction and operations will be provided by a trap and haul facility as described in the Fish Passage Management Plan, which supports the approach to fish passage described in the EIS (Volume 2, Appendix Q) and included as Appendix E of this plan.
- A periodic capture and translocation program for small fish species will be implemented, contingent on the results of investigative studies into the genetic exchange requirements of upstream and downstream populations as described in the FAHMFP.

The Fish Passage Management Plan in the EIS (Volume 2 Appendix Q) described the approach to manage upstream fish passage during construction and operations with trap and haul facilities, and described a periodic capture and translocation program for small fish species. Design of the trap and haul facilities have progressed and the designs have been included in construction planning for the project. As described in Section 2.2, following EAC condition 6, a Fish Passage Management Plan, which includes updates since submission of the EIS, will be prepared by qualified professionals and submitted prior to Project activities that may impact upstream fish passage. The EIS (Volume 2 Section 12) identified the river diversion phase of construction as the first Project activity that is expected to affect upstream fish passage.

6.2.2.3 Mitigation of Total Dissolved Gas

EAC Condition 5 – "EAC Holder must manage harmful Project effects on fish during reservoir filling, turbine commissioning and operations by developing and implementing mitigation measures detailed in operational procedures developed by a QEP to:"

- "Minimize levels of total dissolved oxygen gas in the tailwater"
- "Minimize levels of dissolved gas super-saturation"

"These operational procedures must be developed in consultation with FLNR and MOE prior to reservoir filling, and include monitoring activities."

FDS Condition 8.4.2.4 - "Measures to mitigate the effects of Total Dissolved Gas concentrations in tailwater on fish"

Measures to reduce total dissolved gas concentrations during construction and operations were taken into account in the design and operation of the spillway and generating station as described in EIS Volume 2, Section 12.5. The specific mitigation measures include:

Construction

- The spillway design has been modified to reduce total dissolved gas generation
- Develop and implement an operational procedure to reduce the number of hold points and duration of the reservoir filling and turbine commissioning to reduce total dissolved gas concentration in tailwater

Operations

- The spillway design has been modified to reduce total dissolved gas generation.
- Develop and implement an operational procedure to manage the rate of discharge at each gate to reduce dissolved gas generation
- Develop and implement an operational procedure to reduce total dissolved gas concentration in tailwater

The operational procedures to reduce total dissolved gas concentration in the Site C dam tailwater will be developed in consultation with FLNR and MOE prior to reservoir filling. Monitoring of total dissolved gas will be described in the FAHMFP.

6.2.3 Mitigation Measures in the Site C Reservoir

In the Site C Reservoir, physical works will be undertaken to enhance fish habitat and mitigate the categories of effects (following the EIS) of: 1) altered habitat during construction due to construction headpond and reservoir filling, 2) loss of habitat due to construction of the dam and generating station, Highway 29, and Hudson's Hope shoreline protection and 3) reduced fish health and survival due to stranding during reservoir operations (following the categories of effects listed in the EIS Volume 2 Section 12).

Shallow areas of lakes and reservoirs known as the littoral zone (e.g., <6 m deep) are productive habitats because sufficient sunlight penetrates to the bottom to support the growth of algae, and hence aquatic invertebrates and other food for fish. The Site C reservoir will have limited shallow water habitat relative to deep habitat[6]. Therefore, mitigation measures described in the following Sections (6.2.3.1 – 6.2.3.4) are proposed that focus on increasing the area of shallow water habitat at select sites along the reservoir shoreline, including relocated surplus excavated material (RSEM) sites.

A diversity of substrate types that include large substrate that provides interstitial space as cover is important fish habitats (Waters et al. 1991). These habitat measures are known to support fish species of key management interest at Site C, such as rainbow trout and kokanee (Beauchamp et al. 1994; Hassemer and Rieman1981). The proposed mitigation measures are similar to artificial reef structures constructed in lakes and reservoirs (Bolding 2004).

6.2.3.1 Site C Reservoir Shoreline Enhancement

EAC Condition 4 - “Contour Highway 29 borrow sites prior to decommissioning to provide littoral fish habitat in the reservoir.”

Physical habitat works are proposed at five sites to enhance fish habitat in the reservoir (Figure 1). The sites include contouring at two site on the north bank at Highway 29 borrow sites (i.e., km 34-35 and km 42-44; Fig. 1) and three additional sites on the south bank (i.e., km 22-24, km 25-27, km 49-52; Fig. 1) to increase littoral, backwater, and shoal habitat as described in Appendix C Site C Reservoir Shoreline Enhancement.

The goal of this Site C Reservoir shoreline and littoral zone[7] (i.e., shallow water) enhancement is to create a diversity of shoreline habitats and increase the area of productive shallow water habitat. Based on preliminary designs, the reservoir habitat enhancement at the five reservoir shoreline sites are expected to create 1) a single spawning shoal of 37,500 m^2, 2) a single backwater channel of 708,400 m^2, and 3) 335,000 m^2 of littoral zone habitat between elevation 456 m and 459.75 m.

The shallow water habitats will convert predominant sandy shorelines to constructed littoral habitats expected to be dominated by mud bottoms that supports increased primary production through enhanced macrophyte growth and benthic invertebrate density. This habitat is expected to support increased secondary production and higher densities of juvenile fish.

The design criterion for the littoral habitat creation includes a maximum excavation elevation of 459.75 m. This elevation is just below the lower end of the normal reservoir fluctuation zone between the minimum normal reservoir elevation of 460.0 m and maximum normal reservoir level of 461.8 m. Based on the preliminary design (Appendix C), the estimated area of shallow water habitat between elevations 456 m and 461.8 m within the proposed enhancement sites

[6] EIS, Section 12.4.1.2. P. 12-35.

[7] The littoral zone is the shallow areas along the reservoir shoreline between maximum normal reservoir level (MNRL) of 461.8 m and 6 m below MNRL, which support higher aquatic production considered based on light penetration to bottom sediments supporting algal growth and growth of rooted aquatic plants (EIS, Vol. 2, App P, Part 3).

prior to mitigation is 620,000 m^2. The estimated area of shallow water habitat between elevations 459.75 and 461.8 m, including the area at a constant elevation of 459.75 m as well as the area along the cut slope between elevations 459.75 m and 461.8 m, ranges from 1,040,000 m^2 to 1,080,000 m^2. These works are, therefore, expected to almost double the area of shallow water habitat at these sites, and increase the overall aquatic productivity at these sites as the shallow water habitats will not dewater during normal reservoir operations.

6.2.3.2 Highway 29 Realignment Fish Habitat

EAC Condition 4 - "Incorporate fish habitat features into the final design of the Highway 29 roadway that would border the reservoir, east of Lynx Creek."

Riprap, as fish habitat, will be incorporated into the design of the Highway 29 realignment segments that will border the reservoir east of Lynx Creek. Shoreline habitat of the Site C Reservoir will be enhanced by placing riprap in selected littoral areas. In particular, Highway 29, including causeways at Cache, Lynx and Farrell creeks and the Halfway River will be constructed of large riprap. Riprap provides cover habitat for fish species such as rainbow trout, and a diversity of habitat relative to the predominantly sandy shoreline in these areas of the reservoir. Based on the preliminary design, an estimated 21,900 m^2 of rip rap habitat will be placed within the reservoir littoral zone (elevations 456 m to 461.8 m).

Refuges that reduce predation risk are an important factor in the recruitment of many fish (Ahrens et al. 2012; Walters and Korman 1999). For example, juvenile rainbow trout preferentially use complex shorelines as predation refuges and experience higher mortality rates when these areas are not available (Tabor and Wurtsbaugh 1991). Utilization of boulder cover is part of a more general pattern in which many juvenile fish utilize cover to reduce predation risk (Savino and Stein 1982; Werner and Hall 1988; Laplante-Albert et al. 2010).

6.2.3.3 Hudson's Hope Shoreline Protection Fish Habitat

EAC Condition 4 - "Construct the Hudson‘s Hope shoreline protection with large material that will provide replacement fish habitat. Incorporate additional fish habitat features (e.g., shear zones and point bars) into the final design of the Hudson‘s Hope shoreline protection."

Riprap, as fish habitat, will be incorporated into the design of the Hudson's Hope Shoreline Protection. An estimated 12,000 m^2 to 30,700 m^2 (depending on final shoreline protection design) of rip rap habitat will be placed within the reservoir littoral zone (elevations 456 m to 461.8 m).

Additional fish habitat features will be incorporated into the design of the Hudson's Hope Shoreline. The design concept is to place large boulders, including complexes of boulder piles at the toe of the riprap on the reservoir bed. The boulders would create reef habitat which would be utilized by larger (i.e., 20-30 cm) rainbow and bull trout. The design of these additional features will be completed by a QEP as the overall design of the Hudson' Hope Shoreline Protection progresses.

Other fish habitat enhancement concepts, such as shear zones and point bars, were reviewed for segments of Highway 29 or Hudson's Hope Shoreline Protection bordering the reservoir. However, these alternatives were deemed to be not biologically effective given outputs from hydraulic modelling of the Site C Reservoir that predict an absence of water velocities at these sites, reducing the effectiveness of such features.

6.2.3.4 Dam Site Material Relocation Site Enhancement

EAC Condition 4

a) "Incorporate fish habitat features into the final capping of material relocation sites upstream of the dam."
b) "Contour and cap with gravels and cobble substrate the spoil area between elevations 455 m and 461 m to provide a productive fish habitat that will be available to fish during the operation phase."
c) "Cap material repositioning areas with gravel and cobble, and contour to enhance fish habitat conditions."

Fish habitat features, including spawning gravel and cobbles, will be incorporated into the final capping of material relocation sites upstream of the dam that will be inundated by the reservoir, to provide productive reservoir littoral fish habitat. Two relocated surplus excavated material sites upstream of dam site will be contoured and capped to increase shallow water habitat creation within elevation 456 m to 458.5 m (including gravel/ cobble capping) at RSEM area R5a and RSEM area L5 (Figure 1). Preliminary design concepts estimate approximately 10 ha of enhanced littoral habitat at RSEM area R5a and 4 ha of enhanced littoral habitat at RSEM area L5. The gravel and cobble habitat will provide cover for juveniles as well as spawning habitat for species such as lake whitefish.

6.2.3.5 Reservoir Shoreline Riparian Planting

EAC Condition 4 – "Plant a 15 m wide riparian area along the reservoir shoreline adjacent to BC Hydro-owned farmland where necessary to provide riparian habitat and bank stabilization except as approved by the onsite environmental monitor."

A 15 m wide riparian area will be planted along the reservoir shoreline adjacent to BC Hydro-owned farmland to provide riparian habitat and bank stabilization. Riparian planting is proposed for an estimated 16 ha[8] of land, identified as currently non-forested, with a slope less than 25% suitable for riparian development, and within a 15 m zone surrounding the 5 year beach line[9]. The planting is proposed to include a mix of balsam poplar (60%), willow (30%) and red-osier dogwood (10%) live staked at densities of 4,000 stems/ha.

7.0 Implementation and Reporting

This section has been developed in accordance with Condition 8.7 of the federal Decision Statement: "The Proponent shall implement each component of the plan and provide to the Agency an analysis and summary of the implementation of the plan, as well as any amendments made to the plan in response to the results, on an annual basis during construction and for the first ten years of operation and once every five years for the next 20 years".

A proposed implementation schedule for fish and fish habitat mitigation measures in accordance with EAC and FDS conditions is included as Figure 2. The timing of mitigation measure implementation is coordinated with specific Project activities. For example, the CEMP will be

[8] Comprised of an estimated 4 ha of Crown and 12 ha of BC Hydro owned land.
[9] Five-Year Beach Line is the predicted extent of shoreline retreat at the maximum normal reservoir level five years after impoundment of the proposed reservoir (EIS, Vol. 2, Appendix B, Part 2)

implemented at the start of construction and River Road habitat enhancement construction is concurrent with construction of River Road.

BC Hydro will provide annual reports on the implementation of the Fisheries and Aquatic Habitat Management Plan to the Agency. These reports will include a summary and analysis of plan implementation, and will be submitted to the Agency during construction and for the first ten years of operation and once every five years for the next 20 years.

Annual reports will also include a description of any amendments as described in Section 2.4.

8.0 Qualified Professionals

Table 4 lists the qualified individuals who prepared the FAHMP.

Table 4. Qualified Professionals

Qualified Individual	Expertise
Dave Hunter, BSc., RPBio	Fisheries
Brent Mossop, MRM, RPBio	Fisheries

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Figure 1. Locations of fish and fish habitat mitigation measures.

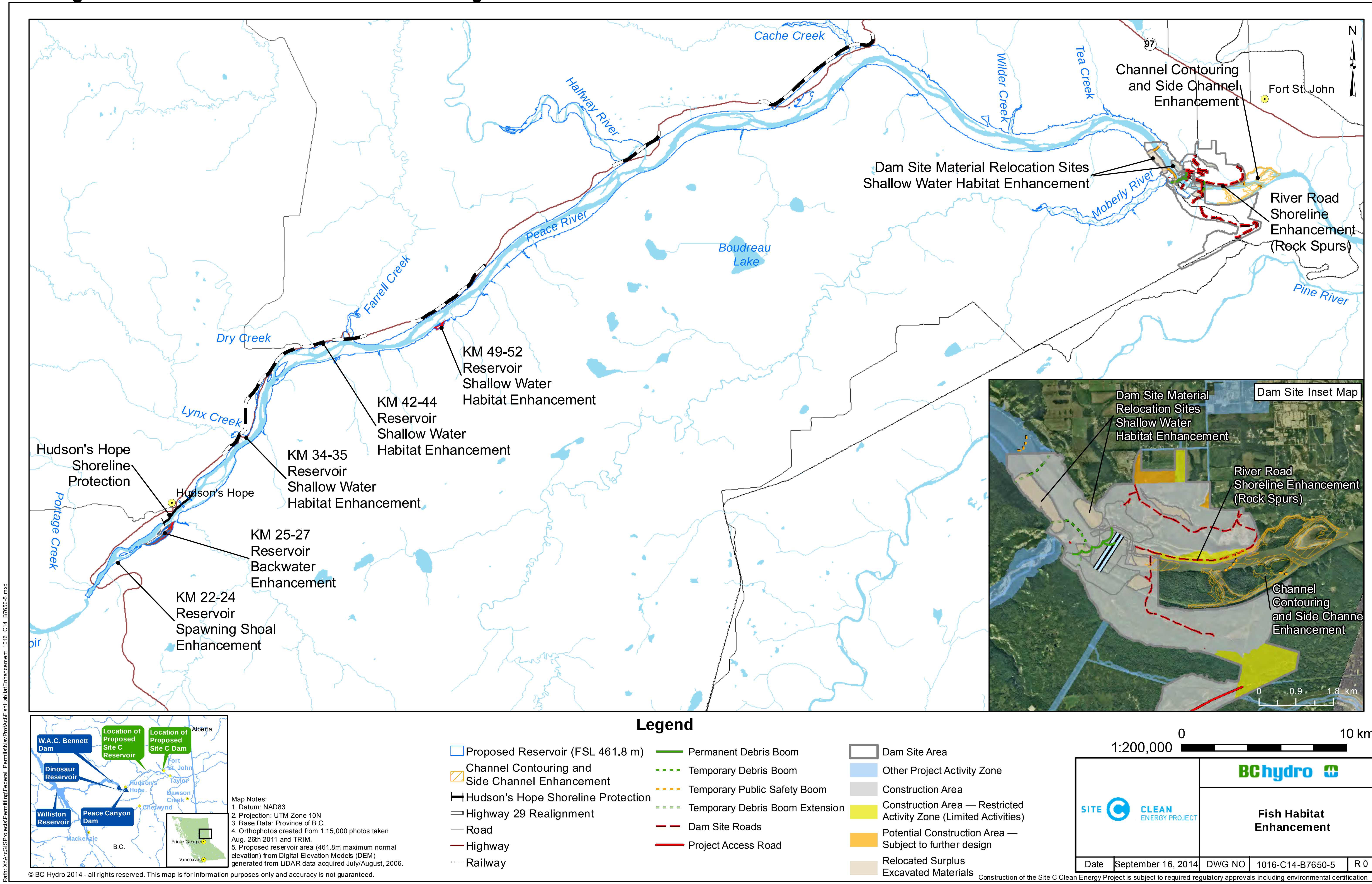
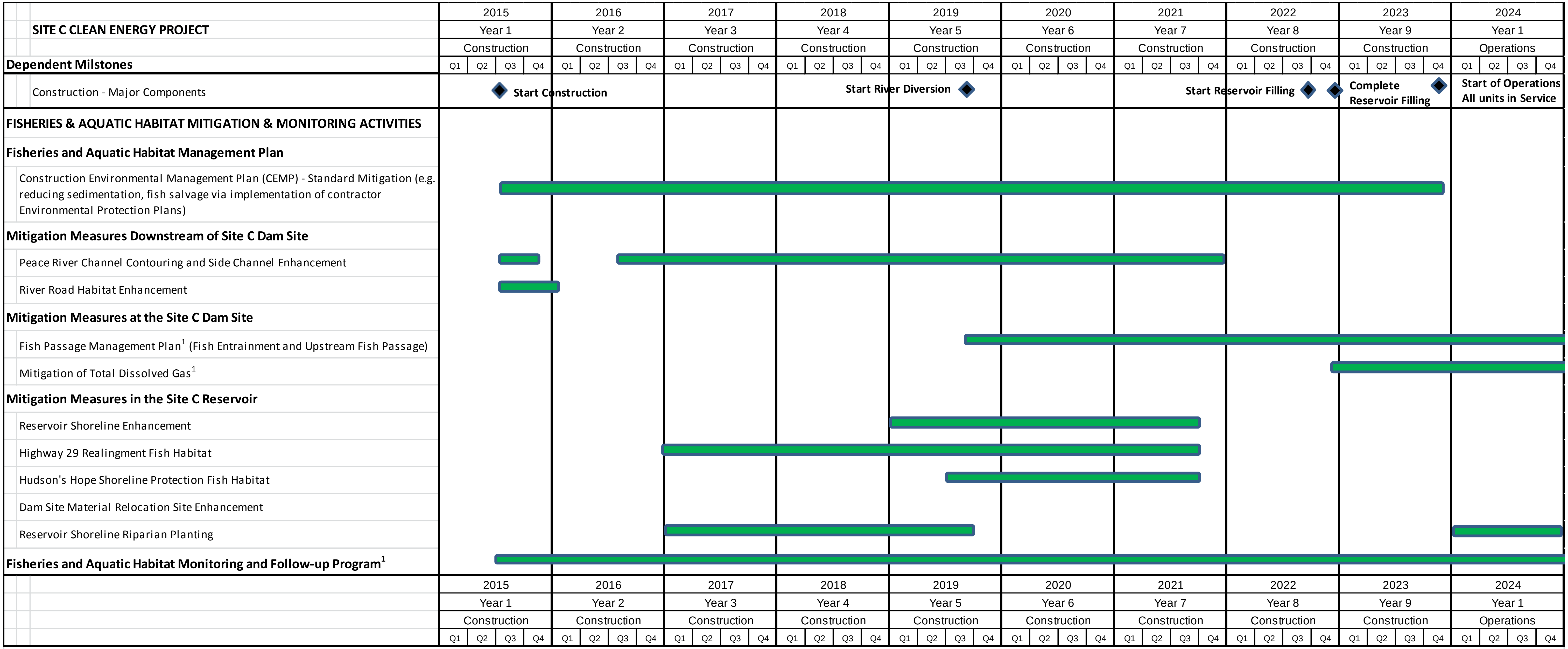


Figure 2. Fish and fish habitat mitigation implementation schedule.



[1] Implementation of mitigation and monitoring activities to continue through operations Year 30 in accordance with EAC and FDS conditions.

Appendix A - Peace River Channel Contouring and Side Channel Enhancement

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memorandum

To:	**Site C Project Team**	**Date:**	29 May 2015
From:	Joanna Glawdel, Barry Chilibeck (NHC)	**No. Pages:**	23 + drawings
cc:		**Project No.:**	3000634
		Ref. No.:	

Re: **Peace River Channel Restoration Downstream of Site C**
Preliminary Design Technical Memorandum - Update - FINAL

1 Introduction

Northwest Hydraulic Consultants Ltd. (NHC 2014a) identified possible locations for fish habitat mitigation works in the Peace River, downstream of the proposed Site C project. The study focused on mitigating downstream effects identified in the Environmental Impact Statement (EIS) in BC Hydro (2013a). This included increasing wetted channel areas at minimum operational flows and decreasing the change in wetted areas between a representative minimum and maximum flows to reduce channel dewatering[1] and potential fish stranding sites.

The NHC 2014a report included a number of opportunities developed at a conceptual level where dewatering could be reduced in the reach downstream of the Site C dam to the Pine River confluence (Site C to Pine River). These mitigation works are focused on reducing potentially dewatered areas and increasing available habitat for fish by:

1. Maintaining channel connectivity in active side channels under modelled high operations Site C flows;
2. Infilling or opening inactive side channels; and
3. Deepening shallow lateral and point bars below the low water surface elevation.

Based on discussion with BC Hydro's Site C Project team two (2) sites were selected for preliminary design; 108R and 109L (**Figure 1**). Details of these preliminary designs were provided in technical memorandum in NHC 2014b which identified the design methodology, proposed construction methodology, and discusses the habitat benefits of the preliminary design sites.

In consideration of inputs received from the preliminary designs presented in NHC 2014b, the designs have been updated with revisions to the design criteria. Specifically, the updated designs presented in this memorandum incorporate a revised upper limit design flow criteria for mitigating dewatering. This revision is intended to reduce changes in areas that are wetted less frequently and where grasses and other vegetation occurs that may provide habitat for wildlife. This technical memorandum discusses the design evolution and replaces the previously issued memorandum (NHC 2014b).

[1] Dewatering is the area of Peace River channel that is wetted and then dried or areas that become isolated between representative maximum and minimum discharges.

1.1 Site Investigation

NHC conducted field investigations in the project area (**Figure 1**) between April and May 2015. During the field investigations, bathymetric and topographic survey data was collected and geomorphic material sampling and gradations of surface and subsurface materials were assessed. In addition, observations of channel and bank conditions were made and the locations of hydraulic controls and hydraulic features were noted.

1.2 Operational Flows

The annual and seasonal Site C reservoir release duration curve as submitted in the Environmental Impact Statement (Volume 2, Appendix D: Surface Water Regime Technical Memos) is shown in **Figure 2**. BC Hydro (2013b) used a synthetic powerhouse discharge data set to assess wetting and drying patterns due to high operations of the Site C project. Details of the synthetic data set development are discussed in BC Hydro (2013b) and NHC (2014a).

Conceptual (NHC 2014a) were completed with maximum and minimum wetted areas for Site C operations considering a minimum flow of 390 m^3/s and maximum flow of 2,520 m^3/s, which are representative of the upper and lower limits of the synthetic flow release.

Conceptual designs (NHC 2014a; NHC 2014b) show large amounts of area where fill would be placed to raise the elevation above that to prevent dewatering. Some of these areas were located where grasses and other vegetation may provide habitat for wildlife (Site C Environmental Impact Statement Vol 2 Section 13). Opportunities were examined to reduce changes to these areas while still providing the benefits to aquatic habitat and fish.

The predicted reservoir release duration curves (**Figure 2**) were reviewed by the project team and a maximum operational flow of 2,520 m^3/s is estimated to be released less than 1% of the time annually. Inundation areas for various flows were examined and options to revise the upper bound design flow criteria for evaluating dewatering were suggested. The synthetic high operational curve for the project was reviewed (BC Hydro 2012a) and a revised design criteria flow of 2,060 m^3/s was selected as the upper bound for wetted areas. This discharge is predicted to be exceeded approximately 8% of the time.

Figure 3 estimates the extents of dewatered areas under with Site C operations when assuming upper limit for wetted areas with a flow of 2,060 m^3/s and 2,520 m^3/s. the interface between the lighter and darker blue polygons shows the approximate reduction in project extents with the reduced upper maximum operational flow of 2,060 m^3/s.

The reduced maximum operational flow reduces changes to areas with vegetation by limiting the area of intermittently wetted area that would otherwise be modified to mitigate aquatic impacts. The additional area between the two flow maxima would continue to function and have similar vegetation characteristics to the current intermittently wetted areas, and maintain wildlife habitat.

Flow conditions used for the development of updated preliminary designs are listed in **Table 1**.

Table 1. Representative Site C high operation minimum and maximum discharges used to assess dewatering and develop preliminary designs.

Flow Description	Discharge (m^3/s)
Maximum flow	2,060
Minimum flow	390

1.3 Design Criteria

The design basis were based on NHC (2013a, 2013b) and Golder (2013), as follows:

1. Provide stable, wetted aquatic habitat for a range of operational flows;
2. Optimize habitat suitability in terms of depths and velocities for expected fish community;
3. Design channel sections and profile provide a range of hydraulic habitat types: cover, feeding, holding; and
4. Provide predominantly gravel/cobble channel substrate suitable for rearing, feeding and benthic production.

Fish species are expected to utilize side channel habitat based on the hydraulic characteristics of the channel, available substrate and cover. Golder (2013) provide depth and velocity suitability curves from literature that outline a range of depths and velocities for rearing and feeding for fish species in the Peace River which include rainbow trout, mountain whitefish and bull trout. Low gradient, slow moving side channel habitats with fine sediments are likely to develop fish communities dominated by sucker, minnows and mountain whitefish. The preliminary design focused on increasing wetted habitat over a range of operational flows rather than targeting specific species, which will be reviewed during detailed design.

Adequate velocities in side channels should be provided under all flows to prevent infilling with fine sediment. NHC (2013c) suggests fine sediments can be flushed with high flows which expose substrates and improve habitat conditions. Preliminary designs are developed to allow for channel flushing.

In addition to aquatic habitat design criteria, the fish habitat works should:

1. Incorporate design features of project infrastructure within the project location (i.e., roads, water intake structures, etc.);
2. Limit changes to, or improve existing terrestrial vegetation and wildlife habitat ; and
3. Incorporate information received from public consultation where relevant in the detailed design. Information from the public consultation can include existing use of the channel, access, and stability.

1.4 Existing Modelling

BC Hydro (2012a) developed a 2D hydraulic modelling study of the reach downstream of the proposed Site C dam to Pine River. Channel and overbank topography was provided by BC Hydro's Digital Elevation Model (DEM).

Adjustments were made by NHC to the BC Hydro DEM in the area of the dam site which incorporated modifications for the dam construction including: the spillway sill, spillway tailrace, diversion tunnel, and island excavation downstream of the tailrace. These modifications were based on general arrangement drawings (Drawing 1016-C14-05917) and River2D bedfiles provided by the Site C team in December 2013. Following further discussions with the Site C team, the gravel bar at River Km 107 was lowered to El. 406.0 m as part of dam construction modifications works and is further discuss in Section 3.

It should be noted that the conceptual (NHC 2014a) were developed considering an island excavation level of El. 408 m which produces a higher difference between the operation low and highwater levels. The finalized elevation of the island and all other in channel works (i.e., north bank road construction) and resulting downstream water levels should be considered in detailed design development.

Using TELEMAC-2D, two model scenarios were run:

1. future flows with Site C without mitigations.
2. future flows with Site C Dam with preliminary mitigation designs.

2 Preliminary Mitigation Design

2.1 Design Basis

Detailed engineering and design of the two selected sites was undertaken using design software (AutoCAD Civil 3D) and hydraulic modelling. Initial conceptual mitigation for the area between Site and the Pine River was developed using ARC GIS and hydraulic modeling (TELEMAC-2D) in NHC (2014a). The resulting modelled water levels and locations of cut and fill were used as a basis for further developing preliminary designs. The procedure used for preliminary design involved the following steps:

1. Surface of the local topography for the preliminary design areas were created in AutoCAD Civil3D© using a combination of BC Hydro's digital elevation model (DEM) and NHC's topographic and bathymetric survey data (collected in April and May 2015) where processed and available.
2. The modelled maximum and minimum water surface elevations in the conceptual modelling were projected on the surface to determine the depth of excavations and height of fills required to prevent dewatering under the maximum operational flow scenario. An additional 0.5 m was added to the water surface elevation to account for potential sedimentation and infilling. Flow depths in channel sections and on bars will be varied to provide variable hydraulic conditions at the low flow.
3. Channel inlet and outlet inverts were selected to maintain continuous wetting under the range of operational flows. Invert elevations were extended upstream and downstream, with sloping and grading to ensure adequate flow at low water conditions.

4. Channel sections widths were determined to ensure adequate velocity at minimum flows to prevent sedimentation, and at the same time limit excessive velocities and shear stresses that may erode the excavated channel side slopes and bed at maximum flows.
5. Efforts were made to balance cut and fill in the areas so that no additional materials are needed to be imported for fill or for construction access. In some cases, material may need to be hauled off site and can be used to develop infrastructure for the dam (e.g., road material) to reduce the area where this material would need to be placed as fill.
6. Local morphology near the excavation and fill sites was incorporated in the designs by shaping and contouring the excavation and fill material to complement existing channel features (e.g., bed, lateral bars, permanent islands, etc.).
7. The preliminary design surfaces were projected and smoothed to the DEM using ARC GIS and modelled in TELEMAC-2D. The existing TELEMEC-2D mesh was refined to include channel details (i.e., channel bottom and slope) where node spacing was too coarse.
8. Using the same methodology as in the conceptual design development (NHC 2014a), polygons of wetted areas were extracted from the model to evaluate effectiveness in mitigating for dewatering. In detailed design development, further refinements can be made to address additional areas where dewatering occurs near the design sites.
9. Preliminary material cut and fill volumes are estimated by comparing design surfaces and the existing design surface. Detailed site survey will be required to develop detailed site designs to more accurately estimate material volumes and refine designs to incorporate additional site features.

3 Site 108R

3.1 Site Description

Site 108R[2] is located immediately downstream of the proposed Site C project site on River right (Figure 1). The site consists of a large vegetated island complex, numerous historic side channels and a distinctive side channel which separates the island from the mainland that is active under typical operational flows. Modelled results of Site C operating conditions indicate that connectivity in the side channels will be disrupted and that isolated pools may result in wetted areas when waters recede. Modelling results also indicate that the point bar at the downstream end of the island (River kilometer 109.5) will also be dewatered in the maximum design scenario.

3.2 Design

The preliminary design for the site is included in Drawing 3000634-108R Sheets 1-2.

[2] River kilometers reported in distance downstream of the GM Shrum (GMS) generating station.

The design includes opening of two ephemeral side channels identified in NHC 2014a. These channel alignments were designed to follow the existing side channel alignment. In opening these channels, the channel inlet, outlet and slopes were designed to maintain continuous wetted habitat for the range of water levels. Material from the side channel excavation can be side cast in the fill areas shown on the drawings and used to infill depressed areas and inlets to ephemeral side channels which pose a dewatering risk.

The design includes deepening of the existing backwater channel in areas where a dewatering risk is shown in modelling results (**Photo 1**). Backwater habitat is provided by deepening sections of the southern side channel where flow will be limited in post project conditions.

The point bar at the downstream end of the island, across stream from Site 109L, is lowered in the design. Excavated material can be placed where vegetation is sparse (i.e., lack of trees and permanent vegetation) to allow for the development of riparian vegetation.

The mid channel bar located at River kilometer 107 has been included in the dam construction design and is lowered to El. 406.0 m. The bar is located downstream of the dam, and immediately downstream of the vegetated island planned for removal to El. 406.0 m during the construction phase. Excavation is to support decrease of generating station tailwater elevations to both facilitate design specification for fish passage and maximize turbine efficiency. The excavation also increases the area of deeper habitat where that fish can inhabit during periods of elevated total dissolved gas. Material from this excavation is to be used to complete upstream dam site works.

3.3 Land Tenure and Site Access

Land tenure, licence to occupy crown lands, and rights of ways are underway or planned, and are handled solely by BC Hydro. There are no private lands within the works proposed for Site108R.

Site access requirements are limited to the initial mobilisation and demobilisation of equipment (e.g., excavators and off-road dump trucks) and daily access for construction crew and inspectors, and demobilization and deactivation of access at the completion of construction.

Access to this site from the south bank is from an existing road network off Highway 29 and Jackfish Lake Road which is to be maintained for Site C dam construction. North bank access will also be available over the temporary Peace River Construction bridge directly upstream from the 108R site. Local access to the site would be along constructed roads within the proposed re-contoured areas. No additional roads are proposed outside the contouring area extents.

Works proposed on the mid-channel bar at River kilometer 107 can be conducted with other in channel works proposed for dam construction.

Materials from excavation can be placed in fill areas at the elevation corresponding to 2060 m^3/s or higher, however, options for use of excess excavated materials will be considered for dam site works. Based on the available fill sites, trucking and export of materials off site will be required.

4 Site 109L

4.1 Site Description

Site 109L is an island complex located at River kilometer 109, on the left bank of the Peace River just downstream of the Site C Project (**Figure 1**).

The island complex contains two (2) primary side channels. The north channel (north arm) is constrained on the left bank by a steep valley wall along the left bank and vegetated island on the right bank. The second channel (south arm) is located between two island bars, of which the southern one has limited established vegetation.

Hydraulic modeling of this area indicates the north arm is partially dewatered under Site C operations (NHC 2014a). The inlet is dry during minimum operation flow and the channel is limited to depths below 0.3 m. The south arm inlet remains connected to the main channel during the low water operation with water depths below 0.7 m, but has potential for dewatering due to high elevation points in the channel profile and adjacent low lying areas along the banks which become dewatered.

4.2 Design

The preliminary design for the site is included in Drawing 3000634-109L Sheets 1-2. Details of works for the north arm (**Photo 2**) are not provided on the drawing. The north arm will be designed to convey the operational flows and limit dewatering through the channel with re-contouring. Options for modifications to the north arm will be shared with the owners of adjacent private properties 2015 and details of preferred design options will be presented in the detailed design package.

Proposed restoration for this site includes the following:

1. Excavation of the south arm of the channel (**Photo 3**) to depths below the Site C operational low water level and increasing the channel wetted width. Material from excavation can be side cast on the right bank bar to reduce existing dewatering risk.
2. Deepening of existing gravel bars to provide shallow water bar habitat in the main stem.
3. Depositing of excavated materials on channel banks above the high operational water elevation and closing of ephermal side channel areas with potential dewatering issues.

The channel invert and elevations were determined from the low water surface elevation from the hydraulic model output, defined at a discharge of 390 m^3/s. The channel slope was made equal to the existing water surface slope of the channels. Channel velocities will provide flushing of fine sediments during higher flows and will be confirmed with morphodynamic modelling in the detailed design report.

The lateral point bar at the entrance of the north arm channel is lowered to El. 407 m (**Photo 4**). Habitat depressions will be included (approximately 1.5 m deep and ranging from 5 to 20 m wide) to provide hydraulic complexity (NHC 2015). This work will be completed with site preparation activities in Year 1 (i.e., 2015).

The south arm is deepened by 0.5 to 1.75 m with a 30 m bottom width and 2:1 side slopes. The location of fill material was chosen to mitigate the areas that are wetted during the maximum design criteria discharge (2,060 m^3/s) and dry at low water and where existing vegetation is sparse.

4.3 Land Tenure and Site Access

The majority of the project site is within Crown and BC Hydro owned land. Some private property boundaries appear to extend into the existing river channel. As noted previously, options for modifications to the north arm will be shared with the owners of adjacent private properties in 2015..

An access road for dam construction to be known as River Road is planned on the left bank of the River and is shown on Drawing 300228-109L-Sheet 2 which will be constructed in Year 1 (in 2015). Site works can be designed and planned with the road construction, with appropriate ramps/access points to the project Site for access.

Model results indicate that the channels separating the site from the mainland (i.e., north and south arm channels) are wadable under low flows, and fording of initial equipment may be possible, although this type of access may have challenges for reasons of safety and reliability associated with construction. The project site can be accessed with temporary bridges or culverts.

The use of excavated river materials from the upstream end of the site (adjacent to the dam site construction access road) will be considered with stockpiling or hauling for use within the dam site construction area; this may reduce the volume of excavated material that would need to be side cast.

5 Constructability

Equipment capability and environmental requirements will define the potential construction methods, work site isolation and dewatering requirements that are expected to form a large part of the contingency and project risk. Due to regulation on the Peace River, extended low flow periods do not typically occur.

The construction of isolation berms at the entrance of large side channel complexes should be considered that would allow more extensive dry excavations as well as wet excavations in static, lowered water depths. Ring berms and wing dikes may be another option that would allow isolation of work areas from flowing water. In most cases, temporary berming or dike construction to isolate work areas will be the most practical and efficient given the large volumes and types of channel sediments. On isolated bars, barge-mounted, long boom excavators and drag lines on raised work platforms could be used to “dig and pile” sediments. For the excavation of the inlet at 109L in site preparation works, a long boom excavators on temporary access causeways will be used; this method could be applied to other sites. Fortunately, most of the excavations are relatively shallow.

The intention of the design is to not require the importing or removal of material from the site, however, options to reduce fill volume in areas will be assessed and materials may be used for dam site construction activities, or if inappropriate for use in construction hauled from site. Given specific site requirements, some processing and screening of materials may be required on site where velocities may lead to scouring. Processing and screening of materials for use in channel construction may be required and would add to cost of construction although alternatives to using graded material could be made by providing allowances for design limited erosion and channel coarsening. Saturated fine sediment material may require stockpiling and draining prior to placing in fill zones or hauling from site as required. Additional habitat complexing features such as boulders and could be gathered from the site boundaries.

Access roads are expected to be developed for some of the construction sites as well as temporary bridge crossings and/or culverts. Following completion of the project, temporary works should be removed and disturbed ground for site haul roads is to be graded back and restored. Natural re-vegetation of disturbed areas, including fill areas, will be advanced through roughening and loosening the ground and the placement of woody debris. Large areas of woody debris were identified by NHC in the field investigation at 109L and 108R. The materials can be salvaged during grubbing, stored and placed over fill areas after a rough and loose surface treatment.

It is expected that replanting with native vegetation will not be required, and optimum conditions for natural succession of plant species in riparian and terrestrial areas will be achieved through surface preparation and grading of existing materials.

6 Assessment of Mitigation

The proposed preliminary mitigation works in NHC 2014b were modeled in TELECMAC-2D to evaluate performance and these results were interoperated to assess the proposed mitigation works as presented in the attached drawings. Two scenarios were investigated: Site C and no mitigation works, and Site C with preliminary design mitigation works. Spatial boundaries representing the instantaneous maximum and minimum wetted areas were extracted from the TELEMAC model into GIS shapefiles, using the similar procedure as outlined in BC Hydro (2012a) and applied in NHC 2014a. The minimum, maximum and change in wetted surface areas for the two conditions are compared in **Table 2** with the two preliminary design sites implemented.

Table 2. Minimum and maximum wetted channel areas in Site C operations without mitigation works and Site C operations with proposed preliminary design mitigation works with a minimum flow of 390 m^3/s and maximum of 2,060 m^3/s.

Model	Parameter	Value
Site C No Mitigation	Minimum wetted area (ha)	628.5[1]
	Maximum wetted area (ha)	800.4[1,2]
	Dewatered area (ha)	171.9
	Dewatered area (%)	21.5%
Site C with Mitigation	Minimum wetted area (ha)	653.4[1]
	Maximum wetted area (ha)	780.7[1,2]
	Dewatered area (ha)	127.3
	Dewatered area (%)	16.3%
Site C with Mitigation	**Percent Increase in dewatered area (ha) vs. PCN**	8.7%
	Percent Reduction in dewatered area (ha) vs. Site C	-25.9%

[1] Note results reported are different than those in NHC 2014a due to modifications to the DEM downstream of the dam

[2] Reported at time step 316,200 s in hydraulic modeling from NHC 2014b.

The preliminary designs implemented at the two sites results in an increase in minimum wetted area in the Site C to Pine River reach by 24.9 ha. The before-after analyzes using the hydraulic modelling and the preliminary design confirms that there is a 26% reduction in the dewatered areas between Site C and the Pine River with implementation of the preliminary design mitigation from 171.9 ha to 127.3 ha.

7 Detailed Design Issues

7.1 Hydraulic Complexing

The primary objective of the designs is to reduce the potential for fish stranding which can be achieved by reducing the amount of dewatered area in the system. The preliminary designs deepen existing side channels and shallow bars which may reduce the available shallow water habitat at high flows. Relatively simple trapezoidal channel sections, steep side slopes and uniform profiles were used in developing the preliminary designs. In detailed design development, consideration should be given to balance the risk of stranding and providing a range of habitats over the operational flows. Methods which could be used to achieve this include:

1. Alternating submerged bar forms that create complex flow patterns in relatively uniform channels.

2. Large submerged riffles, bars or shoals, alternating with deeper pools that provide shear zones at high flows and residual pools for cover and holding at lower flows.
3. More numerous smaller, narrower channels that offer complex flow patterns and can be associated with cover in the form of riparian vegetation or structure (e.g., boulder clusters).

Specific restoration details for habitat complexing and bank protection have not been included in the preliminary designs and should be incorporated in detailed design development. NHC *et al*. (2010) examined materials and structures which can be used to complex and restore habitat within Peace River side channels as well as mitigate the effects of flow fluctuations within the channels. For application on the Peace River for habitat complexing, the following is noted:

1. Individual elements are likely to have less utility due to varying depths within the side channels; boulder clusters (e.g. greater than 2 m in height) associated with deeper pools may be preferred.
2. Individual boulders and boulder clusters are likely to have limited effects in larger side channels due simply to scale of relatively local hydraulic effects. Larger bar forms and shoals are likely more applicable.

Detailed 2-D hydraulic modeling can be developed for detailed designs which incorporate hydraulic features and channel complexity to model performance for maintaining desired velocities and depths under a range of flows.

7.2 Additional Information to Incorporate in Detailed Designs

Specific site survey and elevation data has been collected to develop detail designs and includes information on existing vegetation extents and confirm locations of cut and fill sites. Final designs should be based on the latest survey data and should incorporate finalized dam construction layout and proposed instream channel changes from other works.

Ground investigations of surface and subsurface materials were undertaken (Section 1.1) at multiple locations along the mitigation areas to document surficial materials, groundwater conditions, and access limitations. An assessment of locations of potential bank protection and stabilization works at the design sites should be conducted and mitigation measures incorporated into detailed designs.

Isolation and dewatering techniques for the individual sites will need to be further developed for the individual design sites. Site specific construction techniques will also be further developed for cost efficiency, which could include the usage of barges.

8 Closure

We trust this memorandum documents the preliminary design aspects of the channel restoration work for mitigation of potential impacts related to the Site C Project. For further information or detail, please contact any of the undersigned.

Sincerely,

northwest hydraulic consultants ltd.

Prepared by
Joanna Glawdel, MASc, P.Eng APEGBC#40311
Project Engineer

Reviewed by
Barry Chilibeck, MASc, PEng APEGBC #17430
Principal

ENCLOSURES

NOTIFICATION

9 References

BC Hydro. 2012a. Site C Clean Energy Project – Downstream Flow Modelling (2D). Inter-office memo prepared for Site C Clean Energy Team. Prepared by F. Sadeque and M. Garrett. December, 2012.

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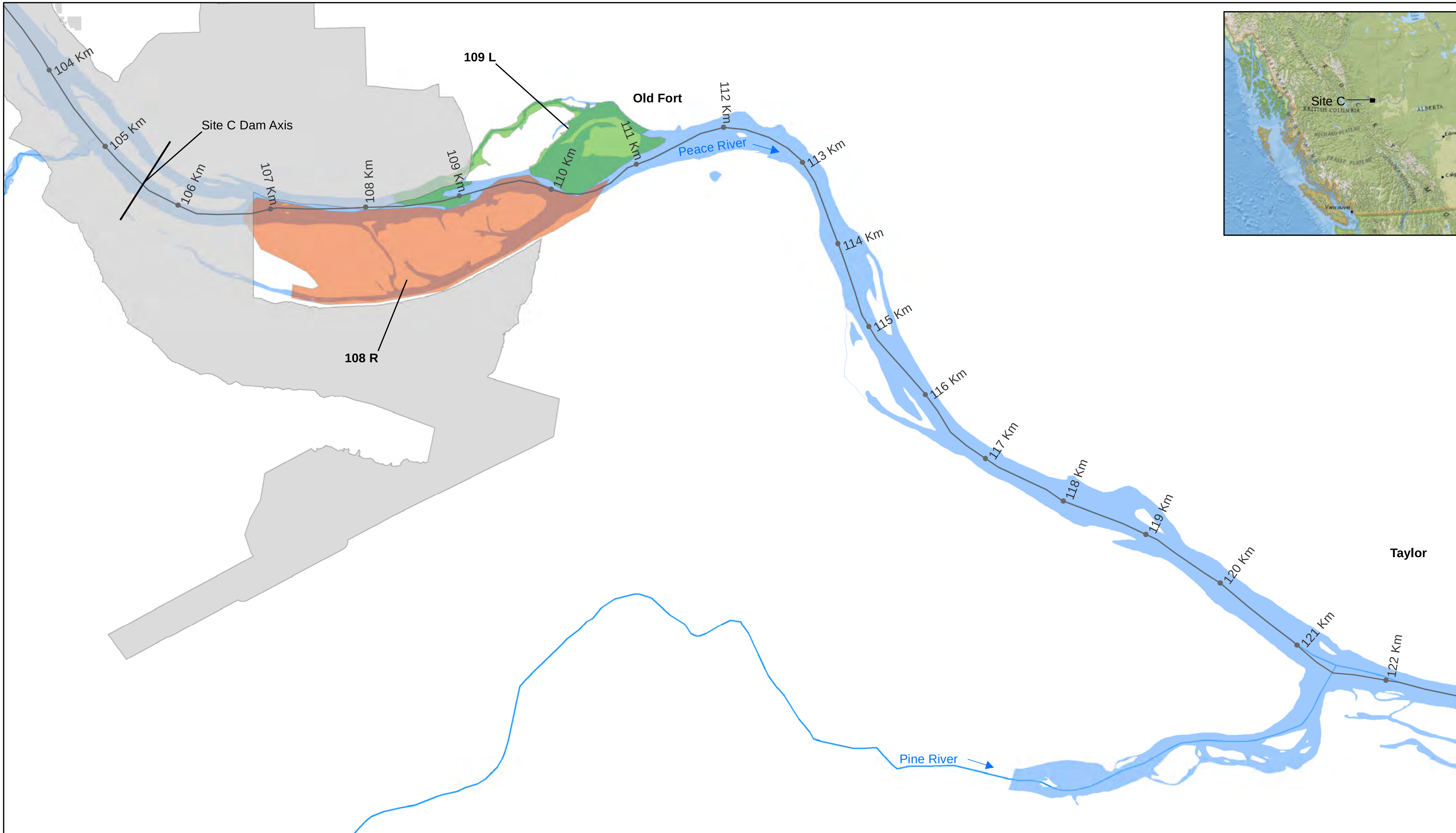
Northwest Hydraulic Consultants (NHC). 2015. Site C –North Bank Road Inlet Fish Habit Depressions Design Rationale. Prepared for BC Hydro April 24, 2105. *Draft for Discussions.*

Figures



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Legend

Site C Dam Construction Area

Site Locations

108 R

109 L

DATA SOURCES:
Background - Esri World Topo Map
Inset Map - National Geographic World Map
Peace River Centreline - Provided by BCH
Streams - FWA

SCALE - 1:40,000

0 500 1,000 1,500 Meters

N

Coordinate System: NAD 1983 UTM ZONE 10N/11N
Units: METERS

Project: 3000634 *Date: 14-MAY-2015*

BC Hydro
SITE C CLEAN ENERGY PROJECT
Fish Habitat Mitigation

Preliminary Design Site Locations

Figure 1

JXD, \\mainfile-van\Projects\300228 Site C Fish Habitat Mitigation\GIS\300228_JXD_Fig_Prelim DesignSiteLocations.mxd

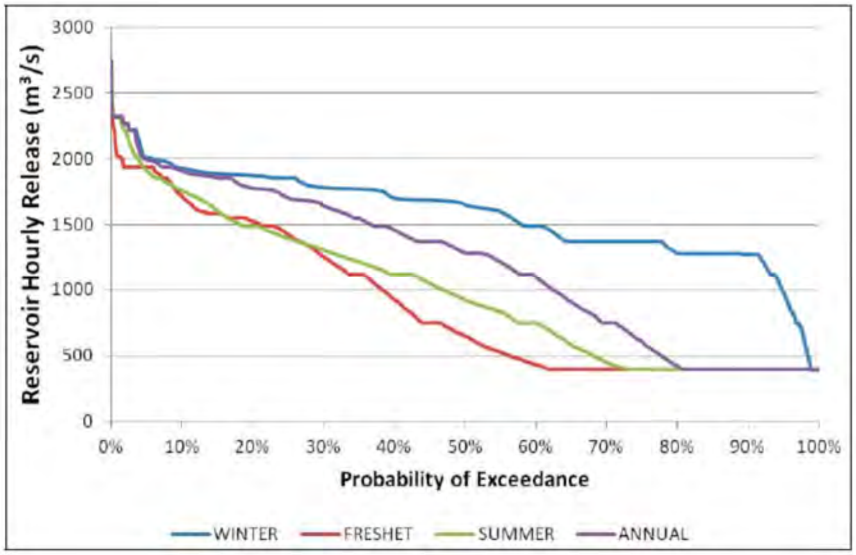

Figure 2. Predicted Annual and Seasonal Site C Reservoir Release Duration Curve (60-year GOM Model Results). From Figure 1 in BCH 2012c.

Legend

Dewatered Areas with Site C at Q = 2,060 cms

Dewatered Areas with Site C at Q = 2,520 cms

DATA SOURCES:
Background - Esri World Imagery
Orthophotos - Provided by BC Hydro
Inset Map - National Geographic World Map
Peace River Centreline - Provided by BCH
De-wattered Areas with Site C - Provided by BC Hydro

SCALE - 1:15,000

0 300 600 M

N

Coordinate System: NAD 1983 UTM ZONE 10N
Units: METRES

Project: 3000634 | Date: 19-MAY-2015

BC Hydro
SITE C CLEAN ENERGY PROJECT
Fish Habitat Mitigation
Site C - Old Fort
Dewatered Areas

Figure 3

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Photos

Photo 1. Backwater channel at Site 108R. View looking upstream (north). Preliminary design includes deepening and increasing the wetted channel and placing fill material adjacent to the existing riparian.

Photo 2. North arm side channel at 109L. View looking downstream (east) from near the inlet at the main channel.

Photo 3. South arm side channel at 109L. View looking downstream (east) from inlet at main channel. Preliminary design works includes deepening the existing channel and re-contour the bankline. Excavated material will be side cast on bank. Yellow shading estimates fill and blue shading estimate cut extents.

Photo 4. Lateral point bar at site 109L inlet to the north arm side channel. View looking upstream (west). Preliminary design includes lowering the gravel bar and vegetated area in photo to increase wetted habitat and reduce dewatering from operations.

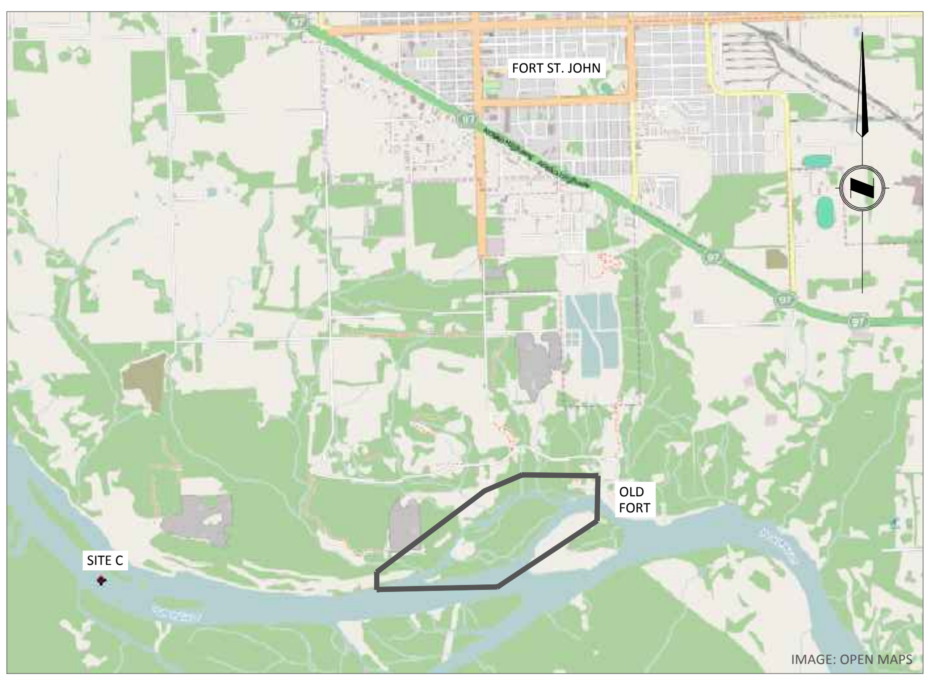
Drawings

SITE C FISH HABITAT MITIGATION

SITE 108R PRELIMINARY DESIGN

DRAWING INDEX

DRAWING No.	TITLE
3000634-108R-1	SITE PLAN, PROJECT LOCATION AND DRAWING INDEX
3000634-108R-2	PLAN VIEW



KEY MAP
SCALE = N.T.S.

SITE PLAN
SCALE = 1:10,000

NOTES:

1. IMAGERY BC HYDRO ORTO PHOTO (2013)

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REVISIONS

A	15 MAY 2015	ISSUED FOR REVIEW
B	20 MAY 2015	ISSUED FOR REVIEW
C	29 MAY 2015	ISSUED WITH FINAL MEMORANDUM

PRELIMINARY NOT FOR CONSTRUCTION

DRAWING INFORMATION

STATUS	ISSUED WITH FINAL MEMORANDUM
DESIGNER	JXG
DRAFTER	KEH
CHECKED	BMC
FILE NAME	20150529 3000634-108R-001 - 002.R0b

SITE C HABITAT MITIGATION

SITE 108R PRELIMINARY DESIGN

SITE PLAN, PROJECT LOCATION AND DRAWING INDEX

PROJECT NUMBER 3000634-108R

SHEET NUMBER 1

REVISION C

NOTES:

1. IMAGERY BC HYDRO ORTO PHOTO (2013)
2. SURVEY BY NHC (2015) AND SUPPLEMENTED WITH BCH DEM (2013)

LEGEND:

- EXCAVATION "CUT" AREA
- DEPOSITION "FILL" AREA

SITE C CLEAN ENERGY PROJECT

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REVISIONS		
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B	20 MAY 2015	ISSUED FOR REVIEW
C	29 MAY 2015	ISSUED WITH FINAL MEMORANDUM
D	01 JUN 2015	UPDATED WITH COMMENTS

PRELIMINARY NOT FOR CONSTRUCTION

DRAWING INFORMATION	
STATUS	ISSUED WITH FINAL MEMORANDUM
DESIGNER	JXG
DRAFTER	KEH
CHECKED	BMC
FILE NAME	20150529 3000634-108R-001 - 002.R0b

SITE C HABITAT MITIGATION
SITE 108R PRELIMINARY DESIGN

PLAN VIEW

PROJECT NUMBER 3000634-108R

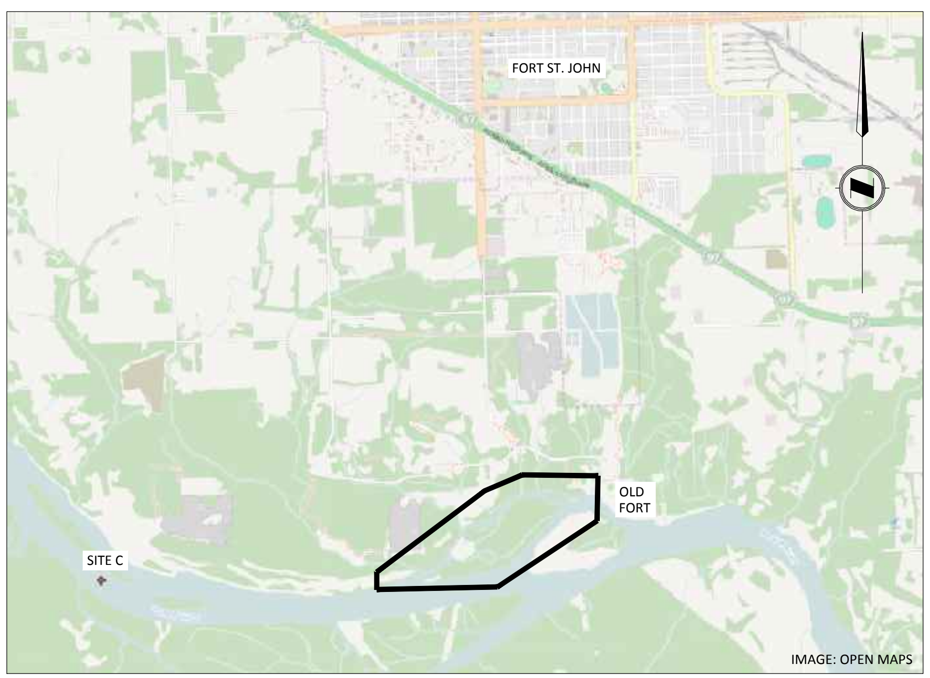
SHEET NUMBER 2

REVISION D

SITE C FISH HABITAT MITIGATION

SITE 109L PRELIMINARY DESIGN

DRAWING INDEX	
DRAWING No.	TITLE
3000634-109L-1	SITE PLAN, PROJECT LOCATION AND DRAWING INDEX
3000634-109L-2	PLAN VIEW



KEY MAP

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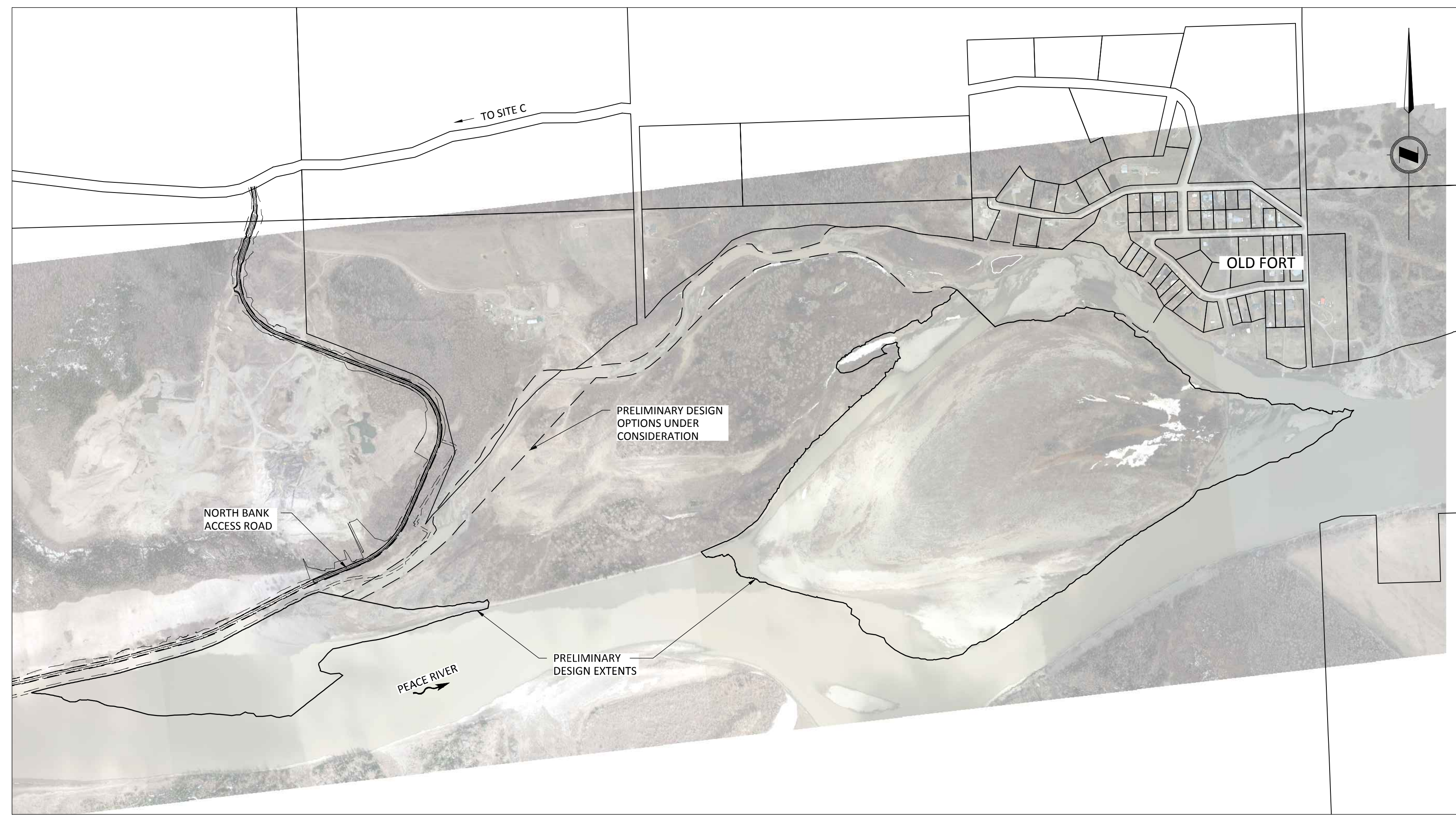

SITE PLAN

SCALE = 1:7500

NOTES:

1. IMAGERY BC HYDRO ORTO PHOTO (2013)

SITE C CLEAN ENERGY PROJECT

BChydro

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C	29 MAY 2015	ISSUED WITH FINAL MEMORANDUM
D	01 JUN 2015	UPDATED WITH COMMENTS

PRELIMINARY NOT FOR CONSTRUCTION

DRAWING INFORMATION	
STATUS	ISSUED WITH FINAL MEMORANDUM
DESIGNER	JXG
DRAFTER	KEH
CHECKED	BMC
FILE NAME	20150529 3000634-109L-001 - 007.R0c

SITE C HABITAT MITIGATION
SITE 109L PRELIMINARY DESIGN

SITE PLAN, PROJECT LOCATION AND DRAWING INDEX

DRAWING NUMBER 3000634-109L

SHEET NUMBER 1

REVISION D

LEGEND:

- EXCAVATION "CUT" AREA
- DEPOSITION "FILL" AREA

NOTES:

1. IMAGERY BC HYDRO ORTO PHOTO (2013)
2. SURVEY BY NHC (2015) AND SUPPLEMENTED WITH BCH DEM (2013)

SITE C CLEAN ENERGY PROJECT

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REVISIONS		
A	15 MAY 2015	ISSUED FOR REVIEW
B	20 MAY 2015	ISSUED FOR REVIEW
C	29 MAY 2015	ISSUE WITH FINAL MEMORANDUM

PRELIMINARY NOT FOR CONSTRUCTION

DRAWING INFORMATION	
STATUS	ISSUED WITH FINAL MEMORANDUM
DESIGNER	JXG
DRAFTER	KEH
CHECKED	BMC
FILE NAME	20150529 3000634-109L-001 - 007.R0c

SITE C HABITAT MITIGATION
SITE 109L PRELIMINARY DESIGN

PLAN VIEW

DRAWING NUMBER 3000634-109L

SHEET NUMBER

2

REVISION C

Appendix B - Rock Spurs for Fish Habitat along River Road

MEMORANDUM

TO:	Dave Hunter	**DATE:**	May 23, 2014
FROM:	Amy Fernandes	**LOG NO.**	1016.Z.02.003.ENY. 00305.MEMO

SUBJECT: **Rock Spurs for Fish Habitat along River Road**

---

1. INTRODUCTION

The purpose of this memorandum is to develop a preliminary design concept for the addition of rock spurs for fish habitat along the River Road downstream of the proposed Site C dam. Rock spurs break up the flow and provide areas of lower velocity and a diversity of velocities between spurs, as well as a diversity of habitat.

These spurs are a commitment in the EIS: "Fish habitat features (shears, large riprap point bars, etc.) will be designed in the final design of the north bank haul road bed material that would be placed in the Peace River."[1]

2. ANALYSIS

2.1 Design Concept

River Road will be built early in construction to aid in the construction of the dam. There is a planned relocated surplus excavated material (RSEM) area labelled L6, which is downstream of the diversion tunnel outlet channel on the north bank of the site (see Figure 1). River Road comes off of RSEM L6 and follows the north bank of the Peace River east for about two kilometres before turning north and heading up to higher elevations. The elevation of the road is currently under design, but is expected to be between elevation 417 m and 418 m just off RSEM L6 and slope down approximately one meter along the length of the road before it turns uphill. The side slope of the road is currently designed as 2H:1V and will be covered with rip rap up to the ice consolidation elevation.

The proposed rock spurs would be built jutting out from River Road and would be constructed at the same time as the riprap for the road. The final elevation of River

[1] EIS Volume 2 Section 12, p. 12-74

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www.snclavalin.com

Road does not impact the spur design. The primary function of the rock spurs is to provide habitat for fish and not the more common reason for use, which is to protect the bank from erosion. As such, the design is slightly modified from the typical design guidelines available and is instead based on experience and the use of the two-dimensional hydraulic modelling program River 2D.

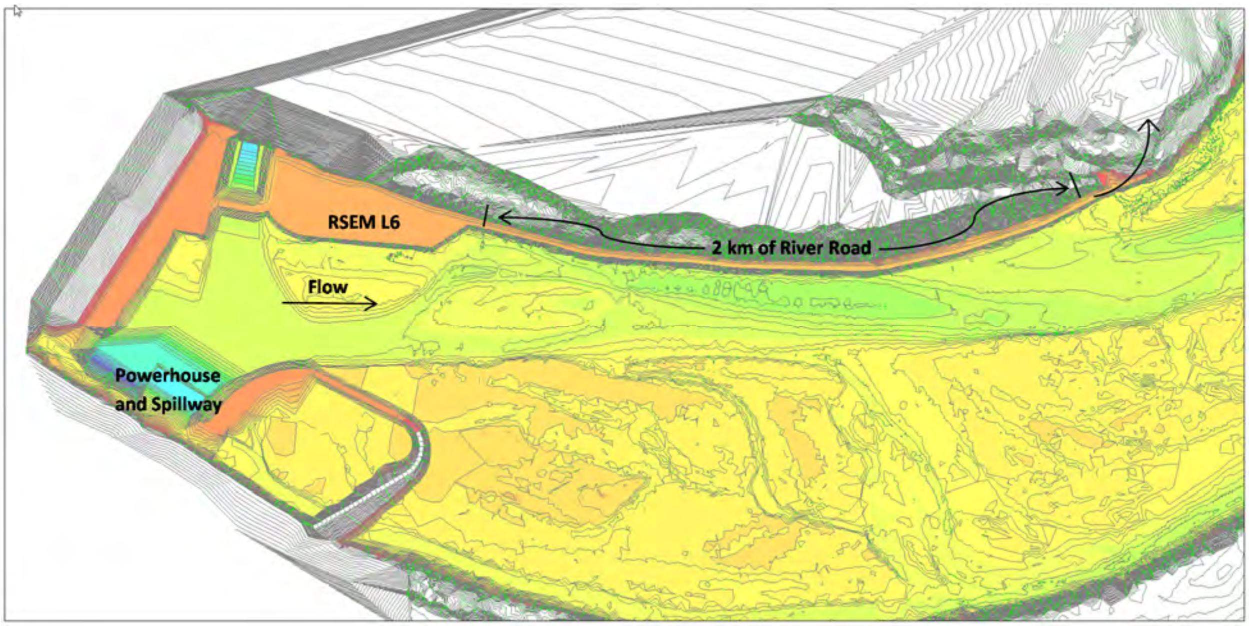


Figure 1. General Layout of Dam and River Road

2.1.1 Spur Geometry

The Peace River is wide at this location with the width varying from 250 m to 400 m. As such, what might be considered a large spur in some rivers does not appear that large or have that significant an impact on flow across the entire channel in the Peace River. The intent of the spurs is to provide localized fish habitat near the bank. The lengths of 25 m and 15 m for the spurs were considered, and it was determined that the slight gain in benefit due to the longer spur was not outweighed by the increase in cost and construction effort. Therefore, the 15 m long spur was chosen for design.

The sideslope of the spurs was initially chosen as 2:1 because this provides a suitably stable slope. A 1 m wide crest was initially chosen because it was learned through discussion with Northwest Hydraulics Consultants (NHC) who has experience with this type of work, that a wide crest is not required as it does not provide additional benefits for fish and would increase the size and volume of material required for the spur. However an alternate geometry was also looked at based on discussion with a senior BC Hydro cost estimator and is discussed in Section 2.2.

NHC also advised that the rounded toes often seen in the design of river spurs used for bank protection were not necessary in this case. Rounded toes are generally used because a significant amount of material loss is expected to happen at the end of the spur. For this case, the extra material in the tip is not expected to be required.

The elevation of the spurs was chosen to be submerged at regular operating levels and to have a slight slope downwards of about 4% from the connection to the road down into the river. The most upstream spur connects to the road at elevation 410 m and the most downstream spur connects at elevation 409.6 m. At low flows, the spurs will be exposed and this could potentially aid in construction.

2.1.2 Spur Alignment and Spacing

The alignment of the spurs was chosen as perpendicular to River Road. This was decided based on discussion with NHC, and the reasoning was because the river is so wide and therefore the most benefit for fish habitat can be gained from having the spurs oriented perpendicular to the bank. The most upstream spur will be oriented downstream in order to direct the streamlines, but the remainder will be perpendicular.

The spacing of the spurs was chosen as four times the length, or 60 m. This provides space between spurs where lower velocities will allow fish to congregate. It is also close enough that the streamlines do not have a chance to redirect towards the bank. The result, however, is a large number of spurs due to the long stretch of road. At 60 m centers, the initial design resulted in 30 spurs.

2.1.3 Spur Material

The spurs will be constructed out of varying sizes of rocks and Project staff confirmed rock is expected to be available for constructing the spurs as long as the rock size used for the spurs is slightly larger than what is needed for the majority of riprap around the dam site. Larger rock sizes are desirable since there is expected to be larger rock available that is not needed elsewhere on the project. A typical practice for spurs is to use riprap that is 20% to 30% larger than what is used on the adjacent bank. At the time this memo was written, riprap along River Road was designed as 250 kg class with a D50 of 600 mm. Checking the spur riprap size using the guidance provided by the US Army Corps of Engineers[2] and the actual velocities from the 2D modeling results as discussed in Section 2.4 of this memo, the 20% to 30% estimate seems adequate.

[2] Hydraulic Design of Flood Control Channels, EM 1110-2-1601, USACE, July 1991

2.2 Construction

As mentioned in Section 2.1, the rock spurs would be constructed at the same time as River Road riprap. This would be done for constructability but would have the benefit of eliminating the mobilization costs that would otherwise be associated with building the spurs. The first spur configuration that was proposed in Section 2.1.1 is shown in Figure 2.

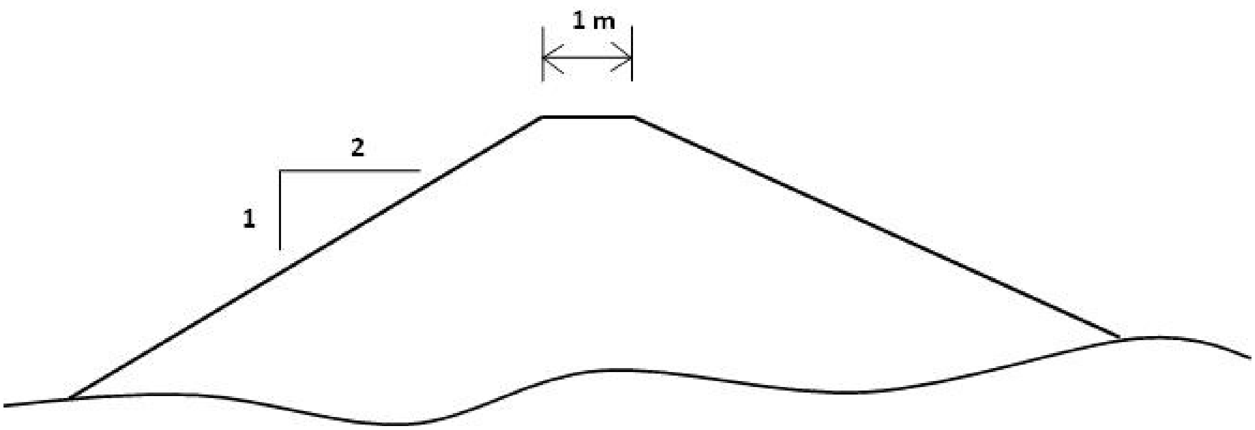


Figure 2. Rock Spur Section – Narrow Crest Width

The length of the spurs, coupled with the narrow crest width, would necessitate the use of a crane for construction. A crane with a long reach dragline could reach out far enough for placement of the rock and could build the spurs with a narrow crest. Even though a crane does not have good shaping abilities, the rough placement of rocks may actually be a benefit in regards to developing fish habitat as opposed to a smoother finished shape. The stability of the spur may become an issue, however, as there is limited control over building the desired shape when using a crane.

Basd on discussion with Project staff, rock that is dumped falls along a natural slope of about 1.5 horizontal to 1 vertical. As a result, the volume of rock calculated for costing the narrow crest width case was assumed to have a 1.5H:1V sideslope as opposed to the 2H:1V sideslope shown in Figure 2.

An alternate means of construction that would be faster is the use of a truck and an excavator. Being able to drive out onto the spurs would facilitate quicker construction of the spurs; however, the crest width would have to be significantly increased for this option. Mike suggested that a spur crest width of 4 m would be required and the sideslopes would again be assumed to be 1.5H:1V (see Figure 3). For this case, the middle of the spur would be built of smaller surplus rock that is a byproduct created when riprap is made. Since this smaller rock is cheap to source, there would be a decrease in cost for this option even though the overall amount of material would be increased because of the larger crest width.

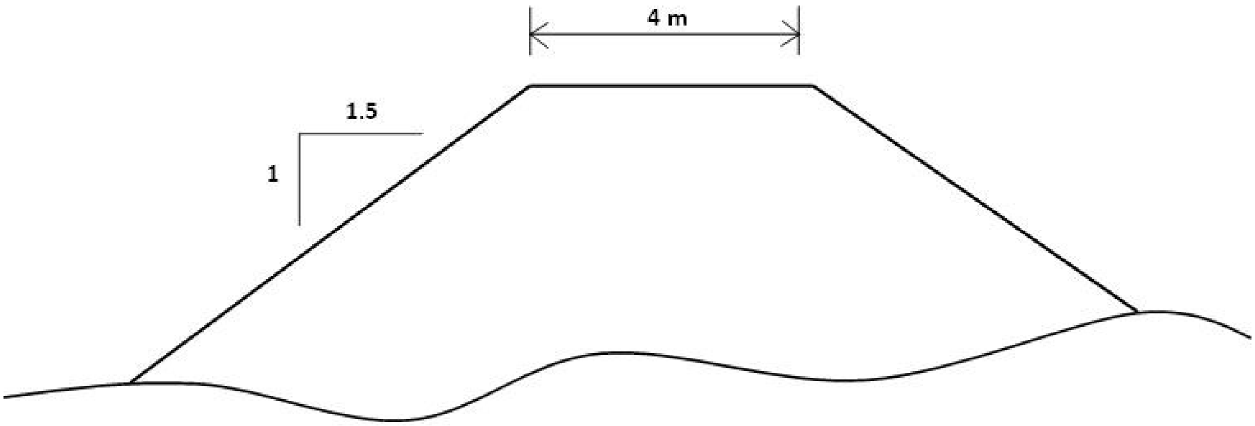


Figure 3. Rock Spur Section – Wide Crest Width

2.4 Hydraulic Modelling Results

2.4.1 Model Setup

Based on the design parameters laid out in Sections 2.1 and 2.2, spurs were added into an existing two-dimensional hydraulic model built in River 2D. The River 2D program provides flow streamlines, water levels and depth-averaged velocities as some of its outputs. The model layout that simulates the operation of the powerhouse was used since this is the long-term condition for which the spurs will be expected to perform. It should be noted, however, that there are other phases through construction that the spurs will need to survive. Most notably, there are two sites of excavation within the riverbed that are proposed as shown in Figure 4. The site furthest downstream is adjacent to the location where the spurs are proposed and as such, its excavation would reduce the constriction of the river towards the north bank and therefore reduce velocities. In order to assess the scenario with the highest velocities near the bank, the downstream excavation was not included in the hydraulic modelling in order to assess the most critical condition that the spurs may see throughout their life.

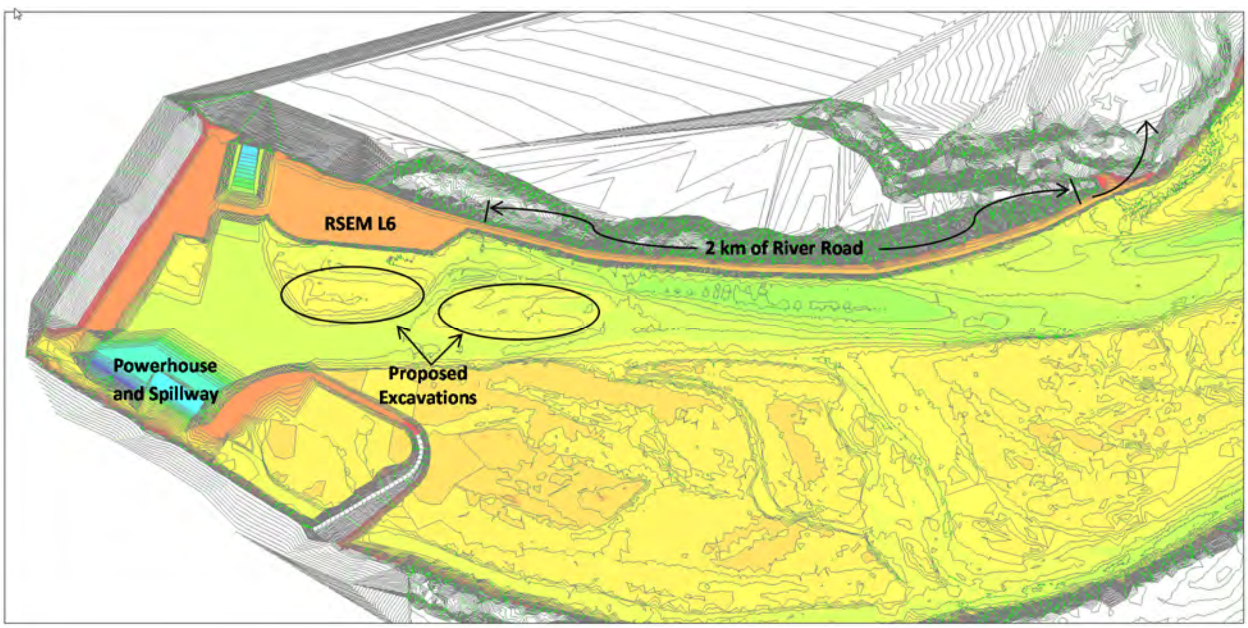


Figure 4. General Layout with Proposed Excavation Areas

Both spur geometries, as shown in Figures 2 and 3, were modelled in River 2D. Figures 5a and 5b show the location of all 30 spurs as modelled in River 2D. It can be seen from these two figures how the bed elevation of the river varies along the stretch where the spurs are located. Since the volume of each spur depends on the adjacent bed elevation, the spur volume will vary along the river.

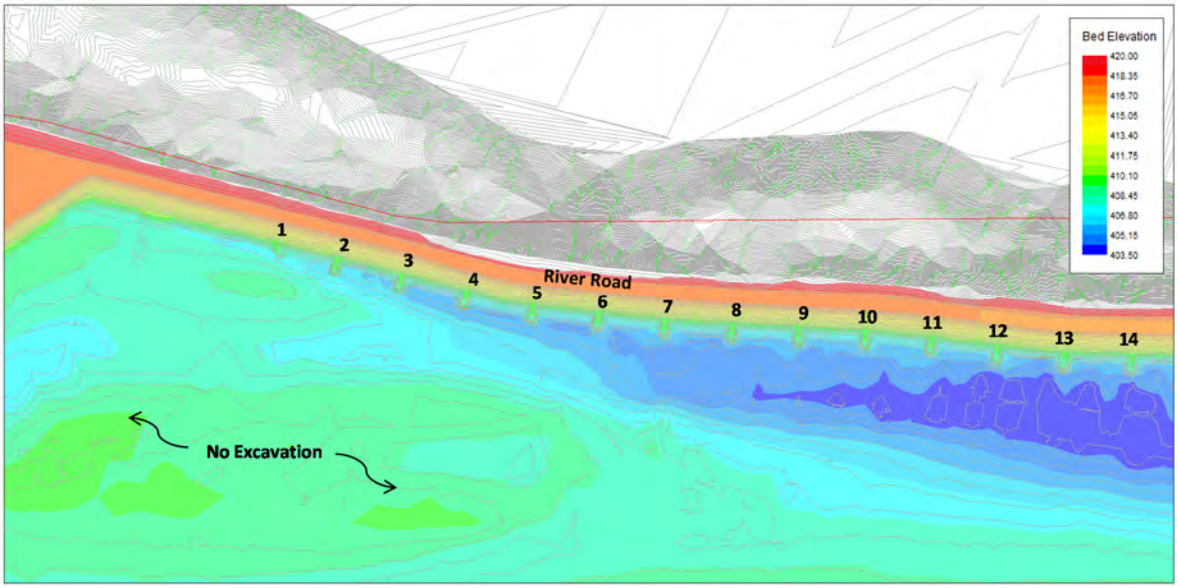


Figure 5a. Wide Crest Rock Spurs 1-14

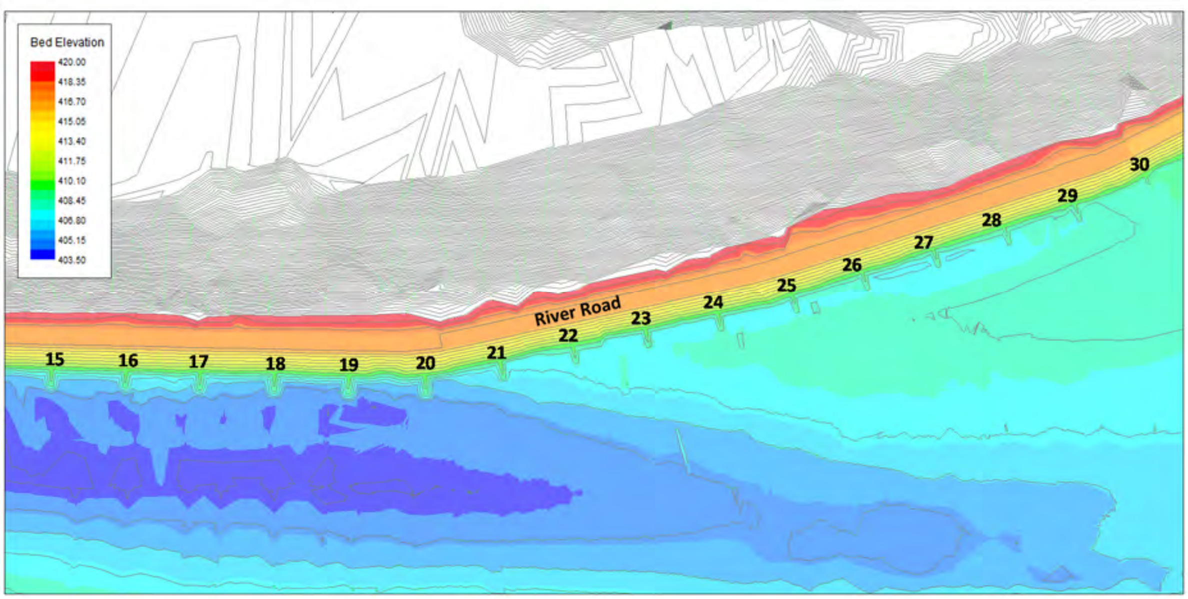


Figure 5b. Narrow Crest Rock Spurs 15-30

2.4.2 Model Results

The two-dimensional hydraulic model was run with flows that covered the range of powerhouse operating conditions from 500 m^3/s to 2500 m^3/s. The minimum flow allowed in the river is 390 m^3/s, however 500 m^3/s was considered close enough to assess the low flow condition. An extreme flow of 10,000 m^3/s was also tested, which is approximately the peak of the Project Design Flood. All flows were run in steady state condition.

A look at velocity outputs from the model provides insight as to how effective the spurs are at providing lower velocities, and hence a diversity of velocities, for fish habitat. The two different spur geometries resulted in similar velocity plots, so examples of each case are shown in the figures below. Figure 6 shows velocity streamlines over depth-averaged velocity for a flow of 1000 m^3/s with and without the wide crest spurs. It can be seen clearly how the higher velocities are moved farther from the bank when the rock spurs are in place. There is some flow and recirculation occurring between the spurs, which is good to avoid fine sediments from depositing between spurs.

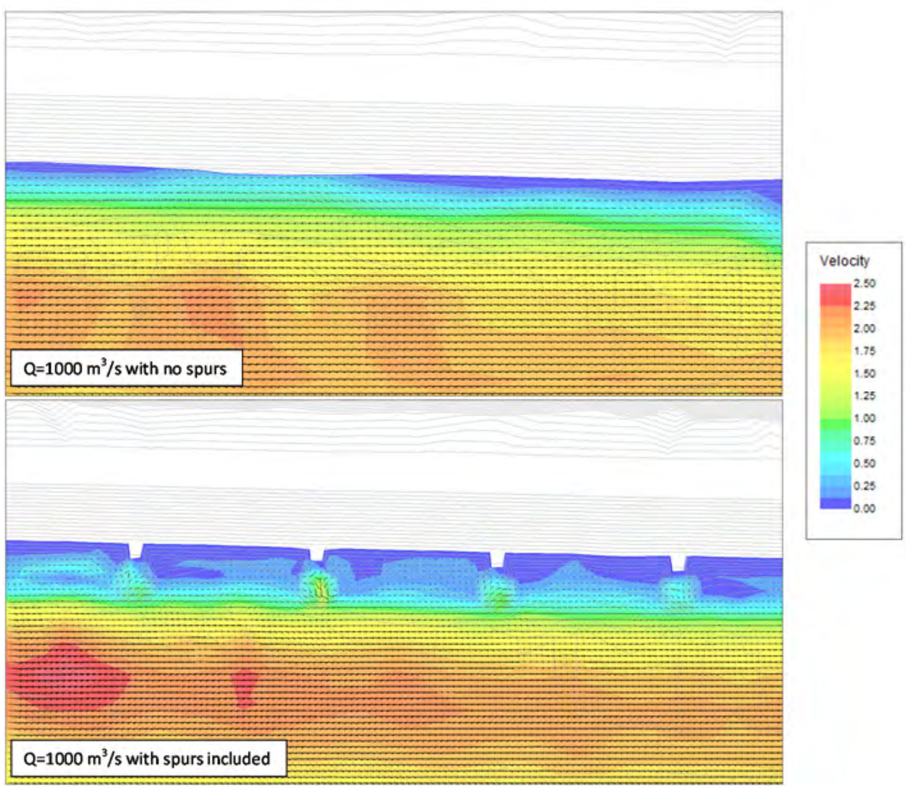


Figure 6. Wide Crest Spurs: Q=1000 m^3/s Velocity Assessment at Spurs 14 to 17

This same scenario of reduced velocities is typical between spurs 6 to 20 for flows of 1000 m^3/s and 1500 m^3/s; however for a flow of 2500 m^3/s it is slightly less obvious. Comparing between spur geometries, the wide crest spur provides a slightly more noticeable low velocity zone between spurs at a flow of 2500 m^3/s.

The depth of water over the toe of the spur for a flow of 1000 m^3/s and 1500 m^3/s is approximately 0.5 m and 1.0 m respectively for both spur geometries. For the 2500 m^3/s case, the depth of water over the toe is closer to 2.0 m so the streamlines are less impacted by the presence of the spur, as suggested above. For a flow of 500 m^3/s the tops of the spurs are dewatered, as shown in Figure 7 for the wide crest spurs.

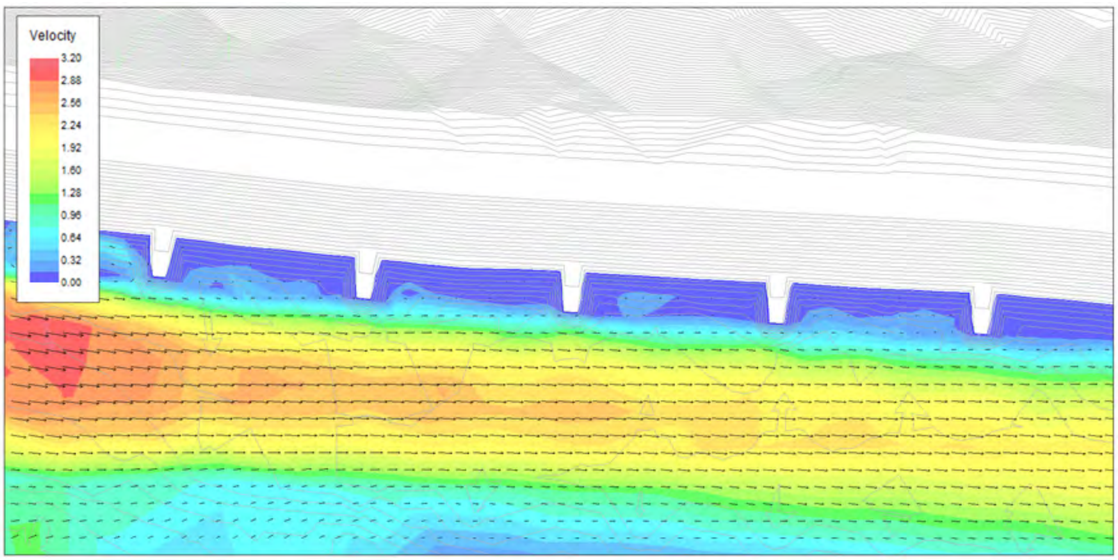


Figure 7. Wide Crest Spurs: Q=500 m^3/s Velocity Assessment at Spurs 6 to 10

For spurs 1 to 5 and spurs 21 to 30, the velocity plots reveal two different scenarios. For spurs 1 to 5, all powerhouse flows give the highest velocities around these five spurs, and particularly at the fifth spur. These high velocities are due to the pinch point in the river between the non-excavated bar and the road embankment (see Figure 4). The velocities associated with these spurs are sometimes higher than the adjacent in-river velocities before the spurs were installed, although this is more prevalent in the narrow crest width spurs. See Figure 8 for an illustration of this using a flow of 2500 m^3/s and the wide crest width spurs.

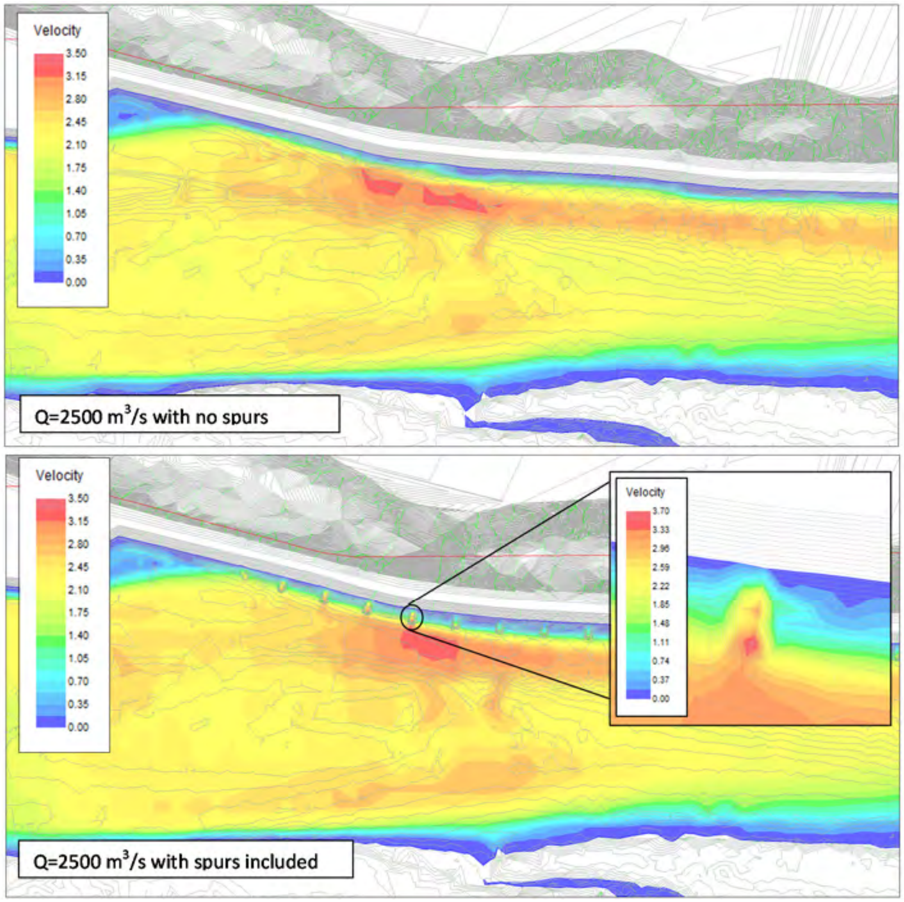


Figure 8. Wide Crest Spurs: Q=2500 m^3/s Velocity Assessment at Upstream Spurs

As a comparison, the narrow width crest case with both areas from Figure 4 excavated to elevation 406 m was run. This is expected to be the long-term scenario. For all powerhouse flow cases, the maximum depth-averaged velocity from these first five spurs was reduced by at least 1.0 m/s as a result of the excavations. This means that these first few spurs have to be built to survive construction before more favourable long-term conditions would occur. Post-excavation, velocities around these first five spurs are similar to, or less than, velocities within the adjacent riverbed.

At an extreme flow of 10,000 m^3/s the spurs are submerged by up to six or seven meters so the velocity streamlines are barely influenced by the spurs. The depth-averaged velocities show a high peak over spur 5, however the rest of the spurs are similar to or less than the velocities in the main river channel. If the spurs were damaged during an extreme event, it would likely mean a loss of functionality until repairs could be performed.

With the existing river bathymetry, spurs 21 to 30 are generally non-effective. The riverbed along this stretch is veering away from the main channel and heading towards a side channel. The bed elevation is rising about two meters over this span, resulting in smaller spurs. Consequently, these spurs have limited effectiveness compared to spurs 1 to 20 and it may be questionable whether they are even necessary at this location because the main river channel is moving away from the bank. See Figure 9 for a flow of Q = 1500 m^3/s with the narrow crest width spurs. Since lower velocities exist in this location without adding in the spurs, their construction may not be necessary.

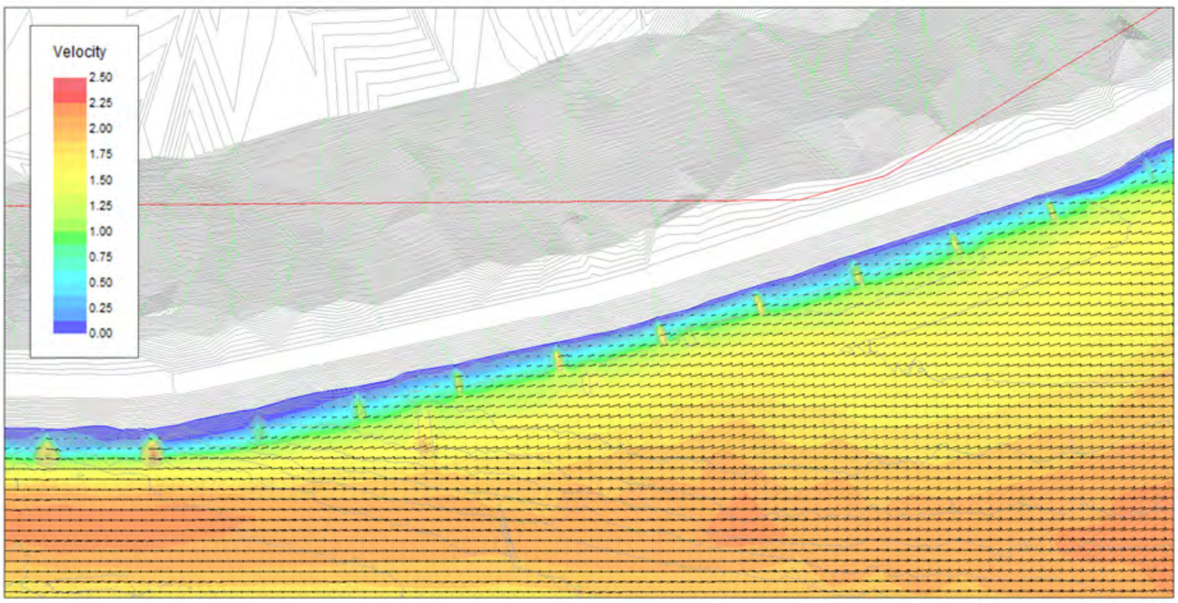


Figure 9. Narrow Crest Spurs: Q=1500 m^3/s Velocity Assessment at Spurs 19 to 30

This particular area where spurs 21 to 30 are located is an area of the river that has been proposed for excavation for fish mitigation purposes. As a part of this mitigation, the riverbed will be excavated to an elevation of 407 m, which is anywhere from 0.1 m to over 1.0 m lower than the current riverbed elevation around the location of the spurs. This configuration was modelled to check the effectiveness of the spurs should this work proceed. The results are shown in Figure 10 with the wide crest spurs. The results show that the spurs are slightly more effective in this reach with the excavation than without the excavation as zones of lower velocity and recirculation are more apparent in Figure 10 than in Figure 9. The degree of effectiveness, however, is difficult to assess. A reasonable approach is therefore to cycle back on the cost. Spurs 19 to 30 pre-excavation had relatively small volumes due to the shallow riverbed. Adding the excavation increases the volume of these spurs, which impacts the cost. Eliminating these spurs altogether also impacts the cost.

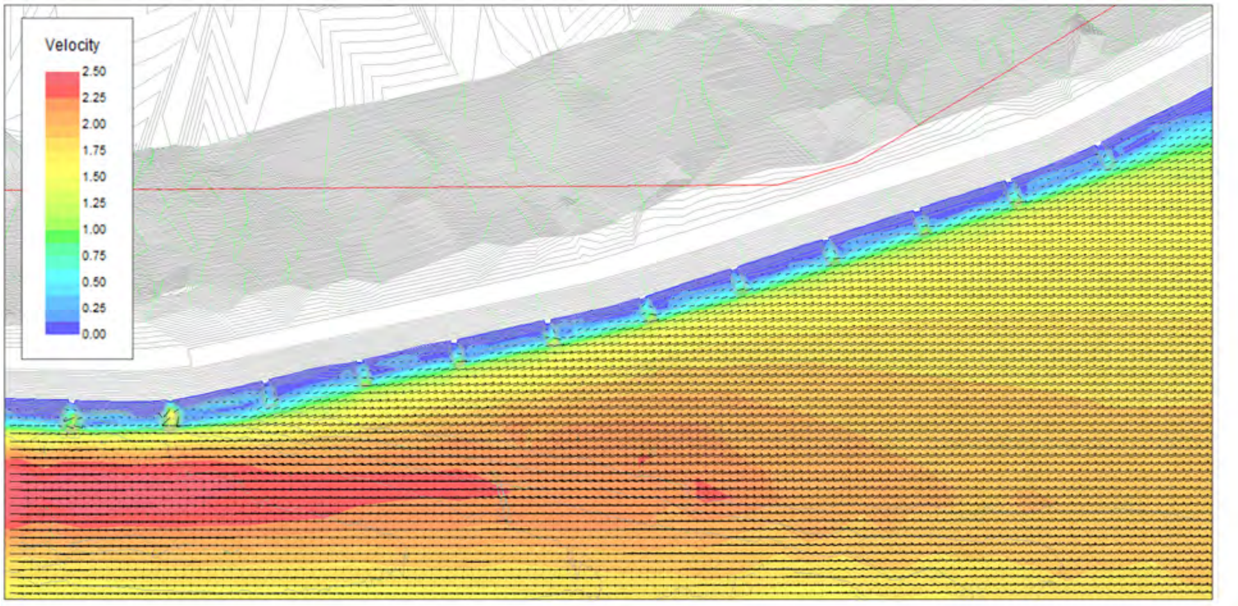


Figure 10. Wide Crest Spurs: Q=1500 m^3/s Velocity Assessment at Spurs 19 to 30 with Channel Excavation to Elevation 407 m

3. CONCLUSION AND RECOMMENDATIONS

The inclusion of rock spurs along the north bank River Road for the development of fish habitat has been assessed in this memo. 30 spurs were added to an existing two-dimensional hydraulic model that runs operation flows. The impact of these spurs was assessed for powerhouse flows as well as for a higher spillway flow. The conclusions and recommendations from this analysis are summarized below:

1) Spurs 1 to 5 have high velocities associated with them because they are located along a pinch point between the bank and the unexcavated bar. Although this bar is expected to be excavated at some point during construction, the spurs will be built early in construction and they will need to be designed to last through this period when the bar is in place. It is recommended that all spurs be constructed with material that is 20% to 30% greater than the River Road riprap size of 250 kg with a D50 of 600 mm. This size of rock should be adequate to handle the velocities the spurs will see.

2) Spurs 6 to 20 are adjacent to a deeper section of the river and therefore require more volume per spur, but they are effective at moving the higher velocities away from the bank and providing an area of low velocity for fish.

3) Spurs 21 to 30 are located along a stretch of the riverbed that is moving away from the main channel and is also rising in elevation. This results in spurs that are quite small and relatively ineffective. A reassessment of this area with the proposed fisheries mitigation excavation along this bank showed a slight improvement in effectiveness, however the extent of improvement is difficult to assess. It is recommended that spurs 21 to 30 be excluded from the design.

4) The 4 m wide crest option is recommended because it results in lower construction cost for the same expected fish benefit as the 1 m wide crest option. In some cases the 4 m wide crest option even showed some benefit over the 1 m wide option in regards to keeping velocities down. It is therefore the better choice for design. The elevation of the spurs shall be at 410 m sloping down to 409 m over the 15 m spur length for spurs 1 to 10, and 409.8 m sloping down to 408.8 m for spurs 11 to 20.

5) Although not previously mentioned in this memo, the issue of safety should be addressed. Having spurs that stick out into the river but which are often submerged may be a hazard to boaters. It is understood that Transport Canada will recommend signage requirements as part of their review.

Appendix C – Site C Reservoir Shoreline Enhancement

MEMORANDUM

TO:	Brent Mossop and Dave Hunter Site C Fish and Aquatic	**DATE:**	December 20, 2013
FROM:	Amy Fernandes Site C Integrated Engineering Team	**LOG NO.**	BCH-O-0347
SUBJECT:	**Site C Reservoir Shoreline Enhancement**		

1. INTRODUCTION

The purpose of this memorandum is to update the previously proposed reservoir shoreline fish habitat enhancement measures for the Site C Clean Energy Project with the purpose of updating the feasibility of the concepts related to fish habitat creation.

A report was completed in 2009 (Reference 1) that identified potential sites for habitat mitigation measures within the proposed Site C reservoir. The Site C Fish and Aquatic team reviewed this report and recommended that certain sites be revisited and reassessed (Dave Hunter, personal communication). The following sites were flagged and will be discussed in this memo:

- Km 22-24
- Km 25-27
- Km 34-35
- Km 37-40
- Km 42-44
- Km 49-52

The design criterion and base assumptions outlined in the 2009 report will be considered to apply to the current analysis, except for the following changes and refinements that were updated by the Site C Fish and Aquatic team (Dave Hunter, personal communication):

1) The elevation that is to be excavated to for the creation of shallow water habitat is 459.75 m. This is just below the lower end of the normal reservoir fluctuation zone between elevations 460.0 m and 461.8 m.

2) It is desirable that all surfaces excavated to elevation 459.75 m be left "rough" in order to facilitate good fish habitat development. A clear definition of a "rough" surface will be required in the contract documents to ensure the desired outcome is achieved. Inclusion of pictures to illustrate what is expected would be beneficial.

3) The upper extent to which excavations occur for the creation of shallow water habitat is elevation 462.8 m, which is one meter above the Maximum Normal Reservoir Level (MNRL) of 461.8 m. A cut slope of 3H:1V is assumed between the elevations of 462.8 m and 459.75 m.

4) Re-vegetation will be done on all surfaces above MNRL, but not on surfaces below MNRL.

5) The additional criterion of littoral zone was included in the evaluation of enhancement sites. The littoral habitat zone between MNRL and 6 m below MNRL is considered high quality fish habitat based on light penetration to bottom sediments and support of a high productivity aquatic zone.

Design details in this memo are based on discussion with the Site C Integrated Engineering Team (EIT). The IET has a vast knowledge of the areas discussed and are familiar with other work going on within, and adjacent to, the proposed reservoir. As a result, they have commented on the areas where the proposed enhancement work has the potential to be done in conjunction with other construction works. In cases where shallow water fish habitat is created by excavating material that can be used for road building, this work will have to be written into the road work contract with specifications tailored for developing fish habitat.

It is assumed that for accessibility and ease of construction, the enhancement works are constructed prior to reservoir filling. In cases where the work is done in conjunction with road works, the scheduling will be dictated by the road contracts. In cases where the work is independent of any other work, the most advantageous time will be determined based on site access conditions, site specific environmental considerations, and design constraints.

2. ANALYSIS

2.1 Km 22-24: Spawning Shoal

The work proposed at this site in the 2009 report included adding spawning gravel on the south bank outcrop and adding fill and trees to the existing island. The adding of trees and fill on the island is no longer being pursued as the existing configuration provides good shallow fish habitat around the island without doing any enhancement works. The spawning site will still be considered.

The outcrop on the south bank at Km 23 is an area that is typically above the current river level as indicated by the growth of brush on its surface, but it will be just below the proposed MNRL after reservoir filling. The design concept for this site is to develop spawning habitat both on and around this outcrop. In order to do this, the outcrop will be excavated down to elevation 459.25 m so that when the 0.5 m of spawning gravel is placed, it will be at the correct elevation of 459.75 m.

From air photo investigation, the material on the outcrop appears to be adequate for use as spawning gravel; however this would need to be confirmed prior to construction. Assuming the material is adequate and does not require additional cleaning, the excavation could then occur down to the desired final elevation of 459.75 m to create spawning habitat on the existing outcrop. The excavated material would then be pushed out 0.5 m thick on the shallow area adjacent to the outcrop to create additional spawning habitat.

Should the material on the outcrop prove to be inadequate for spawning gravel, the excavation on the outcrop would occur down to elevation 459.25 m and the excavated material would be placed within the reservoir footprint nearby in an appropriate manner. In this case, the necessary spawning gravel would have to be sourced from nearby. It is likely that gravel from the adjacent island could be used and placed 0.5 m thick on the outcrop as well as on the shallow area adjacent to the outcrop.

Access to the site is assumed to be from the south bank. The EIT has looked at the slope down to the outcrop and has confirmed that equipment can get down the slope. Should access from the south bank prove to be impossible because of property issues, the site would have to be accessed from the river.

The work at this site will be done by one excavator that will grub, excavate and redistribute the gravel. If gravel needs to be sourced from the vicinity, a fleet of machinery will be required to access the nearby island and haul it onto the outcrop.

The extent for this site is captured by the surface area covered by the spawning gravel. See Appendix A for the enhancement area and see Appendix B, Map 1 for a map of this site.

2.2 Km 25-27: Backwater

The enhancementmeasure proposed in the 2009 report at this site was to create a berm to elevation 461.8 m along the existing island between KM 25 and 27. This berm would then be extended across a deep channel on the south end to isolate the existing side channel and effectively create a back channel. Also proposed was terracing on the south side of the berm and deflectors on the north side of the berm. The current design maintains the same overall concept with some slight changes including revising the alignment of the cut-off portion of the berm, increasing the berm height so that it becomes an island and removing the deflectors.

The existing islands are accessible from the north by temporary clearing roads. After the clearing and grubbing is done, excavation can begin on the north end of the large island and on the smaller island to the south-east. The excavated material will be moved along the larger island to start building up a strip of the berm 10 m wide to elevation to 462.8 m with 3H:1V side slopes, and to begin terracing to the south of the built-up berm. Simultaneous work will begin on the cut-off portion of the berm that will isolate the side channel. This part of the berm will be built across a narrower section of the side channel than initially proposed in order to minimize the extent of the work. Once the desired configuration is achieved, riparian vegetation will be planted on the berm above MNRL.

The work at this site will be done by a fleet of machinery that will grub, excavate, haul and place material.

The extents for this site are captured by the following criteria:

Pre-Enhancement:

- Productive fish habitat up to 6 m below MNRL on the existing islands (littoral zone).

Post-Enhancement:

- Total backwater area developed between MNRL and 6 m below MNRL (littoral zone).
- Total backwater area developed at greater depths than 6 m below MNRL.

See Appendix A for the enhancement areas and see Appendix B, Map 2 for a map of the site.

2.3 Km 34-35: Shallow Water Habitat

There is an embayment created just north of River Km 34 by the reservoir flooding the mouth of Lynx Creek. This is a prime location for potential fish enhancement works. The 2009 report suggested creating terracing alongside the preferred highway alignment as well as placing spawning gravels within shallow waters. The current design concept focuses instead on creating shallow water habitat at the upstream end of the embayment. The reason for this change is that the highway causeway itself will create good fish habitat, including rip-rap materials in the littoral zone, without additional construction work that would likely require additional material and labour.

Access to this site is available by existing local access to the north of Lynx Creek. Excavation of the proposed area will be taken down to elevation 459.75 m. The excavation will stay within BC Hydro owned or leased lands and will be bounded by Lynx Creek to the south and the existing road to the north. The type of material within the proposed excavation site is uncertain and will need to be confirmed prior to construction. The presence of shale could complicate the environmental feasibility of the site. This assessment assumes the material is mainly soil or gravel.

Nearby construction in the Lynx Creek embayment includes extensive embankments for a causeway and bridge. There is the potential that material excavated for developing shallow water habitat could be used for embankment construction. If the excavated material is not required for nearby construction, it can be deposited within the deeper sections of the embayment, creating additional shallow water habitat. Since there is more material being excavated than there is space to fill, the additional material will have to be disposed of.

The work at this site will be done by a fleet of machinery that will grub, excavate, haul and place material.

The extents for this site are captured by the following criteria:

Pre-Enhancement:

- Shallow water habitat from elevation 459.75 m to elevation 461.8 m with dewatering due to reservoir fluctuations.

Post-Enhancement:

- Shallow water habitat at constant elevation 459.75 m and between elevations 459.75 m and 461.8 m along the cut slope.

See Appendix A for the enhancement areas and see Appendix B, Map 3 for a map of the site.

2.4 Km 37-40

Two fairly complex options were discussed in the 2009 report regarding this location. The work was planned on the north bank adjacent to the proposed highway alignment and included tasks such as excavation, filling, benching, bank stabilization, pothole lake development and island development. The current study of the site revealed a limited area available for enhancement work compared to what was originally assumed due to property ownership issues. Upon further discussion with the EIT, it was determined that this site will be needed for removing the maximum amount of material possible to aid in the road construction within the vicinity. This excavation may result in some inadvertent creation of shallow fish habitat, but the design of any enhancement measures is not possible nor can any desirable result be counted on. This site will therefore not be included in the enhancement results.

2.5 Km 42-44: Shallow Water Habitat

The design concept proposed in 2009 for this site was to excavate down to one meter below MNRL on the north bank of the river just south of the highway alignment. The design concept has not been altered for this analysis, however with the current changes to the design criterion, specifically excavating to 459.75 m for shallow water habitat creation, the extent of the work increased substantially. Additionally, the excavation has been expanded to the east to include a much wider area of land.

The location of this work is an area already targeted by the road designers for extraction of road building material. Similar to the situation for Km 34-35, the material excavated for developing fish habitat could be utilized in the road construction. However, should the material not be needed for road construction, the excavated material will be pushed out into the deeper parts of the bank to develop additional shallow water habitat. At this location, there is an upper terrace and a 10 meter drop to a lower terrace. The cut to elevation 459.75 m takes up a large part of the upper terrace and it is assumed that the fill will extend to the edge of the upper terrace only. This leaves a large amount of additional fill that will then need to be disposed of. This fill could be pushed down onto the lower terrace for disposal.

For the option where the material is pushed out onto lower lying contours, this work will be done by an excavator that will grub and a tractor that will redistribute material.

The extents for this site are captured by the following criteria:

Pre-Enhancement:

- Shallow water habitat from elevation 459.75 m to elevation 461.8 m with dewatering due to reservoir fluctuations.

Post-Enhancement:

- Shallow water habitat at constant elevation 459.75 m and between elevations 459.75 m and 461.8 m along the cut slope.

See Appendix A for the enhancement areas and see Appendix B, Map 4 for a map of the site.

2.6 KM 49-52: Shallow Water Habitat

The 2009 design for this site included two areas of excavation and island building. The current design limits the work to just the southwest site for excavation and island building. The northeast site is not considered because it does not develop any shallow fish habitat.

By excavating to elevation 459.75 m as dictated in the current design, there is a much larger amount of material to be excavated than in the original design. The original design called for an even amount of cut and fill (excavation volume = island volume), but this would now create an island that is too big. A large island is not desirable since the creation of shallow fish habitat is the goal of the site. In order to handle the extra material, the new design fills in a low lying terrace adjacent to the river with the extra material. This, in turn, creates additional shallow water habitat.

The type of material at this site is unknown and will need to be checked prior to construction. Due to the presence of heavy forestation that is visible from air photos, it is possible that there are large amounts of soil present. Since soil is not ideal for constructing the island or for fish habitat, the need for gravel may arise. There are two small gravel bars adjacent to the site within the Peace River that can be accessed and excavated if necessary. Additional gravel deposits likely exist on the low lying bench just downstream of the design site. If soil needs to be disposed of, this low lying bench could be used for disposal as well since it will be inundated post reservoir filling. New temporary roads are proposed parallel to the river throughout this area and should allow for good access and smooth movement of equipment.

The work at this site will be done by a fleet of machinery that will grub, excavate, haul and place material.

The enhancement extents for this site are captured by the following criteria:

Pre-Enhancement:

- Shallow water habitat from elevation 459.75 m to elevation 461.8 m with dewatering due to reservoir fluctuations.

Post-Enhancement:

- Shallow water habitat at constant elevation 459.75 m and between elevations 459.75 m and 461.8 m along the cut slope.

See Appendix A for the enhancement areas and see Appendix B, Map 5 for a map of the site.

3. CONCLUSION

The reservoir shorline enhancement measures presented in this memorandum have been developed based on the best land contours and river bathymetry available at this time. Additional information, including material type and surveyed elevations, may result in some design changes, although an attempt has been made in this analysis to assess the foreseeable outcomes.

Surface area is the measurement used to determine the extent of the enhancement presented in this memo. The pre-enhancement surface area, defined as the area between elevations 459.75 m and 461.8 m within the proposed sites, is 620,000 m^2. The post-enhancement surface area, defined as the area at a constant elevation of 459.75 m as well as the area along the cut slope between elevations 459.75 m and 461.8 m, ranges from 1,040,000 m^2 to 1,080,000 m^2. Not only is the surface almost doubled with the enhancement measures in place, but overall aquatic productivity is expected to benefit in the post-enhancement area as it will not dewater during regular reservoir operations.

The productivity of the post-enhancement fish habitat is illustrated in Table 1, which summarizes the total areas for cases where shallow fish habitat is created (Km's 34-35, 42-44 and 49-52) into categories that either dewater or do not dewater.

Table 1. Pre-Enhancement vs. Post-Enhancement Shallow Water Habitat Surface Areas

	Zone with Dewatering Risk (area between elevation contours 460m and 461.8 m) (m^2)	Littoral Zone with No Dewatering Risk[1] (area between elevation contours 455.8 m to 459.75 m) (m^2)
Pre-Enhancement	165,000	67,000
Post-Enhancement	15,000	335,000[2]

[1] No dewatering risk under normal reservoir operation
[2] Includes new upland area (e.g. >461.8 m excavated to 459.75 m)

4. REFERENCES

1. Technical Memorandum No. 04, Task 27: Engineering Support for the Stage 2 Cost Estimate. “Environmental Mitigation & Compensation Measures”. March 2009.

APPENDIX A – SUMMARY OF SURFACE AREAS

KM	EnhancementConcept	Habitat Type	Area of Fish Habitat Pre-Enhancement (m^2)*	Area of Fish Habitat Post-Enhancement (m^2)**
22-24	Excavate and place spawning gravel on and around existing outcrop. The following options have been assessed: 1 – Access from south bank and material on outcrop good for spawning gravel. 2 – Access from south bank but material for spawning gravel sourced from nearby.	Spawning/Rearing	No spawning habitat pre-mitigation.	***Option 1 (area where gravel placed)*** 37,500 ***Option 2 (area where gravel placed)*** 37,500
25-27	Build berm 1485 m long to elevation 462.8 m, 10 m crest, 3H:1V slope; Build terracing to the south of the berm; Develop backwater channel for habitat by connecting berm to south bank; and Plant riparian vegetation on top of berm above MNRL.	Pre-Enhancement: Productive fish habitat up to 6 m below MNRL. Post-Enhancement: Productive fish habitat up to 6 m below MNRL and backwater habitat deeper than 6 m.	***Up to 6 m below MNRL:*** 435,700	***Up to 6 m below MNRL:*** 410,300 ***Deeper than 6 m below MNRL within backwater channel:*** 298,100 ***Total:*** 708,400

KM	Enhancement Concept	Habitat Type	Area of Fish Habitat Pre-Enhancement (m²)*	Area of Fish Habitat Post-Enhancement (m²)**
34-35	Excavate upstream end of embayment area for shallow water fish habitat. The following options have been assessed: 1 – Excavate to elevation 459.75 m and use material for road construction. 2 – Excavate to elevation 459.75 m and lay down material for additional habitat.	Shallow Water Habitat	18,800	***Option 1*** ***(excavation up to 461.8 m)*** 18,800 ***(excavation from 461.8-462.8 m)*** 2,700 ***Option 2*** ***(excavation up to 461.8 m and fill)*** 29,900 ***(excavation from 461.8-462.8 m)*** 2,700

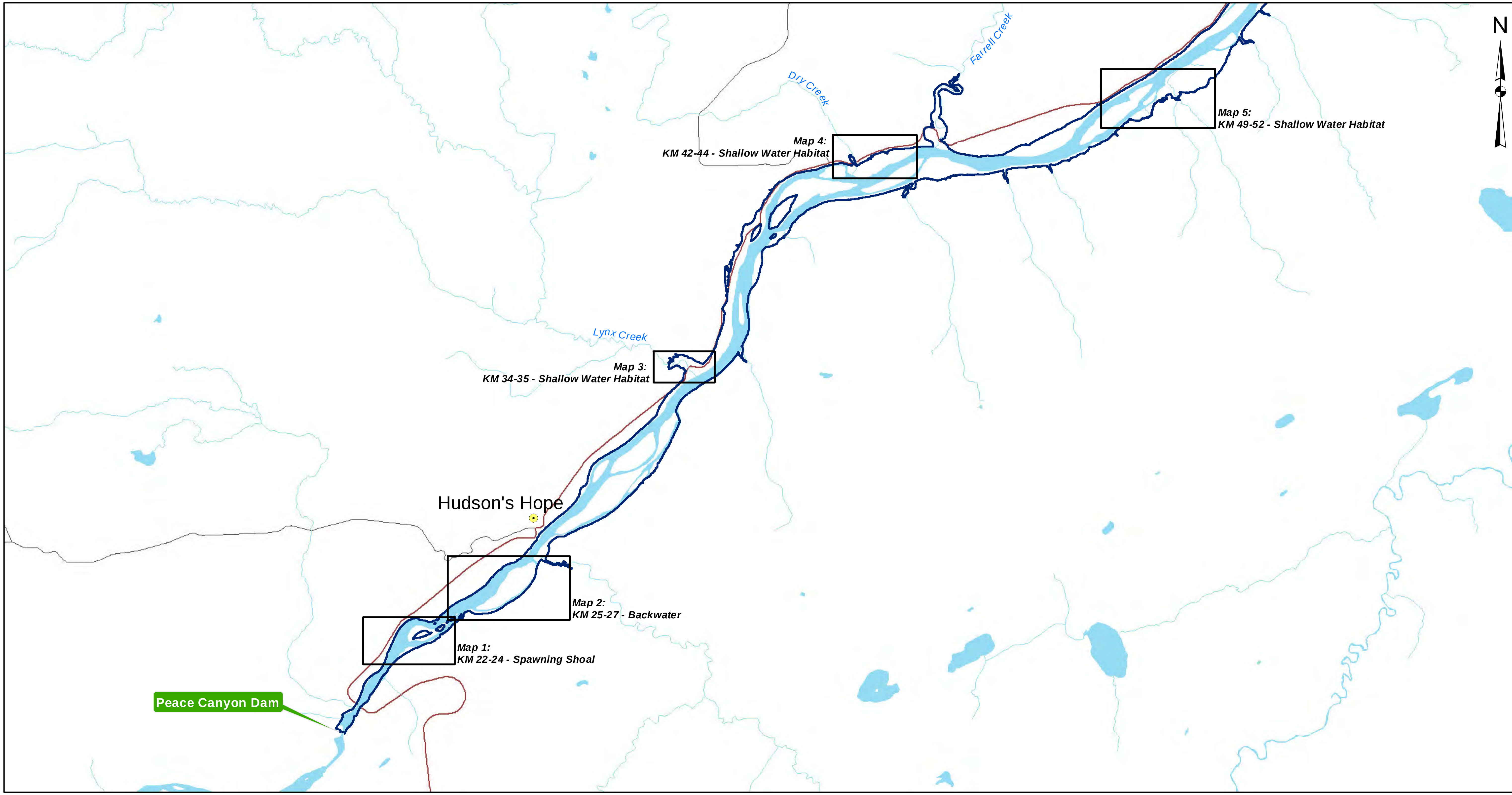
KM	Enhancement Concept	Habitat Type	Area of Fish Habitat Pre-Enhancement (m^2)*	Area of Fish Habitat Post-Enhancement (m^2)**	
42-44	Excavate for shallow water fish habitat. The following options have been assessed: 1 – Excavate to elevation 459.75 m and use material for road construction. 2 – Excavate to elevation 459.75 m and lay down material to elevation 459.75 m for additional habitat.	Shallow Water Habitat	67,800	***Option 1 (excavation up to 461.8 m)*** 69,700 ***(excavation from 461.8-462.8 m)*** 29,800 ***Option 2 (excavation up to 461.8 m and fill)*** 99,400 ***(excavation from 461.8-462.8 m)*** 29,800	

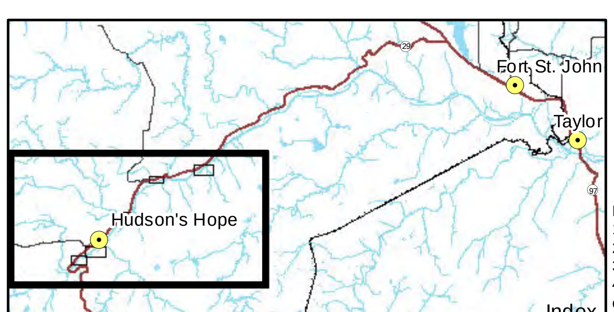
KM	Enhancement Concept	Habitat Type	Area of Fish Habitat Pre-Enhancement (m^2)*	Area of Fish Habitat Post-Enhancement (m^2)**	
49-52	Excavate to elevation 459.75 m; Fill low lying terrace to elevation 459.75 m; and Build island to elevation 462.8 m. The following options have been assessed: 1 – Excavated area proves to be suitable for building island and for fish habitat. 2 – Excavated area proves to be unsuitable for building island and gravel must be sourced from nearby (half of island volume assumed to be hauled in for costing purposes).	Shallow Water Habitat	97,300	***Option 1*** ***(excavation up to 461.8 m and fill)*** 108,600 ***(excavation from 461.8-462.8 m)*** 59,900 ***Option 2*** ***(excavation up to 461.8 m and fill)*** 108,600 ***(excavation from 461.8-462.8 m)*** 59,900	

*Unless otherwise noted, the area of fish habitat pre-enhancement includes the surface area between 459.75 m and 461.8 m. The area between elevations 460 m and 461.8 m is within the regular fluctuation zone of the reservoir and is often dewatered. As a result, it is not ideal for fish habitat.

** Unless otherwise noted, the area of fish habitat post-enhancementincludes the area that is at a constant elevation of 459.75 m as well as the area along the cut slope between elevations 459.75 m and 461.8 m. The area between elevations 460 m and 461.8 m has the potential to be dewatered due to regular reservoir fluctuations but the area at a constant elevation of 459.75 m does not.

APPENDIX B – Maps





Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

Legend

- Maximum Normal Reservoir Level (461.8 m)
- Road
- Highway

1:100,000 0 5,000 m

BC hydro

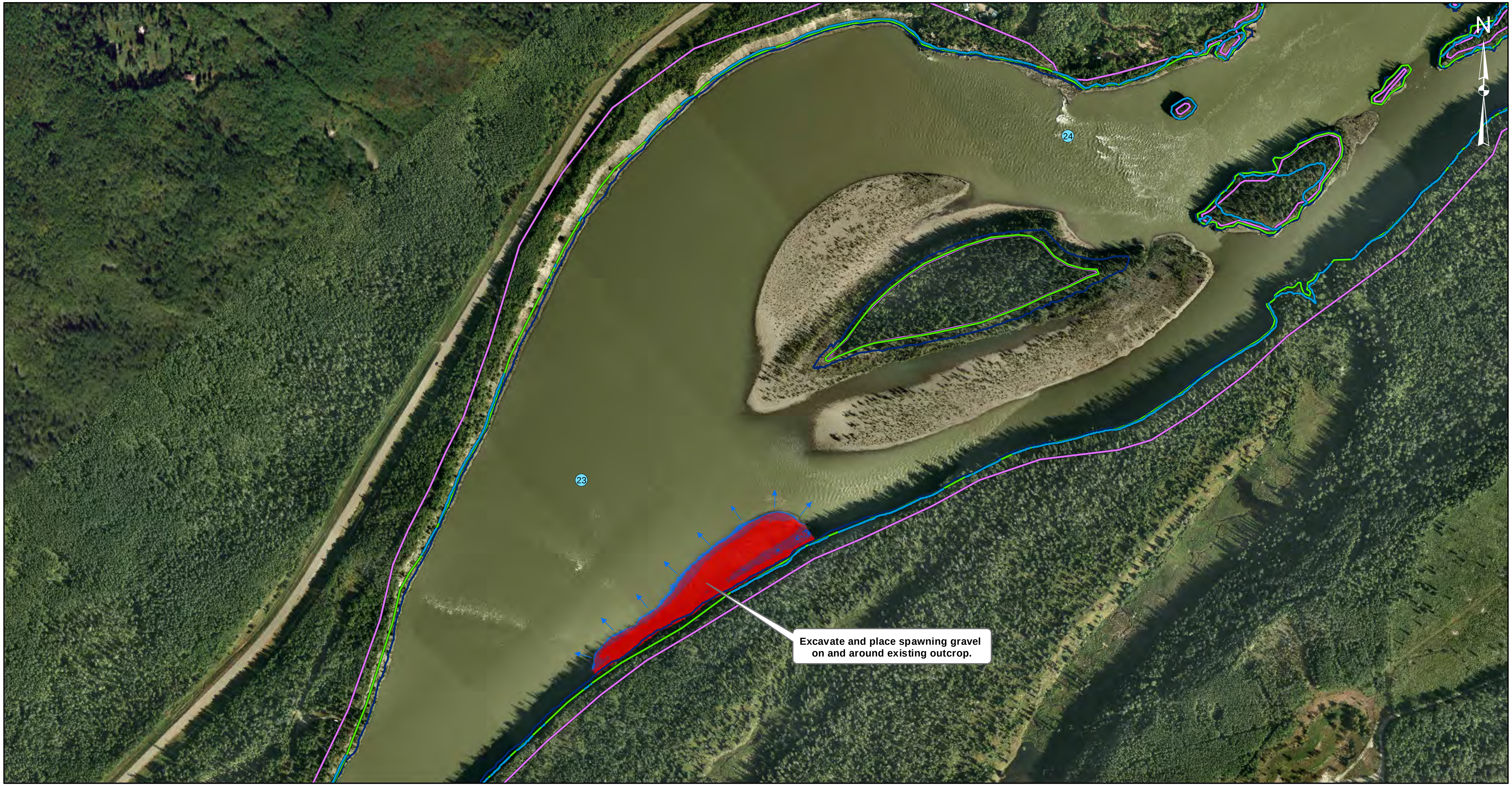
SITE C CLEAN ENERGY PROJECT

Areas of Potential Fish Habitat Enhancement Overview

Date	November 25, 2013	DWG NO	1016-C14-B6442	R 0

Path: X:\ArcGIS\Projects\Mitigation\Fish Habitat Mitigation\Fish Hab Mitigation 1016 C14 B6442 KM23 Overview.mxd

Construction of the Site C Clean Energy Project is subject to required regulatory approvals including environmental certification



Legend

- Area of fill
- Area cut to 459.25m
- Area cut to 459.75m
- Maximum Normal Reservoir Level (461.8 m)
- River Km Markers
- Highway Realignment Corridor
- Highway Realignment Right-Of-Way
- Highway Realignment
- Preliminary Stability Impact Line
- Preliminary Stability Impact Line - Subject to final highway design
- Preliminary Landslide-Generated Wave Impact Line
- Preliminary Erosion Impact Line
- Preliminary Erosion Impact Line - Subject to final highway design
- Preliminary Flood Impact Line
- Preliminary Flood Impact Line - Subject to final highway design

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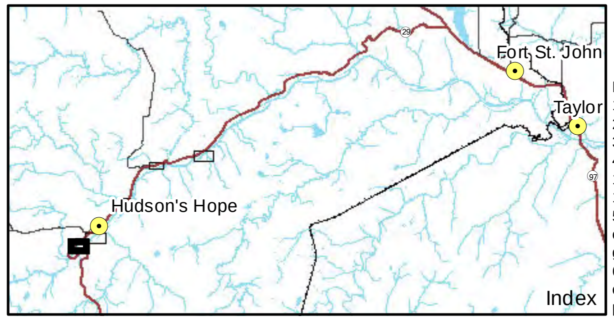


Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007; 1:15,000 photos taken Aug. 26th 2011 and 1:5,000 photos taken Aug. 26th, 2011.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.
6. Preliminary flood impact line is based on an elevation of 466m and is only shown when located outside of the preliminary erosion impact line.

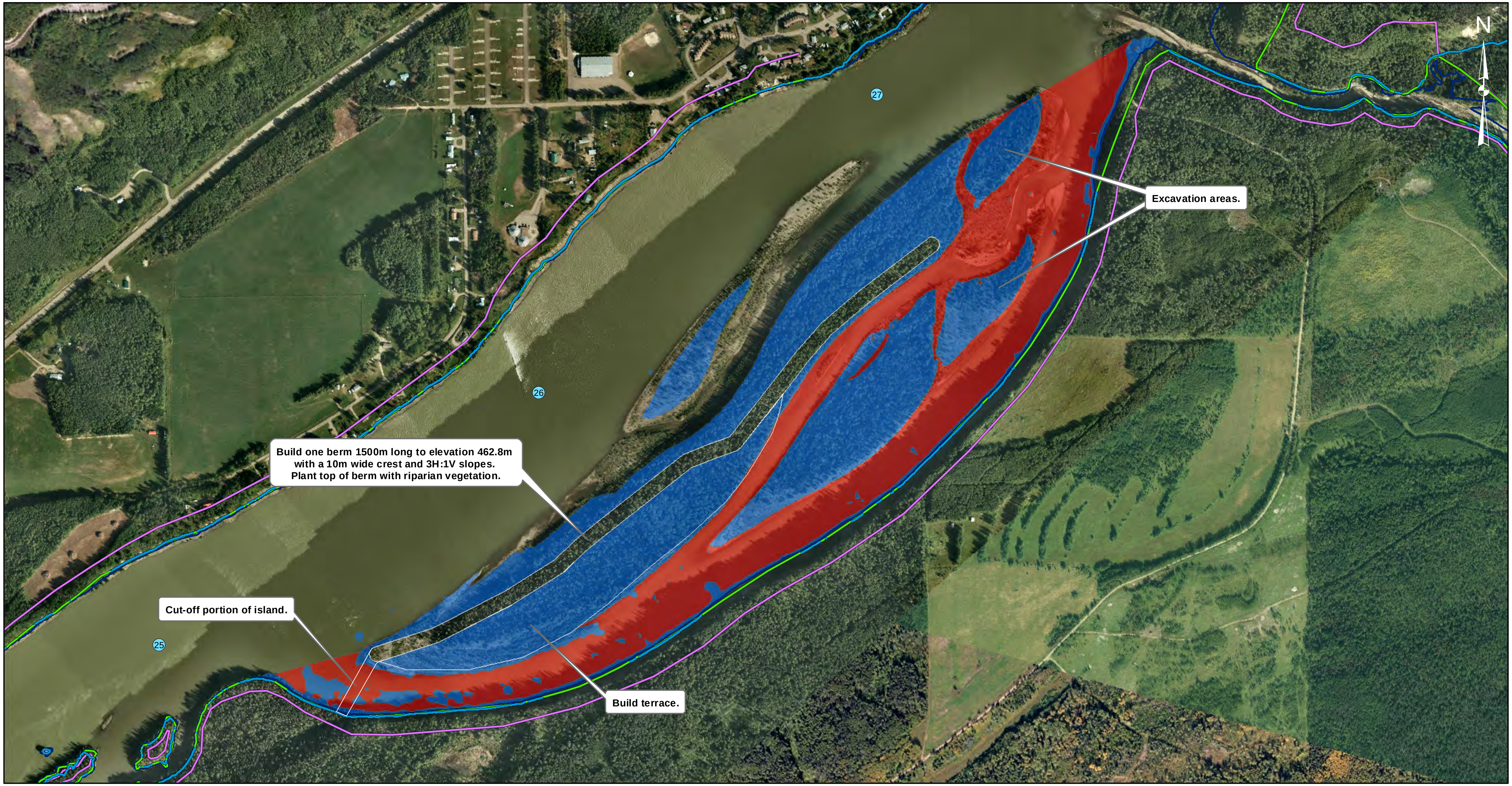
BC hydro

SITE C CLEAN ENERGY PROJECT

Areas of Potential Fish Habitat Enhancement KM 22-24 - Spawning Shoal Map 1 of 5

Date	December 20, 2013	DWG NO	1016-C14-B6442	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory approvals including environmental certification

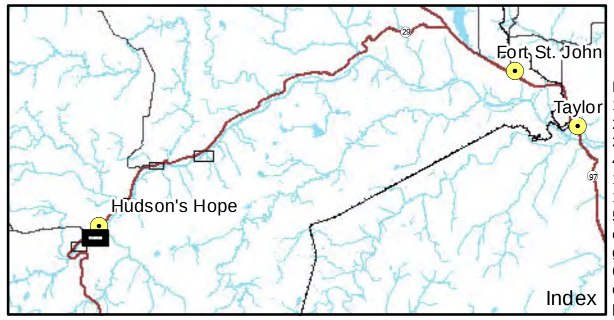


Legend

- Fish Habitat (<6m below FSL)
- Backwater Channel Area
- Maximum Normal Reservoir Level (461.8 m)
- River Km Markers
- Highway Realignment Corridor
- Highway Realignment Right-Of-Way
- Highway Realignment
- Preliminary Stability Impact Line
- Preliminary Stability Impact Line - Subject to final highway design
- Preliminary Landslide-Generated Wave Impact Line
- Preliminary Erosion Impact Line
- Preliminary Erosion Impact Line - Subject to final highway design
- Preliminary Flood Impact Line
- Preliminary Flood Impact Line - Subject to final highway design

1:8,000

0 400 m



Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007; 1:15,000 photos taken Aug. 26th 2011 and 1:5,000 photos taken Aug. 26th, 2011.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.
6. Preliminary flood impact line is based on an elevation of 466m and is only shown when located outside of the preliminary erosion impact line.

BC hydro

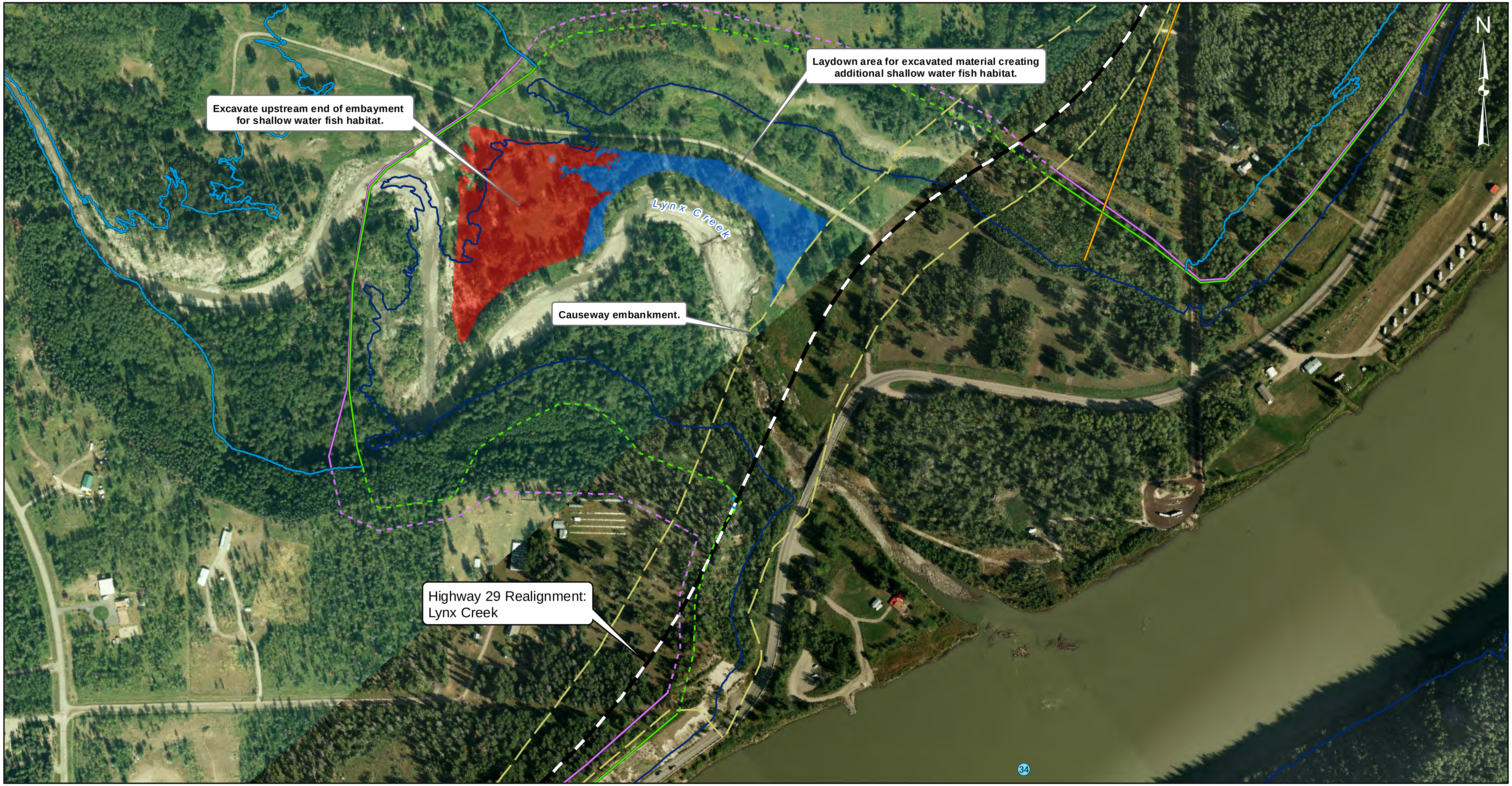
SITE C CLEAN ENERGY PROJECT

Areas of Potential Fish Habitat Enhancement KM 25-27 - Backwater Map 2 of 5

Date	December 20, 2013	DWG NO	1016-C14-B6442	R 0

Path: X:\ArcGIS\Projects\Mitigation\Fish_Habitat_Mitigation\Fish_Hab_Mitigation_1016_C14_B6442_KM26_Map2.mxd

Construction of the Site C Clean Energy Project is subject to required regulatory approvals including environmental certification

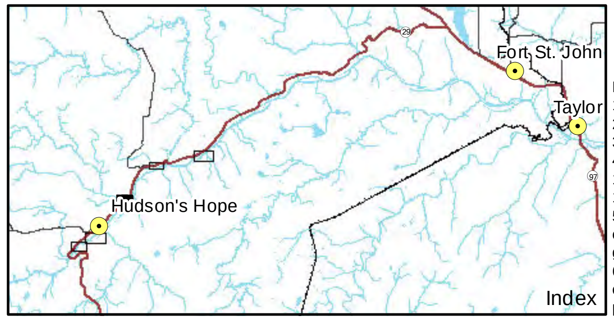


Legend

- Area of fill
- Area cut to 459.75m
- Maximum Normal Reservoir Level (461.8 m)
- River Km Markers
- Highway Realignment Corridor
- Highway Realignment Right-Of-Way
- Highway Realignment
- Preliminary Stability Impact Line
- Preliminary Stability Impact Line - Subject to final highway design
- Preliminary Landslide-Generated Wave Impact Line
- Preliminary Erosion Impact Line
- Preliminary Erosion Impact Line - Subject to final highway design
- Preliminary Flood Impact Line
- Preliminary Flood Impact Line - Subject to final highway design

1:4,000

0 — 200 m



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2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007; 1:15,000 photos taken Aug. 26th 2011 and 1:5,000 photos taken Aug. 26th, 2011.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.
6. Preliminary flood impact line is based on an elevation of 466m and is only shown when located outside of the preliminary erosion impact line.

BC hydro

SITE C CLEAN ENERGY PROJECT

Areas of Potential Fish Habitat Enhancement KM 34-35 - Shallow Water Habitat Map 3 of 5

Date	December 20, 2013	DWG NO	1016-C14-B6442	R 0

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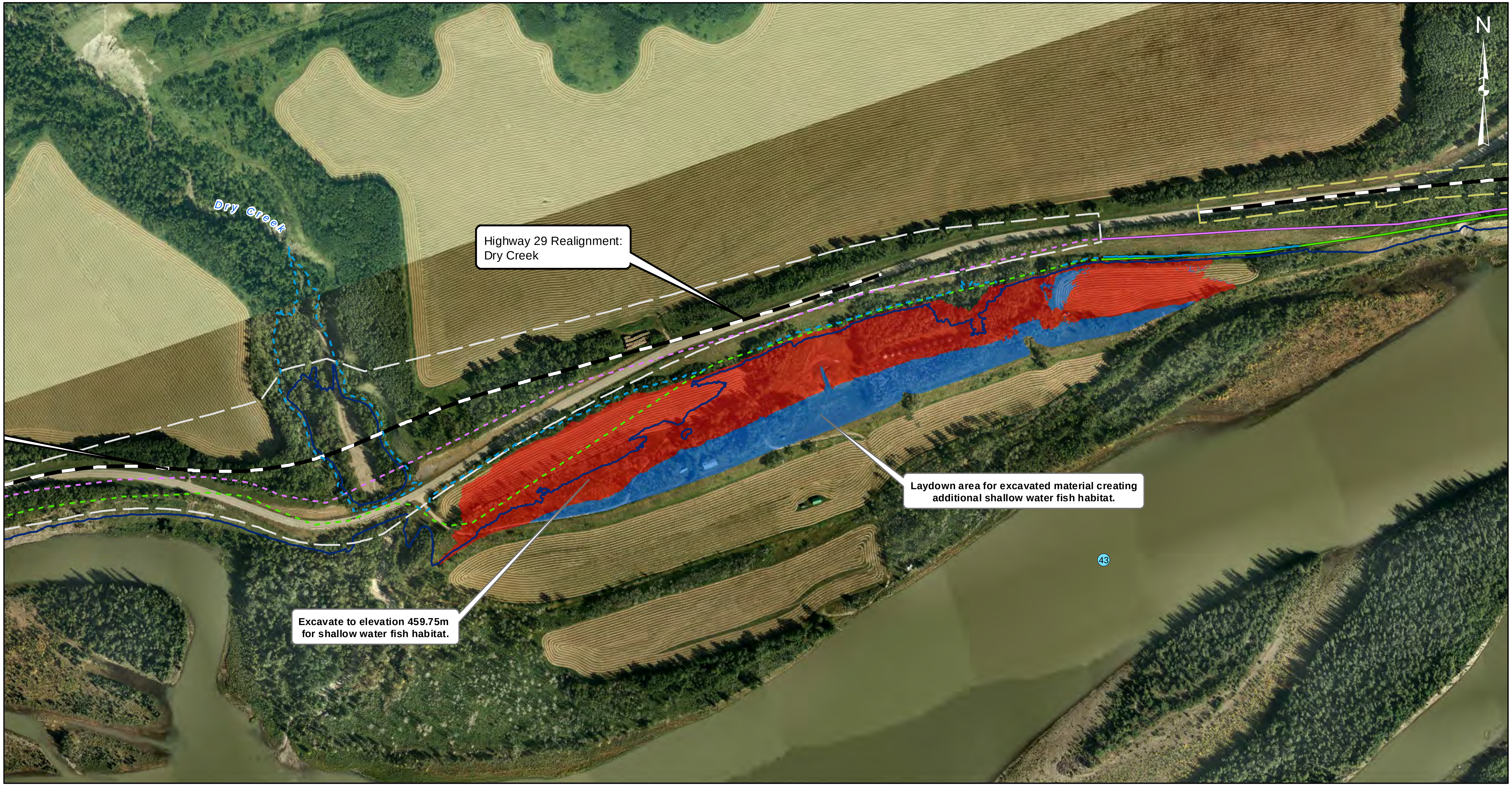
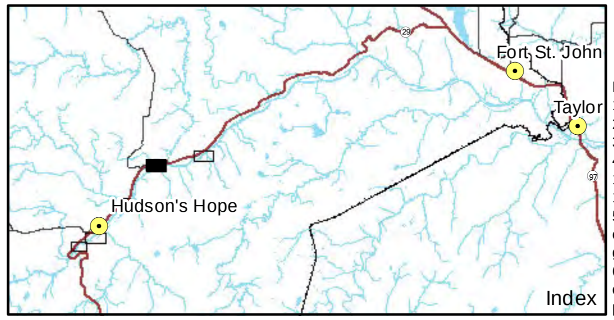
Construction of the Site C Clean Energy Project is subject to required regulatory approvals including environmental certification





Map Notes:
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3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007; 1:15,000 photos taken Aug. 26th 2011 and 1:5,000 photos taken Aug. 26th, 2011.
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6. Preliminary flood impact line is based on an elevation of 466m and is only shown when located outside of the preliminary erosion impact line.

Legend

- Area of fill
- Area cut to 459.75m
- Maximum Normal Reservoir Level (461.8 m)
- River Km Markers
- Highway Realignment Corridor
- Highway Realignment Right-Of-Way
- Highway Realignment
- Preliminary Stability Impact Line
- Preliminary Stability Impact Line - Subject to final highway design
- Preliminary Landslide-Generated Wave Impact Line
- Preliminary Erosion Impact Line
- Preliminary Erosion Impact Line - Subject to final highway design
- Preliminary Flood Impact Line
- Preliminary Flood Impact Line - Subject to final highway design

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SITE C CLEAN ENERGY PROJECT

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Areas of Potential Fish Habitat Enhancement KM 42-44 - Shallow Water Habitat Map 4 of 5

Date	December 20, 2013	DWG NO	1016-C14-B6442	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory approvals including environmental certification

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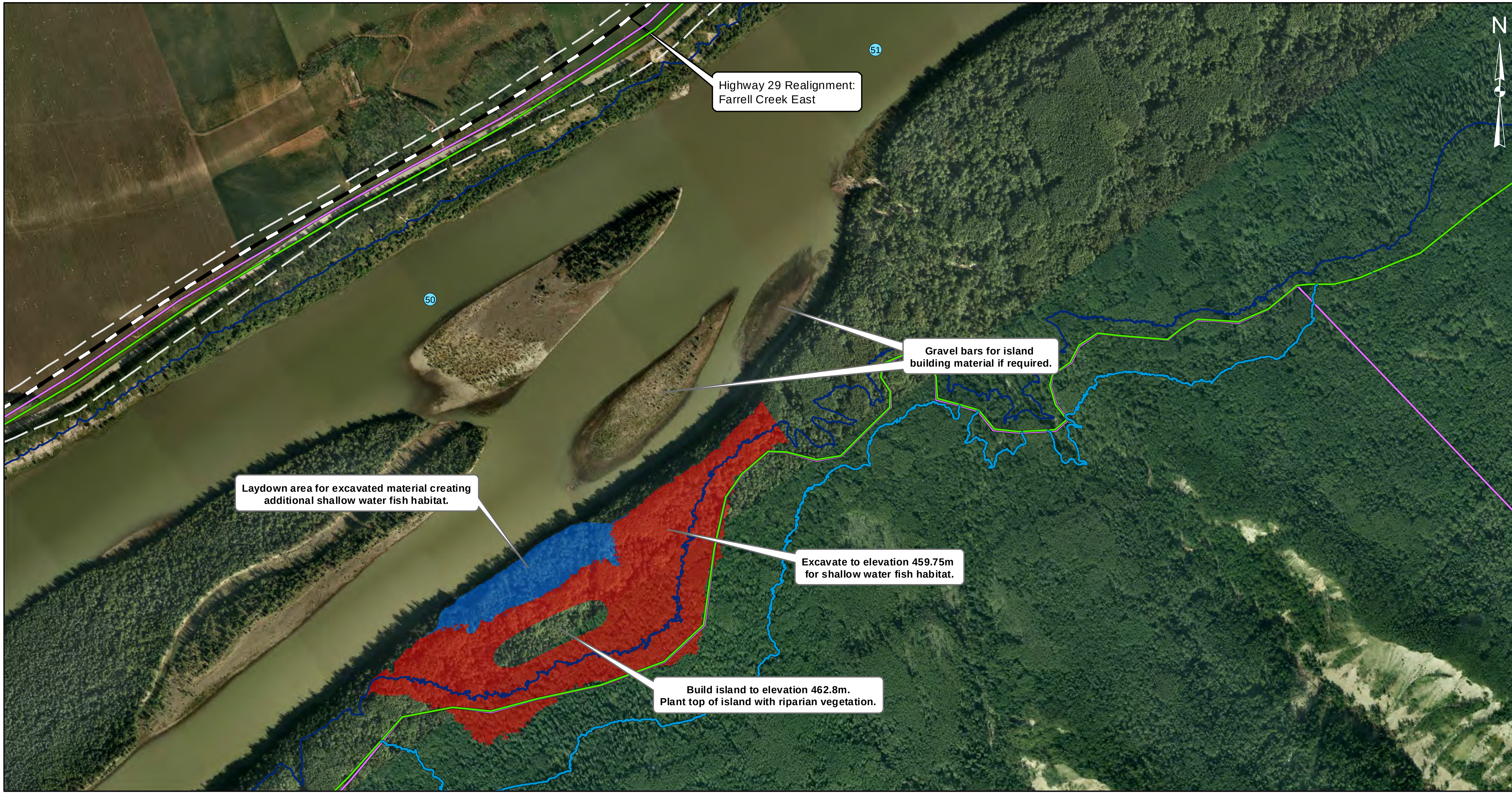

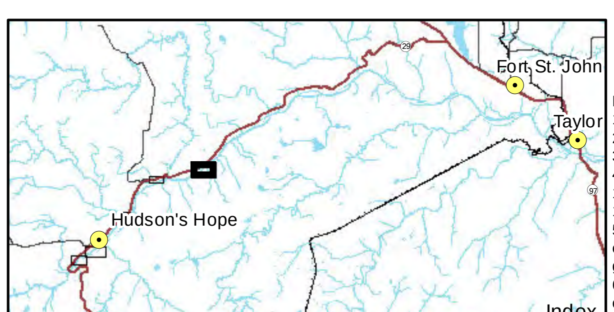

Legend

- Area of fill
- Area cut to 459.75m
- Maximum Normal Reservoir Level (461.8 m)
- River Km Markers
- Highway Realignment Corridor
- Highway Realignment Right-Of-Way
- Highway Realignment
- Preliminary Stability Impact Line
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- Preliminary Erosion Impact Line
- Preliminary Erosion Impact Line - Subject to final highway design
- Preliminary Flood Impact Line
- Preliminary Flood Impact Line - Subject to final highway design

Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007; 1:15,000 photos taken Aug. 26th 2011 and 1:5,000 photos taken Aug. 26th, 2011.
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6. Preliminary flood impact line is based on an elevation of 466m and is only shown when located outside of the preliminary erosion impact line.

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SITE C CLEAN ENERGY PROJECT

Areas of Potential Fish Habitat Enhancement KM 49-52 - Shallow Water Habitat
Map 5 of 5

Date	December 20, 2013	DWG NO	1016-C14-B6442	R 0

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Construction of the Site C Clean Energy Project is subject to required regulatory approvals including environmental certification

Appendix D - Proposed Fisheries and Aquatic Habitat Monitoring Plans[10]

[10] Fisheries and Aquatic Habitat Monitoring plans will be submitted as a component of the Fisheries and Aquatic Habitat Monitoring and Follow-up Program due for submission as draft to FLNRO, MOE and Aboriginal Groups for review within 90 days following the commencement of construction.

Monitoring Program #	Title	Monitoring Program Objective
1a	Site C Reservoir Fish Community Monitoring	To monitor the effects of the river to reservoir transformation on the fish community in the Site C Reservoir and associated tributaries.
1b	Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program	To monitor fish populations in Site C Reservoir tributaries to determine effects of the Project and the effectiveness of mitigation measures for fish and fish habitat.
2	Peace River Fish Community Monitoring Program	This program will monitor fish population in the Peace River to determine effects of the Project and the effectiveness of mitigation measures for fish and fish habitat.
3	Peace River Physical Habitat Monitoring	To monitor the effects of the Site C Dam on physical habitat downstream of Site C Dam.
4	Site C Reservoir Riparian Vegetation Monitoring	To monitor the effectiveness of the planned riparian planting of the Site C Reservoir shoreline.
5	Peace River Riparian Vegetation Monitoring	To monitor the effects of the Project on riparian vegetation downstream of the Site C Dam.
6	Site C Reservoir Fish Food Organisms Monitoring	To monitor the effects of reservoir formation on production of fish food organisms.
7	Peace River Fish Food Organisms Monitoring	To monitor the effects of dam construction and operations on the biomass of invertebrates and availability of fish food organisms downstream of the Site C Dam.
8	Site C Reservoir Water and Sediment Quality Monitoring	To monitor the effects of reservoir formation on water and sediment quality.
9	Peace River Water and Sediment Quality Monitoring	To monitor the effects of the Site C dam on water and sediment quality downstream of the Site C Dam.
10	Site C Fish Entrainment Monitoring	To monitor entrainment rates and survival rates of entrained fish during construction and operation of Site C Dam.
11	Site C TDG Monitoring	To monitor total dissolved gas (TDG) supersaturation and potential downstream fish population effects resulting from gas bubble disease during Project construction and operation.
12	Site C Fish Stranding Monitoring	To monitor Site C Dam construction and operation effects associated with flow fluctuations and fish stranding on the resident fish community.
13	Site C Fishway Effectiveness Monitoring	To monitor the performance of the fishway including the temporary trap and haul facility at the outlet of the diversion tunnels and permanent trap and haul facility at the Site C Dam.
14	Site C Trap and Haul Fish Release Location Monitoring	To monitor the optimum fish release locations for fish collected at the Site C Dam fishway and transported and released upstream.

Monitoring Program #	Title	Monitoring Program Objective
15	Site C Small Fish Translocation Monitoring	To monitor fish population in the Peace River to determine effects of the Project on genetic structure, movement, and genetic exchange of small fish species.
16	Site C Reservoir Constructed Shallow Water Habitat Monitoring	To monitor the suitability of benthic substrates in constructed shallow water habitats of Site C Reservoir for aquatic planting trials as well as monitor the natural colonization of aquatic plants in these habitats.

Appendix E – Fish Passage Management Plan[11]

[11] EIS, Volume 2, Appendix Q1. This version is appended for reference.

SITE C CLEAN ENERGY PROJECT

VOLUME 2 APPENDIX Q1

TECHNICAL DATA REPORT:
FISH PASSAGE MANAGEMENT PLAN

Prepared for:
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December 2012

SITE C CLEAN ENERGY PROJECT

VOLUME 2 APPENDIX Q1

TECHNICAL DATA REPORT:

FISH PASSAGE MANAGEMENT PLAN

Prepared for BC Hydro Power and Authority

Prepared by BC Hydro

December 2012

Lead Author: Brent Mossop, Senior Environmental Coordinator

Section Contributors: Paul Higgins, Environmental Technical Principal

Lead Author, Brent Mossop

Section Contributor, Paul Higgins

AUTHORSHIP

Brent Mossop...Senior Environmental Coordinator

EXECUTIVE SUMMARY

For the proposed Site C Clean Energy Project (the Project), BC Hydro undertook a structured approach to assess fish passage management options in terms of potential fish passage risks, technical feasibility, biological benefits and costs. This Fish Passage Management Plan contains the recommendations from this assessment as a coordinated series of actions and tests to manage upstream and downstream fish passage at the Project, and associated effectiveness monitoring during the construction and operation of the Project. The Fish Passage Management Plan has four primary components.

1) Upstream passage – a staged approach to the design, construction, operation and evaluation of trap and haul facilities for mature bull trout as the primary target species.
2) Downstream passage – a suite of integrated design features to maximize fish survival.
3) Periodic Translocation Program – a periodic capture and translocation program for small fish species, contingent on the results of investigative studies into the genetic exchange requirements of upstream and downstream populations.
4) Monitoring and Adaptive Management – a monitoring and assessment program aimed at reducing key uncertainties and informing ongoing operation of the trap and haul facilities, supported by a technical advisory committee.

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1 INTRODUCTION

1.1 Fish Passage

The key considerations for fish passage for hydroelectric developments are:

- Upstream passage: Provide safe movement of fish upstream past the dam.
- Downstream passage: For fish that may pass downstream through the dam facilities (commonly termed 'entrainment' of fish through the facility), to a) minimize injury or mortality, and b) manage loss of 'productive capacity' and fisheries in upstream water bodies due to the entrainment of fish into downstream water bodies.

1.2 Context for this Report

The Environmental Impact Statement Guidelines for the Site C Clean Energy Project (the Project) require that the potential effects of the Project on upstream and downstream fish migrations be assessed, and any mitigation options being considered to minimize potential impacts of the Project on fish passage be described.

This Fish Passage Management Plan, the first document in series of reports outlined below, describes a coordinated series of actions and tests to manage upstream and downstream fish passage at the Site C dam site (Site C), and associated effectiveness monitoring during the construction and operation of the Project. This Fish Passage Management Plan is supported by additional technical reports that are appended as outlined below:

Fish Passage Management Plan – BC Hydro's proposed approach to fish passage at the Project. The plan is based on the key outcomes described in the Fish Passage Alternatives Assessment (Attachment A below).

Attachment A Fish Passage Alternatives Assessment – A summary report of the structured and transparent approach to assess fish passage management options in terms of potential fish passage risks, technical feasibility, biological benefits and costs.

Attachment B Fish Passage Biological Modelling – A summary of the biological modelling for fish passage alternatives.

Attachment C Fish Passage Expert Reports – A compilation of technical memos that document fish passage risks, and the technical feasibility and initial assessment of fish passage options.

Attachment D Fish Passage Conceptual Designs – A compilation of technical memos that describe the feasibility assessments and conceptual designs for the short-listed fish passage alternatives identified and discussed in Attachments A and C above.

This documentation on fish passage supports the effects assessment on the Valued Component Fish and Fish Habitat (Volume 2 Section 12 Fish and Fish Habitat Effects Assessment).

2 FISH PASSAGE MANAGEMENT PLAN

2.1 Overview

BC Hydro undertook a structured approach to assess fish passage management options in terms of potential fish passage risks, technical feasibility, biological benefits and costs. The results of this assessment led to the recommendations presented below.

This Fish Passage Management Plan has four primary components:

1) Upstream passage – a staged approach to the design, construction, operation and evaluation of trap and haul facilities for mature bull trout as the primary target species.
2) Downstream passage – a suite of integrated design features to maximize fish survival.
3) Periodic Translocation Program – a periodic capture and translocation program for small fish species, contingent on the results of investigative studies into the genetic exchange requirements of upstream and downstream populations.
4) Monitoring and Adaptive Management – a monitoring and assessment program aimed at reducing uncertainties and informing ongoing operation of the trap and haul facilities, supported by a technical advisory committee.

2.2 Upstream Fish Passage

BC Hydro proposes to address upstream fish passage at the Project through a staged approach to the design, construction, operation and evaluation of trap and haul facilities. The key design parameters include:

- Bull trout completing their upstream spawning migration are the primary target species for upstream passage. The design of the trap and haul facility would also accommodate other species including Arctic grayling, mountain whitefish, rainbow trout and other large-bodied fish that may attempt to pass upstream. Long-term operation of the facilities would be contingent on the formal evaluation of the effectiveness of the facilities in meeting provincial fisheries management objectives, which are described in Volume 2 Appendix Q2 Fish Passage Management Plan, Attachment A Fish Passage Alternatives Assessment.

- Upstream fish passage facilities would be developed to meet the distinct requirements of both the four-year river diversion stage of construction and the long-term operating phase of the Project. Experience gained during operation of the trap and haul facilities during the river diversion stage would be incorporated into the implementation design the trap and haul facilities for the operations phase of the Project.
- The facilities would be operated during the fish upstream migration window, expected to be April 1 – October 31 based on available information (Volume 2 Appendix O Fish and Fish Habitat).

The commitment is to provide for ongoing upstream fish passage if this is proven to be biologically required, as supported by the follow-up and monitoring program described below.

2.2.1 Trap and Haul Facility Components

A technical memorandum has been prepared that describes a conceptual design for the proposed trap and haul facilities (Volume 2 Appendix Q5 Fish Passage Management Plan, Attachment D-1 Trap and Haul Conceptual Design). The conceptual design is based on:

1) Recommendations from the Site C fish passage expert panel (Volume 2 Appendix Q2 Fish Passage Management Plan, Attachment A Fish Passage Alternatives Assessment; Volume 2 Appendix Q4 Fish Passage Management Plan, Attachment C-1 Upstream Fish Passage Assessment),
2) Design information from a trap and haul facility that was designed for and passes bull trout (GEI 2010); and
3) Compatability with the design, construction and operation of the Project. Other trap and haul designs are possible. A staged approach to trap and haul design and implementation during the construction and operation phases of the Project will enable ongoing refinements and effectiveness improvements (see Section 2.2.2 below).

Components of the upstream trap and haul facilities include systems for:

- Fish Collection – technologies to attract and guide fish to collection locations (e.g., fishway entrance).
- Fish Conveyance – technologies to sort, sample and enumerate fish, and then facilitate the transport of target species upstream or downstream.
- Fish Release – technologies for safe release of target species in preferred locations (e.g., tributaries to the reservoir).

2.2.1.1 Fish Collection

The current conceptual design includes construction of a fishway for fish to swim up ten vertical meters to a collection, sorting and loading facility. During the four-year river diversion stage of the Project, this facility would be constructed near the outlet of the diversion tunnels, whereas during the long-term operating phase the facility would be constructed on the deck of the dam near the generating station tailrace.

Key components of the facility would include:

- Entrance structure – the location where upstream migrating fish leave the river and begin ascending. The structure must be designed to accommodate the expected range river levels and flows.
- Fish ladder – designed as a series of pools that would enable fish to ascend ten vertical metres to a trapping pool. During the interim river diversion stage, the fish ladder would be constructed out of timbers with steel supports to allow for ease of reconfiguration. During the permanent operating phase, the fish ladder would need to be constructed out of concrete given its location on the training wall at the base of the dam.
- Water supply pumping station – designed to provide the necessary attraction flows into the fish ladder. Water would be drawn from the river via a series of pumps.

2.2.1.2 Fish Conveyance

The conceptual design includes facilities to sort, sample and enumerate fish, and then facilitate the transport of target species upstream or downstream.

Key components of the facilities would include:

- Anaesthetic pool – a concrete pool used to anaesthetize fish. The pool would be located adjacent to the trapping pool at the top of the fish ladder and fitted with a fish lift.
- Sorting area – would include a sorting trough where fish are sorted by species, aerated recovery tanks and flumes, transportation tanks (for those fish targeted for upstream transport) and a tailrace return pipe (for those species targeted for return to the river).

2.2.1.3 Fish Release

Management and transportation plans will be developed for each species. Release locations may vary by species and by phase of the Project. For example, bull trout are expected to be released into the Halfway River during the operations phase of the Project. Other species may be released in the Site C reservoir or tributaries to the reservoir. In all cases, special care and attention would be placed on selecting release locations and developing release protocols that minimize the risk of predation by wildlife or other fish, and the risk of subsequent entrainment back downstream. Release locations may also be adjusted over time as new information emerges from the monitoring and adaptive management program (see Section 2.5 below).

The equipment required for the transport system would include trucks and watercraft as required, designed to carry the transport tanks and fitted with necessary cranes and outlet flumes.

2.2.2 Staged Approach to Implementation

In view of the uncertainties of upstream trap and haul programs, a key objective for the design and operation of such a facility is to maximize the success of the attraction, collection, sorting, transportation and release process for the target species at the Project. A limited number of existing hydroelectric projects include facilities designed for these target species. Experience from these facilities highlights that a period of trial and adjustment (e.g., with respect to water attraction flow rates) would be required to maximize the efficiency of the upstream fish passage system. In addition, ecological and management uncertainties include: i) how the resultant fish communities upstream and downstream would establish over the long term, and ii) how provincial fishery management objectives may be adjusted to best suit the resultant fish communities.

For these reasons, this plan proposes a staged approach to the design and operation of upstream passage facilities that can sort fish based on the intended release location for each species (upstream or downstream). The staged approach includes a follow-up program with monitoring to reduce the ecological uncertainties, and a technical committee to advise on operations based on monitoring results and their implications to management (e.g., transportation plans and release locations). Such a staged approach to implementation is consistent with regulatory guidance to address uncertainties associated with fish passage at new facilities (DFO 2007).

The proposed trap and haul facilities would include three progressive trap and haul design phases prior to trap and haul construction and operations (Figure 1). This staged approach offers the best opportunity to integrate experience from ongoing monitoring programs (see Section 2.5 below) into the design and operations. A summary of the staged approach includes:

Conceptual design – The conceptual design has been completed, as described above and in (Volume 2 Appendix Q5 Fish Passage Management Plan, Attachment D-1 Trap and Haul Conceptual Design)

No	Activity	Pre-Construction			Channelization			Diversion				Site C Early-Ops					Site C Ongoing Ops				
		-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	1	2	3	4	5	6	7	8	9	10
1	Biological Data Collection																				
1a	Population Monitoring (ongoing)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
1b	Collect pre-Construction Biological Information to Guide Trap & Haul Design	■	■	■	■	■	■														
1c	Trap and Haul Effectiveness Evaluations							■	■	■	■	■	■	■	■	■	■	■	■	■	■
2	Trap and Haul Conceptual Design (Complete)																				
2a	Diversion Facility																				
2b	Permanent Facility																				
3	Trap and Haul Definition Design																				
3a	Diversion Facility	■	■																		
3b	Permanent Facility	■	■																		
4	Trap and Haul Implementation Design																				
4a	Diversion Facility			■																	
4b	Permanent Facility			■	■	■	■	■													
5	Trap and Haul Construction																				
5a	Diversion Facility				■	■	■														
5b	Permanent Facility							■	■	■	■										
6	Trap and Haul Operation																				
6a	Diversion Facility							■	■	■	■										
6b	Permanent Facility											■	■	■	■	■	■	■	■	■	■

Figure 1. Anticipated implementation schedule for upstream trap and haul. Years are identified as prior to and following commissioning of the Project. For reference purposes only, 10 years are identified following commissioning. Ops = Operations.

Definition design – The definition design would explore alternative trap and haul facility designs. It would incorporate, as required, additional hydraulic modelling and further characterization of hydraulic criteria for the fish species. The definition design phase would begin to develop more detailed engineering requirements (e.g., detailed entrance structure configuration) based on key guidance documents for fish passage (e.g., NMFS 2011) as adapted to the fish species and site-specific requirements at the Project.

Implementation design – This final design phase provides the detailed engineering specifications and requirements for equipment procurement and construction. Given the requirement to design for two phases of the Project – construction and operations – special attention will be placed on designing for reuse. Experience gained during operation of the trap and haul facilities during the river diversion stage would be incorporated into the implementation design for the long-term operations phase.

Construction – The construction of each trap and haul facility would be coordinated with the overall construction sequence for the Project. Construction of the trap and haul facilities for the river diversion would be completed and operation would begin when the four-year river diversion stage begins. Construction of the permanent facilities would occur in parallel with operation of the river diversion facilities.

Operations – Operation of the trap and haul facilities would include two main components: a) operations for fish, including sorting, sampling, transport, and release; and b) maintenance of the facilities. This phase is expected to involve an ongoing period in which operations would be adjusted to optimize effectiveness.

2.3 Downstream Fish Passage

BC Hydro recommends that downstream fish passage at the Project be addressed through a suite of integrated design features to maximize fish survival.

The key features of this approach during each phase (and stage) of the Project are described below.

River Channelization Stage

Conditions for downstream fish movement in the channelized section of the Peace River would be similar to natural river conditions (Volume 2 Appendix Q4 Fish Passage Management Plan, Attachment C-4 Fish Mortality During River Diversion).

River Diversion Stage

Regulated Peace River flows will be diverted through two tunnels during the four-year river diversion stage. The potential risk to fish in terms of descaling, pressure change, shear and strike are projected to be minimal for the expected flows and tunnel design and configuration (Volume 2 Appendix Q4 Fish Passage Management Plan, Attachment C-4 Fish Mortality During River Diversion). Specific design features to be integrated into the construction and operations of the tunnels would include:

- Incorporating smooth and gradual transitions from the round tunnels to the square exits.
- Completing tunnel linings with a smooth concrete surface finish.
- Reducing any obstructions (e.g., boulders) from the tunnel tailrace area.

Site C Dam and Generating Station Operating Phase

During typical operations the Peace River will flow through the approach channel, penstocks and turbines, exiting into the tailrace area. Fish moving downstream will pass through the turbines with a fish size-dependent survival rate calculated to be greater than 90% for small fish (100 mm fork length) and greater than 60% for the largest fish (750 mm fork length; described in Volume 2 Appendix Q4 Fish Passage Management Plan, Attachment C-3 Turbine Passage Survival Estimates).

To minimize the potential further risk to fish in terms of descaling, pressure change, shear and strike, the following specific design features would be integrated into the construction and operation of the dam and generating station:

- Incorporating smooth and gradual transitions at the approach channel and penstock entrances and tailrace exit structures.
- Designing the orientation and sizing of all openings and exits to reduce hydraulic turbulence.
- Completing linings with smooth surface finishings.
- Reducing any obstructions (e.g., boulders) from the turbulent zone in spillway and tailrace areas

2.4 Periodic Translocation Program

The approach to upstream fish passage as described above is targeted toward large-sized fish species (≥200 mm fork length at maturity) that undertake extensive movements (e.g., bull trout; described in Volume 2 Appendix O Fish and Fish Habitat). Small fish species (<200 mm fork length at maturity) such as redside shiner do not undertake extensive migrations or movements (Volume 2 Appendix O Fish and Fish Habitat). Ongoing upstream and downstream passage is not required to meet population abundance objectives for small fish species (Volume 2 Appendix Q2 Fish Passage Management Plan, Attachment A Fish Passage Alternatives Assessment). However, some movement may occur between locations and it is uncertain whether this provides genetic exchange between locations. These small fish species may not pass upstream using the trap and haul facility.

To address this uncertainty for small fish, BC Hydro recommends that a periodic translocation program be investigated at a conceptual level. Based on available information, there is no precedent for such a translocation program, although a recent program of capture and translocation for non-anadromous salmonids (Epifanio et al. 2003) reflected this concept. Such a program would first study the movement patterns of small fish species and determine whether facilitating genetic exchange between upstream and downstream populations could result in a conservation benefit. Contingent on identifying the potential for such a benefit, the program would evaluate the technical options for implementing a periodic capture and translocation program in terms of feasibility, cost and potential conservation benefit.

2.5 Follow-up Program: Monitoring and Adaptive Management

2.5.1 Follow-up Program: Monitoring and Adaptive Management

The best available information was used during the fish passage alternatives assessment in order to inform the fish passage recommendations described above (Volume 2 Appendix Q2 Fish Passage Management Plan, Attachment A Fish Passage Alternatives Assessment). The assessment helped to identify biological and technical uncertainties that should to be addressed to help inform the ongoing, adaptive implementation of the recommendations for the design, construction and operation of the trap and haul facilities during the construction and operation phases of the Project.

Uncertainties are:

1) How will the abundance and distribution of target fish species upstream and downstream of the Site C dam site change following construction of the Project? What will the movement patterns of target fish species be?
2) Given these potential changes, what will the corresponding provincial fish management objectives be?
3) What will the rates of downstream entrainment and turbine survival be?
4) How effective will the upstream trap and haul facilities and system be at helping to meet provincial fish management objectives?
5) How effective will the periodic translocation program be, if developed, at helping to meet provincial fish management objectives?

BC Hydro proposes to develop and implement a monitoring and assessment program to investigate these uncertainties and improve the understanding of the biological response of the fish communities. The program will also take an adaptive management approach to improve the effectiveness of the proposed upstream trap and haul system. Key features of the program would include:

- Status and trend monitoring of priority species indicators, collecting pre-construction biological information to guide trap and haul design, and evaluating the biological effectiveness of trap and haul operations (Figure 1),
- Clearly stating uncertainties and testable hypotheses as the basis of each monitoring plan,
- Identifying performance measures with pre-determined thresholds and triggers to guide ongoing adjustment and decision making.

2.5.2 Technical Advisory Committee

BC Hydro proposes to establish a technical advisory committee to advise on the development and ongoing implementation of the follow-up program for fish passage.

Responsibilities of the technical advisory committee for fish passage would include:

- Identifying and prioritizing uncertainties to help develop monitoring program objectives,
- Providing guidance on monitoring program designs,
- Advising on the ongoing trial and adjustment of operating decisions for the upstream fish passage facilities,
- Supporting the scientific interpretation of monitoring program results,
- Supporting the assessment of the management implications of the monitoring results (e.g., to determine transportation plans and preferred release locations),
- Supporting coordination with other monitoring and assessment programs for Fish and Fish Habitat, where applicable.

3 REFERENCES

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Appendix F - Fish and Fish Habitat Technical Data Report[12]

[12] EIS, Volume 2, Appendix O

SITE C CLEAN ENERGY PROJECT
FISH AND FISH HABITAT TECHNICAL DATA REPORT

Prepared for

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December 2012

Document No. 12002F

Citation: Mainstream Aquatics Ltd. 2012. Mainstream Aquatics Ltd. 2012. Site C Clean Energy Project – Fish and Fish Habitat Technical Data Report. Prepared for BC Hydro Site C Project, Corporate Affairs Report No. 12002F: 239 p.

EXECUTIVE SUMMARY

The purpose of the fish and fish habitat technical data report is to synthesize and interpret fish and fish habitat baseline information collected from the technical study area in order to understand the ecology of the fish community potentially affected by the Site C Clean Energy Project (the Project). This understanding will be the foundation of the Environmental Impact Statement in regards to fish and fish habitat. The specific objectives of this report are to identify and review relevant information sources, provide a concise summary that describes fish and fish habitats, and interpret the information in order to understand the potential effect to fish and fish habitat by the Project.

The technical study area used for the information synthesis includes the mainstem Peace River from Peace Canyon Dam to the Many Islands Area located 121 km downstream of the provincial boundary. Information from outside the technical study area is incorporated into the review when appropriate. This includes information from upstream (i.e., Dinosaur Reservoir) and downstream Peace River and tributaries in Alberta (i.e., Many Islands to Vermillion Chutes). These spatial boundaries were established for the technical study area to ensure that the biological boundaries of fish populations (i.e., spatial distributions) potentially affected by the Project are included in the information synthesis. The study period encompasses information collected from the early 1970s up to and including 2011.

<u>Information Sources</u>

Data collections in the technical study area have been conducted since the 1970s and continue to the present day. Work has occurred in the mainstem Peace River and many of its tributaries from Peace Canyon Dam downstream to the Dunvegan area in Alberta (distance of 275 km).

General surveys completed during the 1970s in preparation for the initial Site C development were followed by structured large scale inventories of fish communities in the Peace River and its tributaries in the late 1980s and early 1990s. From 2005 to present, numerous baseline studies that investigated fish communities, fish habitats, fish movements, and genetic connectivity have been completed for the Project.

As part of the Peace Water Use Plan monitoring requirements BC Hydro initiated fisheries studies in 2001. One important component of this work is the annual Peace River Fish Index Project.

A number of investigations have been completed upstream of the technical study area, on Williston Reservoir and Dinosaur Reservoir, and an extensive amount of work has been completed on the Peace River downstream in Alberta. A comprehensive series of multi-year investigations of fish communities, fish habitats, and fish movements were completed between 1999 and 2009 for the Dunvegan Hydroelectric Project, which is located 125 km downstream of the Site C dam site.

Species and Regulatory Status

In total, 32 fish populations have been recorded in the technical study area (Table 9.1.1). None of the 32 populations are officially listed as endangered, threatened, or a special concern under Schedule 1 of the federal *Species at Risk Act (SARA)*, or are being considered for listing under Schedule 2 or 3 of the *Act*.

In British Columbia, under the provincial Conservation Framework, one species is listed as “red” (endangered or threatened); spottail shiner, and three are listed as “blue” (special concern); bull trout, goldeye, and pearl dace. The remaining species are designated as “yellow”, described as secure and not at risk of extinction.

In Alberta, two species are identified as “may be at risk” -- pygmy whitefish and spoonhead sculpin. A total of 6 species have “sensitive” designations including; bull trout, Arctic grayling, lake trout, brook stickleback, northern pikeminnow, and northern redbelly dace. The rainbow trout designation as “at risk” refers to the Athabasca River population. The remaining fish species are “secure”, “not assessed”, or “not determined”.

Fish Community Ecology

The technical study area fish community is composed of fish populations that use one or more ecological strategies. There are two primary groups of fish in the technical study area -- coldwater and coolwater fish. The technical study area is a transition zone for these two groups of fish. Coldwater species dominate the fish community primarily upstream of the Pine River confluence, but coolwater fish also reside in the area. The abundance of the coolwater fish group increases downstream of the Pine River confluence until it becomes the dominant fish group in Alberta.

Seven sportfish species that are part of the fish community belong to the coldwater group. They include Arctic grayling, bull trout, kokanee, lake whitefish, lake trout, mountain whitefish, and rainbow trout. Arctic grayling and rainbow trout are the only species in the group that are spring spawners. Rainbow trout is also a species whose population has limited natural recruitment within the technical study area.

Coolwater fish species that are part of the fish community include the three sucker species and nine species listed in the minnow group. They include largescale sucker, longnose sucker, white sucker, flathead chub, lake chub, longnose dace, northern pikeminnow, redside shiner, spottail shiner, and trout-perch.

The three sculpin species appear to do well in both types of environments. Slimy sculpin and prickly sculpin do better in cold, clear water systems, while spoonhead sculpin prefer cool, turbid water systems.

A number of species recorded in the techncial study area are rare and are not considered part of the existing fish community. These include brook trout, pygmy whitefish, brook stickleback, finescale dace, northern redbelly dace, peamouth, and pearl dace.

The technical study area fish community can be divided in two groups based on maximum fish size – large-and small-fish species. Large-fish species generally attain a length of at least 200 mm at maturity, but are also represented by smaller age classes (i.e., young-of-the-year and juveniles). The large-fish category in the technical study area includes sportfish and suckers. In the small-fish group, all age classes are typically smaller than 200 mm. This category includes minnows and sculpins. The rationale for the size distinction relates to the relative difference between large-fish species and small-fish species in their ability to move extended distances. In flow-regulated systems like the Peace River, adults of large-fish species are capable of moving long distances upstream. Given their small size, small-fish species typically undertake much smaller movements. The exception to this statement is downstream dispersal of small-fish species and younger age classes of large-fish species, which can involve long distances.

Within the technical study area, several species demonstrate extended upstream movements. These include Arctic grayling, bull trout, and mountain whitefish. Movements by adults typically involve long distance migrations to tributary spawning habitats. Arctic grayling migrate to the Moberly River where they spawn. Bull trout migrate to the upper Halfway River tributaries to access spawning habitats. Walleye undertake post-spawning feeding upstream movements in the Peace River from spawning areas in the lower portion of technical study area. Goldeye is a migratory species that travels approximately 500 km from wintering habitats downstream of the Town of Peace River to as far upstream as the Moberly River. The goldeye population spawns in the Peace River and in several tributaries, primarily in Alberta. Goldeye spawning and early rearing has been confirmed in the Beatton River.

Some species residing in the Peace River technical study area utilize both local and extended movement strategies depending on the availability of important habitats. These include all three sucker species and mountain whitefish. Mountain whitefish may complete all life history activities within a 1 or 2 km section of the Peace River, or mountain whitefish migrate many kilometres (from upstream and downstream) in order to access tributary spawning habitats in the Pine River, Moberly River, and Halfway River.

Downstream dispersal by small-fish species and younger age classes of large-fish species has been recorded for most species present in the technical study area within the Peace River and from all tributaries. This movement strategy is the source of recruitment for some fish populations (e.g., Arctic grayling). For other populations, it represents a loss to the population (e.g., kokanee).

The Peace River fish community in much of the technical study area is dominated by adults and older juveniles of large-fish species, with a paucity of younger fish in the large-fish species group and most small-fish species. This is most apparent upstream of the Halfway River confluence. The mechanism thought to drive this outcome is the absence of suitable habitats needed by small-sized fish in the Peace River. This is caused by the regulated flow regime of the Peace River and/or life history strategies that rely heavily on tributary habitats for important life requisites such as spawning and early rearing. Downstream of the Halfway River, this pattern of large- versus small-fish gradually lessens, but still remains the primary feature of the technical study area Peace River fish community. Species populations that appear not to follow this pattern are rainbow trout, kokanee and sculpin, which likely receive recruitment from upstream sources. Prickly sculpin and slimy sculpin are widely distributed in the Peace River in areas that contain large amounts of physical cover in the channel bed that is not dewatered by flow regulation.

In contrast to the Peace River, tributaries in the technical study area support a diverse number of small- and large-fish species. The fish species populations that utilize Peace River tributaries between Peace Canyon Dam and the Site C dam site depend on the environmental characteristics of the watercourse. Smaller tributaries and the lower sections of larger tributaries tend to have limited coldwater fish habitats due to water flow regimes that are dominated by large spring freshets and low summer and winter flows, high summer water temperatures and elevated suspended sediment loads caused by watercourse down cutting through the Peace River valley wall. These areas support populations of minnows and suckers, which tend to use tributary confluence areas as population focal points.

Farther up in the watersheds of larger tributaries such as the Halfway River and Pine River, there is an abundance of habitats that can support coldwater fish populations. These habitats are utilized by some Peace River fish populations (e.g., bull trout) and resident populations may provide recruitment to Peace River populations by downstream dispersal (e.g., Arctic grayling).

The Peace River fish community within the technical study area utilizes two primary habitat areas – main channel and side channel. Fish populations use one or both habitat areas depending on species life stage requirements, the physical characteristics of the side channel area, and the Peace River flow regime. Side channels typically provide less adverse habitats than habitats in main channel areas. Side channels are important habitats for smaller-sized fish species and younger age-classes of large-fish species. Side channel areas provide critical refuge during high river flows and during periods of fry emergence.

A small number of side channels provide unique fish habitats that exhibit specific physical characteristics. These side channels are sheltered from high water velocities (i.e., one inlet at the downstream end), have low water turbidity during much of the year, and support growth of aquatic vegetation. These side channel habitats are restricted in distribution and few in number within the technical study area. These unique side channel areas support a unique fish assemblage consisting of five species (i.e., lake whitefish, northern pike, yellow perch, white sucker, and spottail shiner). Populations of these species have specialized habitat requirements and can complete all their life history requisites in these areas.

Natural recruitment to fish populations in the technical study area may originate from the mainstem Peace River and/or Peace River tributaries. Tributaries provide spawning and early rearing habitats for most species populations that reside in the Peace River. In addition, several tributaries contain resident populations that provide recruitment to the Peace River via downstream dispersal. This is true for most fish populations in the technical study area. Baseline studies suggest that resident fish in Maurice Creek are an important recruitment source for Peace River rainbow trout. The Halfway River, Pine River, and Beatton River appear to be an important source for recruitment of Arctic grayling.

Few fish populations in the technical study area rely entirely on mainstem Peace River recruitment sources. Spawning by sculpin species, mountain whitefish, sucker species, and possibly walleye occur in the mainstem Peace River. However, the contribution of mainstem spawning to recruitment is minimal given the temperature, flow, and ice regime of the system and evidence of rapid downstream dispersal of recently emerged fry. Sculpin, mountain whitefish, sucker, and walleye populations in the technical study area all utilize tributary spawning and early rearing habitats.

A source of recruitment for some fish populations in the technical study area is entrainment from upstream sources (i.e., Williston Reservoir and/or Dinosaur Reservoir). Recruitment via entrainment likely maintains the rainbow trout, kokanee, and lake trout populations. Other species known to recruit from sources upstream of the Peace Canyon Dam include bull trout, lake whitefish, and peamouth.

Fish Abundance

In terms of overall abundance of large-fish and small-fish species, fish numbers are much higher in the technical study area compared to the Peace River downstream of the technical study area. Extensive work in the Dunvegan area of the Peace River, which is approximately 187 km downstream of the Site C dam location, recorded an order of magnitude lower abundance of large-fish and of small-fish.

Mountain whitefish is the dominant large-fish species in the technical study area. Longnose sucker replaces mountain whitefish as the dominant large-fish species in the Peace River in Alberta. Redside shiner is the numerically dominant species in the Peace River upstream and downstream of the Site C dam location.

In general, smaller tributaries in the technical study area contain fish communities numerically dominated by suckers and minnows. Spring trapping studies recorded several thousands of fish belonging to these groups in monitored streams. These included Lynx Creek, Farrell Creek, and Cache Creek. An exception is Maurice Creek, which supports a rainbow trout population. The lower portions of larger tributaries contain fish communities dominated by suckers and minnows, but the upper watersheds also support coldwater sportfish such as Arctic grayling, bull trout, and rainbow trout.

Important Habitats

Important fish habitats are present throughout the technical study area. Depending on the species, important habitats are located on the Peace River upstream and downstream of the Site C dam location and in Peace River tributaries within and outside of the Site C reservoir inundation zone. In general, the lower sections of Peace River tributaries provide spawning and early rearing habitats for suckers and minnows. Important spawning and rearing habitats for sportfish have been recorded only in upstream areas of large tributaries.

The upper Halfway River watershed provides spawning and rearing habitats for the Peace River bull trout population. The Moberly River provides spawning and rearing habitats for the Peace River Arctic grayling population. Maurice Creek provides spawning and rearing habitats for the Peace River rainbow trout population. The Halfway, Moberly, and Pine Rivers provide spawning habitats for the Peace River mountain whitefish population. The Beatton River provides spawning and rearing habitats for walleye. All tributaries to the Peace River provide spawning and rearing habitats for suckers, minnows, and sculpins. The Peace River downstream of the Halfway River confluence provides rearing habitat for mountain whitefish. Side channels provide habitats for several fish species, in particular northern pike, yellow perch, and spottail shiner. Finally, the mainstem Peace River is a migration area for several species by providing an upstream and/or downstream movement corridor. Several populations require the Peace River as a movement corridor. They include Arctic grayling, bull trout, mountain whitefish, burbot, goldeye, walleye, largescale sucker, and longnose sucker.

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ABBREVIATIONS AND ACRONYMS

GR	-	Arctic grayling
BT	-	Bull trout
AEB	-	Brook trout
KO	-	Kokanee
LT	-	Lake whitefish
LW	-	Lake trout
MW	-	Mountain whitefish
PW	-	Pygmy whitefish
RB	-	Rainbow trout
BB	-	Burbot
GE	-	Goldeye
NP	-	Northern pike
WP	-	Walleye~~Yellow perch~~
YP	-	Yellow perch~~Walleye~~
CSU	-	Largescale sucker
LSU	-	Longnose sucker
WSC	-	White sucker
BSB	-	Brook stickleback
FDC	-	Finescale dace
FHC	-	Flathead chub
LKC	-	Lake chub
LNC	-	Longnose dace
NSC	-	Northern pikeminnow
RDC	-	Northern redbelly dace
PCC	-	Peamouth
PDC	-	Pearl dace
RSC	-	Redside shiner
STC	-	Spottail shiner
TP	-	Trout-perch
CAS	-	Prickly sculpin
CCG	-	Slimy sculpin
CRI	-	Spoonhead sculpin
TSS	-	Total suspeneded sediments
YOY	-	Young of the year

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1.0 INTRODUCTION

Four information reviews of baseline conditions have been previously completed for the Site C Clean Energy Project (the Project). Those reviews, by Valenius (2001), Pottinger Gaherty (2001, 2005) and AMEC (2008), compiled summaries of environmental and socio-economic studies and identified deficiencies in the baseline data. AMEC (2008) completed the most recent review of fish and fish habitat studies related to the Project (to 2006). This synthesis report builds on the AMEC (2008) work by incorporating the results of more recent studies and providing a more in-depth interpretation of the data.

1.1 PURPOSE AND OBJECTIVES

The purpose of the fish and fish habitat information synthesis is to synthesize and interpret fish and fish habitat baseline information collected from the technical study area in order to understand the ecology of the fish community potentially affected by the the Project. This understanding will be the foundation of the Environmental Impact Statement with regards to fish and fish habitat. The specific objectives of this study are as follows:

1. Identify and review relevant information sources;
2. Provide a concise summary that describes fish and fish habitats; and,
3. Interpret the information in order to understand the fish community ecology.

1.2 TECHNICAL STUDY AREA

The technical study area used for the information synthesis extends along the mainstem Peace River from Peace Canyon Dam to the Many Islands Area located in Alberta, 59 km downstream of the provincial boundary (Figure 1.2.1). Information from outside the technical study area is incorporated into the review when appropriate. This includes information from upstream (i.e., Dinosaur Reservoir) and downstream Peace River (i.e., Many Islands to Vermillion Chutes, Alberta). These spatial boundaries were established for the technical study area to ensure that the biological boundaries of fish populations potentially affected by the Project are included in the information synthesis.

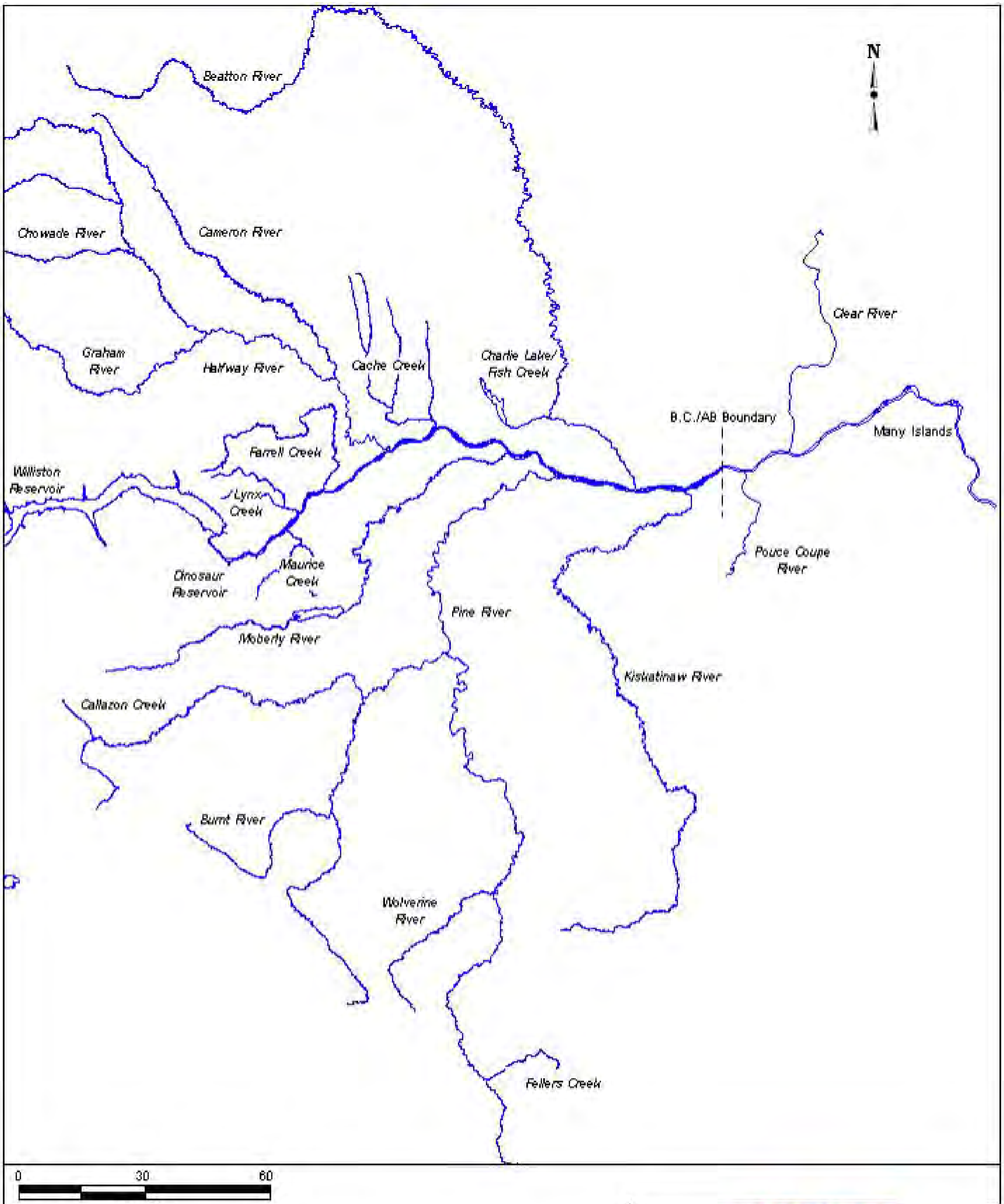
Major waterbodies and points of interest discussed within the synthesis report are listed in Table 1.2.1. All technical study area waterbodies referenced in this document are listed in Appendix A.

Table 1.2.1 Major waterbodies and points of interest.

Waterbody/Point of Interest	Description (Km location downstream of Peace Canyon Dam)
Williston Reservoir	Reservoir created by W.A.C. Bennett Dam
Dinosaur Reservoir	Reservoir created by Peace Canyon Dam
Maurice Creek	Tributary to Peace River (Km 7.3)
Lynx Creek	Tributary to Peace river (Km 13.6)
Farrell Creek	Tributary to Peace River (Km 23.7)
Halfway River	Tributary to Peace River (Km 45.2)
Chowade River	Tributary to Halfway River 128 km upst of the Peace River.
Cache Creek	Tributary to Peace River (Km 61.7)
Wilder Creek	Tributary to Peace River (Km 72.6)
Moberly Lake	Headwater lake for Moberly River 120 km upstream of Peace River
Moberly River	Tributary to Peace River (Km 84.5)
Proposed Site C dam	Located just downstream of Moberly River (Km 85.1)
Pine River	Tributary to Peace River (km 101.0)
Beatton River	Tributary to Peace River (Km 122.5)
Charlie Lake	Headwater lake to Beatton River via Fish Creek
Kiskatinaw River	Tributary to Peace River (Km 135.5)
Alces River	Tributary to Peace River (Km 143.4)
British Columbia/Alberta Boundary	Km 147.6
Pouce Coupe River	Tributary to Peace River (Km 153.4)
Clear River	Tributary to Peace River (Km 167.4)
Many Islands	Peace River islands complex (Km 206.6)
Dunvegan Hydroelectric Project	Located just upstream of the Highway 2 Bridge (Km 272.4)
Smoky River	Tributary to Peace River (Km 368.2)

1.3 STUDY PERIOD

The study period encompasses information collected from the early 1970s up to and including 2011.



NOTES:

1. DATUM/PROJECTION: NAD 83/UTM ZONE 10, 11
2. DATA SOURCE: GOVERNMENTS OF B.C. AND ALBERTA

CONSTRUCTION OF THE SITE C CLEAN ENERGY PROJECT IS SUBJECT TO REQUIRED REGULATORY APPROVALS INCLUDING ENVIRONMENTAL CERTIFICATION.

BC hydro

Figure 1.2.1 Fish and Fish Habitat Technical Study Area

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2.0 METHODS

The majority of the documents were obtained from BC Hydro, with additional documents obtained from Mainstream's in-house library, the Peace Williston Compensation Program website (http://www.bchydro.com/pwcp) and the British Columbia Ecological Reports Catalogue (http://www.env.gov.bc.ca/ecocat/).

The review process began with identification of relevant information sources. Documents were read for content, sample methods, and study location. If the document provided a useful description of fish or fish habitats within the technical study area the results were summarized for use by the report. Selection of a relevant information source and interpretation of the information was completed by an experienced fish biologist. The outcome of the process was a description of fish and fish habitats that was used to understand the ecology of the fish community. Appendix A1 and Appendix A2 provide information for reviewed information sources.

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3.0 DATA SOURCES

Data collections in the technical study area have been conducted since the 1970s and continue to the present day. Work has occurred in the mainstem Peace River and many of its tributaries from Peace Canyon Dam to the B.C./Alberta boundary. The following provides a general overview of the information most relevant to the fish and fish habitat synthesis report. Table 3.1.1 lists major information sources, the type of information provided, and its spatial location. Appendix A2 lists fish and fish habitat baseline studies completed in the technical study area.

A general investigation of the technical study area fish and fish habitat was completed during the 1970s in preparation for the Site C development (Renewable Resources Ltd. 1978). After this initial investigation, structured large scale inventories did not occur until the early 1990s when multi-year inventories were completed on the Peace River (Pattenden 1992, Pattenden *et al.* 1990, 1991) and its tributaries (ARL 1991a,b), again in anticipation of a Site C development. This work focused primarily upstream of the Site C dam location and generally provided descriptive information. These studies were also the first attempt to examine fish movements using radio telemetry (Pattenden *et al.* 1990, 1991).

In 1994, the B.C. government commissioned a fish fence study on the Chowade River (RL&L 1995) to establish the importance of this tributary to the Halfway River as sport fish habitat. A focus of the study was to characterize the spawning bull trout (*Salvelinus confluentus*) population, which was thought to originate, in part, from the Peace River. This work was followed by a study by the province that examined movements of bull trout and Arctic grayling (*Thymallus arcticus*) in the upper Halfway River watershed (Burrows *et al.* 2001). The results of this study were reanalyzed and submitted in a report to BC Hydro (AMEC and LGL 2010b).

A study that focused on habitat utilization by small fish in the B.C. portion of the Peace River was completed in 1999 and 2000 (RL&L 2001). This was the first attempt to characterize small fish use of near-shore habitats on the river, map fish habitats, and quantify availability of these habitats relative to flow regulation effects. Small fish were defined as small-fish species and younger age-classes of large-fish species.

Table 3.1.1 Major information sources, the type of information and location of data[a].

Year Work Done	Citation	Upst.	Peace R.	Tribs.	Dwst.	Move.	Genetics	Micro.
1989	Pattenden, R., C. McLeod, G. Ash, and K. English. 1990. Peace River Site C Hydro Development Pre-construction Fisheries Studies. Fish movements and population status. 1989 studies. Report prepared for BC Hydro by R.L. & L. Environmental Services Ltd., Edmonton, Alberta, in association with K. English of LGL Ltd., Sidney, B.C. 97 p.		X			X		
1990	Pattenden, R., C. McLeod, G. Ash, and K. English. 1991. Peace River Site C Hydro Development Pre-construction Fisheries Studies. Fish movements and population status. 1990 studies. Report prepared for BC Hydro by R.L. & L. Environmental Services Ltd., Edmonton, Alberta, in association with K. English of LGL Ltd., Sidney, B.C. 121 p.		X			X		
1999	RL&L Environmental Services Ltd. 2001. Peace River fish habitat utilization study. Prepared for BC Hydro - Environmental Services Burnaby, BC. RL&L Report No. 725F.		X					
2001	P&E Environmental Consultants Ltd. 2002. Peace River Fish Community Indexing Program - Phase I Studies. Prepared for BC Hydro. P&E Report No. 01005F: 76 p.		X					
2004	Mainstream Aquatics Ltd. 2006. Baseline Fish Inventory Study. Dunvegan Hydroelectric Project. Prepared for Glacier Power Ltd. Report No. 04011F: 100 pp.				X			
2005	Amec Earth & Environmental and LGL Limited 2008. Peace River Fish and Aquatics Investigations - Peace River and Tributary Summer Fish Distribution, Habitat Assessment and Radio Telemetry Studies 2005. Prepared for BC Hydro. 93 p.		X	X				
2007	Amec Earth & Environmental and LGL Limited 2008. Peace River Fisheries Investigation - Peace River and Pine River Radio Telemetry Study 2007. Prepared for BC Hydro. 148 p.					X		
2007	Amec Earth & Environmental and LGL Limited 2008. Peace River Fisheries Investigations - 2007. Prepared for BC Hydro. 148 p.					X		
2008	Amec Earth & Environmental and LGL Limited 2009. Peace River Fisheries Investigation - Peace River and Pine River Radio Telemetry Study 2009. Prepared for BC Hydro. 135 p.					X		
2008	Mainstream Aquatics Ltd. 2009. Site C fisheries studies – Baseline Peace River tributaries fish use assessments in spring and fall 2008. Prepared for BC Hydro. Report No. 08008BF: 64 p.			X				
2008	Mainstream Aquatics Ltd. 2009. Site C fisheries studies – Juvenile fish use and habitat inventory of Peace River tributaries in summer 2008. Prepared for BC Hydro. Report No. 08008CF: 78 p.			X				
2009	Amec Earth & Environmental and LGL Limited 2009. Further Analysis and Assessment of the Ministry of Environment's Peace River Bull Trout and Arctic Grayling Radio Telemetry Database 1996 to 1999. Prepared for BC Hydro. 48 p.					X		
2009	Mainstream Aquatics Ltd. 2009. Fish movement study (2008/09) – Dunvegan Hydroelectric Project. Prepared for Glacier Power Ltd. Mainstream Report No. 08010F					X		
2009	Mainstream Aquatics Ltd. 2010. 2009 Burbot Study – Dunvegan Hydroelectric Project. Prepared for TransAlta Corporation. Report No. 09006F: 52 p.				X	X		
2009	Mainstream Aquatics Ltd. 2010. Site C fisheries studies – Halfway River and Moberly River fall mountain whitefish migration and spawning study 2009. Prepared for BC Hydro. Report No. 09008CF.			X				
2010	Clarke, A., N. LaForge, and K. Telmer. 2010. Site C Fisheries Studies – 2010 Elemental Signature Pilot Study. Prepared for BC Hydro Site C Project, Corporate Affairs Report No. 10007F.							X
2010	Diversified Environmental Services and Mainstream Aquatics Ltd. 2011. Dinosaur Reservoir Sampling and literature Review 2010. Prepared for BC Hydro. Report No.10017: 27 p.	X						
2010	Diversified Environmental Services and Mainstream Aquatics Ltd. 2011. Upper Halfway River Watershed Bull trout Spawning Survey 2010. Prepared for BC Hydro. Report No.10016: 21 p.			X				
2010	Mainstream Aquatics Ltd. 2010. Site C Fisheries Studies – 2010 Pilot Rotary Screw Trap Study. Report No. 10004F: 63 p.		X	X				
2010	Mainstream Aquatics Ltd. 2011. Site C Fisheries Studies – 2010 Moberly River and Halfway River Summer Fish Inventory. Report No. 10006F: 59 p.			X				
2011	Taylor, E. B. and M. Yau. 2012. SITE C CLEAN ENERGY PROJECT FISHERIES STUDIES Microsatellite DNA analysis of bull trout (*Salvelinus confluentus*), Arctic grayling (*Thymallus arcticus*), and mountain whitefish (*Prosopium williamsoni*) in the Peace River and tributaries near the proposed BC Hydro Site C hydroelectric development in northeastern British Columbia: 2006-2011. Prepared for BC Hydro. 51 p.						X	
2011	Earth Tone Environmental R&D and Mainstream Aquatics Ltd. 2012. Site C Fisheries Studies 2011 Elemental Signature Study - Draft Interim Report. Prepared for BC Hydro Site C Project, Corporate Affairs Report No. 11007D: 104 p.							X
2011	Mainstream Aquatics Ltd. 2012. Site C fisheries studies – 2011 Peace River Fish Inventory. Prepared for BC Hydro Site C Project, Corporate Affairs Report No. 11005D: 98 p.		X					
2011	Mainstream Aquatics Ltd. and W.J. Gazey Research. 2012. Peace River Fish Index Project - 2011 Studies. Prepared for BC Hydro. Report No. 11011F: 86 pp. .		X					
2011	Mainstream Aquatics Ltd., M. Miles and Associates Ltd, Integrated Mapping Technologies Inc., and Northwest Hydraulic Consultants. 2012. Peace River Hydraulic Habitat Study (Contract Q9-9105). Prepared for BC Hydro. Report No. 09005D: 65 pp.		X					

[a] Upst. (Upstream reservoirs); Peace R. (technical study area Peace R.); Tribs. (technical study area tributaries); Dwst. (Peace R. downstream of technical study area); Genetics (genetic connectivity study); Move. (Fish movements study); Micro. (Otolith elemental signature study).

In 2001, BC Hydro initiated a multi-year, annual Large River Fish Community Indexing Program on the Peace River. The purpose was to quantify large-fish (i.e., ≥ 250 mm length) population characteristics (i.e., abundance, growth, and population structure) that were to be used to monitor effects of flow manipulations. The river was stratified into discrete sections located between the Peace Canyon Dam and the Pine River confluence and then sampled using structured and repeated fish collection methods. In 2009, the program became the Peace River Fish Index Project and was integrated into the Peace Water Use Plan administered by the Water License Requirements (WLR) program. Though this study has concentrated on three target species (bull trout, mountain whitefish [*Prosopium williamsoni*], and Arctic grayling), it provides yearly data describing abundance and distribution on all large-fish species in the Peace River.

In 2005, fish and fish habitat studies on the Peace River and its tributaries were initiated by BC Hydro in support of anticipated regulatory application for the Project. These studies have been multidisciplinary and have encompassed the technical study area. They include the following:

- standardized fish investigations of the Peace River within B.C. and downstream into Alberta (Mainstream 2009a, 2010a, 2012a)
- standardized fish investigations of the Moberly and Halfway Rivers (Mainstream 2009a,b,c, 2010b,c, 2011a,b)
- fish habitat surveys in all minor and major tributaries affected by the proposed Site C reservoir (AMEC and LGL 2008b, Mainstream 2009a,b,c)
- movement studies of sportfish using radio telemetry (AMEC and LGL 2008a,b,c,d, 2010a,b)
- fish fences to document spring and fall fish use of tributaries (AMEC and LGL 2008b, Mainstream 2009a,b)
- rotary screw traps in the Peace River and major tributaries to monitor downstream movements of small fish (Mainstream 2010d, 2011c)
- bull trout spawner and redd surveys of the Halfway River watershed (Diversified and Mainstream 2009, 2011b)
- examine fish recruitment sources using the elemental signature method (Clarke *et al.* 2010, Earth Tone Environmental and Mainstream 2012)
- examination of genetic characteristics of selected fish populations (Taylor and Yau 2012)

During the same general period several Water License Requirement studies were completed under the Peace Water Use Plan. Three works of interest to this review include:

- evaluation of Peace River side channel characteristics and fish community structure (NHC *et al.* 2010)
- study designed to map and quantify fish habitats at five river flows (Mainstream *et al.* 2012)
- study that described Peace River riparian habitats (MacInnis *et al.* 2011)

A number of investigations also have been completed upstream of the technical study area, on Williston Reservoir and Dinosaur Reservoir. Most recent work includes fish surveys of Williston Reservoir (Sebastian *et al.* 2009) and Dinosaur Reservoir (Diversified and Mainstream 2011a).

An extensive amount of work has been completed on the Peace River downstream in Alberta. Two general inventories of the entire river (from the B.C./Alberta boundary to the Peace Athabasca Delta) were completed – one for 1989 and 1990 (Hildebrand 1990), and the other in 1993 (Boag 1993). A comprehensive series of multi-year investigations of fish communities, fish habitats, and fish movements were completed between 1999 and 2009 for the Dunvegan Hydroelectric Project, which is located 125 km downstream of the B.C./Alberta boundary. Relevant investigations include those documented by RL&L (2000a) and Mainstream (2006a, 2006b, 2009d, 2009e, 2010e).

4.0 FISH HABITAT

This section summarizes work that describes fish habitat in the technical study area. The general characteristics of the Peace River and its tributaries are presented first, followed by more detailed information about fish habitats present in each system. Quantitative data are presented when applicable.

4.1 PEACE RIVER

4.1.1 General Characteristics

The Peace River has a length of 148 km in the area between Peace Canyon Dam and the B.C./Alberta boundary. NHC *et al.* (2010) indicates that the average water surface slope within this area is 0.0022 m/m. The Peace River has generally formed a sinuous channel that is occasionally confined by valley walls up to 250 m in height. The valley flat is discontinuous and ranges up to 1,300 m in width. The wetted river channel width can range between approximately 200 m at low flow and 500 m at high flow.

The Peace River frequently contains unvegetated gravel bars or islands prior to regulation (Church and Rood 1982). Many of these bars are now in varying stages of re-vegetation. Decreased flood flows have also allowed sediment deposition and vegetation growth in former secondary channels. Depending on elevation, secondary channels can be free flowing, seasonally wetted or non-functional.

River bed materials typically consist of gravels and cobbles which are infrequently mobilized in the post-regulation hydrologic regime (Church 1995). Within British Columbia primary sources of bed materials are the Halfway River, Pine River, and Beatton River. Bedrock is extensively exposed in the river bed in one area – a 7 km section immediately downstream of the Peace Canyon Dam. Bedrock exposures occur infrequently downstream of this location (Mainstream *et al.* 2012).

The major tributaries have formed fans at their confluences with the Peace River. Studies by Ayles (2001) indicate that mainstem aggradation has occurred adjacent to the larger streams (such as the Halfway, Moberly and Pine) in the post-regulation period.

Based on descriptions by Pattenden *et al.* (1991) and RL&L (2001), P&E (2002) divided the Peace River from Peace Canyon Dam to the British Columbia/Alberta Boundary into four reaches (Table 4.1.1). The reach designations illustrate a continuum of physical characteristics and general water quality.

Table 4.1.1 Reach designations and descriptions of the Peace River (from P&E 2002).

Reach	Length (km)	Description Gradient		Dominant Substrates	Island Complexes	Side to Main Channel Ratio	Water Clarity	Summer Water Temp. (°C)
1	48	B.C./AB boundary to the Pine R.	low	sand-gravel	10	0.74	low	10.7 - 17.0
2	55	Pine R. to the Halfway R.	low-moderate	gravel	8	0.53	low	10.0 - 14.2
3	38	Halfway R. to Maurice Ck.	low-moderate	gravel-cobble	5	0.44	moderate	9.2 - 13.1
4	7	Maurice Ck. to the Peace Canyon Dam	high	bedrock-cobble	3	0.35	high	-

Mainstream *et al.* (2012) stratified the Peace River between Peace Canyon Dam and the Pine River confluence into three reaches based on a detailed examination of channel characteristics using air photos, which closely followed previous designations – Peace Canyon, Hudson's Hope, and Halfway River (Table 4.1.2). The Peace Canyon reach was characterized by bedrock-dominated bed material and bedrock valley walls. The Hudson's Hope reach and Halfway River reach was generally similar, but one difference included the influence of the Halfway River on channel features recorded in the Halfway reach (i.e., numerous island complexes and shoals immediately downstream of the Halfway River confluence).

Table 4.1.2 Peace River reach characteristics (from Mainstream *et al.* 2012).

Reach	Km Location[a]	Channel Thalweg Length (km)	Channel Surface Area[b] (ha)	Channel Perimeter[b] (km)	Dominant Bed Material	Dominant Feature (s)
Peace Canyon	0 to 7.3	7.3	251	35	Bedrock	Bedrock sills; Vertical bedrock valley walls
Hudson's Hope	7.3 to 46.6	39.3	1,526	190	Boulder and Cobble	Island complexes; shoals
Halfway River	46.6 to 103.0	56.4	2,235	337	Cobble and Gravel	Multiple island complexes; numerous shoals
Total	**-**	**103.0**	**4012 562**		**-**	**-**

[a] Measured from base of Peace Canyon Dam.
[b] Based on target discharge of 1,982 m^3/s.

4.1.2 Fish Habitats

RL&L (2001) mapped habitats in selected sections of the Peace River in 1999 at a discharge of approximately 330 m^3/s. Channels, bank habitat and instream habitat were mapped for each area studied (Kiskatinaw River to Beatton River, Cache Creek to Halfway River, Farrell Creek to Peace Canyon Dam) using aerial photos. Habitat in the Peace River was dominated by run type habitat in all sections (> 96% of all available habitat) and the river banks were armoured. The percentage of other habitat and bank types was low. The total channel area and the ratio of side channel to main channel decreased moving upstream. Habitats containing physical cover were present but infrequent.

RL&L (2001) concluded that small fish habitat was limited due to flow regulation which restricted the amount of habitat available in side channels and in near-shore areas of the Peace River. However, despite the absence of small fish habitat, the large fish community appeared to consist of several viable species populations. The authors hypothesized that the large fish community was maintained, at least in part, by recruitment from tributaries, which were not affected by the operational flow regime of BC Hydro facilities.

In 2009, the Peace River Hydraulic Habitat Study was commissioned by BC Hydro to investigate how changes in water levels affect fish habitat on the Peace River in the area between the Peace Canyon Dam and Taylor, B.C. (Mainstream *et al.* 2012). The purpose of the study was to quantify fish habitat of the Peace River at five steady state flows using a series of large scale air photos flown during a representative range of flows between 283 m^3/s and 1,982 cms.

The area studied included a 105 km section of the Peace River between the Peace Canyon Dam and the confluence of the Pine River. The study area boundaries encompassed the main channel, side channel, and tributary confluence areas of the Peace River from the downstream margin of the structural base of the Peace Canyon Dam to the center line of the Highway 97 Bridge that crosses the Peace River 1.5 km downstream of the Pine River confluence. The upstream boundary of each tributary confluence was set at a fixed location which encompassed the range of Peace River flows to be investigated.

The habitat classification system used by the study was based on the physical characteristics of the active channel bed and adjacent river banks, which enabled the calculation of habitat surface area by combining the digital habitat boundaries with the wetted area of the river at each flow. The habitat surface area data allowed quantification of habitat availability at three spatial scales -- river reach, channel type, and habitat type.

Use of physical characteristics to classify fish habitat was chosen for three reasons. Firstly, fish community investigations on the Peace River indicate that there are differences in species composition, fish abundance, and life stage use based on the physical characteristics of the channel and the river banks (Hildebrand 1990, R&L 2001, P&E 2002, Mainstream and Gazey 2002 to 2012). Secondly, physical characteristics are identifiable on large scale colour air photos. Thirdly, the use of physical characteristics to describe fish habitat allows the quantification of habitat availability within the same habitat unit at different water levels.

The classification system does not incorporate attributes such as water velocity or water depth because changes to these features are not easily identifiable on air photos. Similarly, features such as changes to water clarity caused by tributary inputs were considered as they are not in the scope of the study. The habitat classification system used by Mainstream *et al.* (2012) is presented in Table 4.1.3.

Table 4.1.3 Habitat classification system used by Mainstream *et al.* 2012.

Category	Physical Characteristic	Code	Type
Channel		M	Main channel
		S	Side channel - open
		C	Side channel - closed
		T	Tributary confluence
Bank		A	Anthropogenic
		F	Fluvial or terrace bank
		M	Mass wasting deposit
		R	Bedrock wall
		V	Valley wall bank
Habitat	Bed Material	R	Bedrock
		B	Boulders
		C	Coarse (gravel and cobbles)
		F	Fine (> 50% sand or finer)
	Near shore slope	L	Low
		M	Moderate
		H	Steep
	Bank Irregularities	I	Irregular bank
		R	Rough bank
		S	Smooth bank
	Cover	B	Backwater
		R	Rock
		W	Woody debris
		V	Nonwood vegetation
Isolated Habitat Type		POND	Isolated

<u>Channel Type</u>

The number, surface area, and perimeter of channel types available to fish differed between reaches (Table 4.1.4). The number of side channel zones, which include one or more individual side channels, was highest in the Halfway River reach with 11 open side channel (i.e., exposed to typical river flow) and 12 closed side channel (i.e., protected from typical river flow) zones. Within the Hudson’s Hope reach, 7 and 4 open and closed side channel zones were recorded, respectively. The highest number of tributary confluences, which included permanent and intermittent streams, was recorded in the Hudson’s Hope (n = 17) and the Halfway River reaches (n = 16). Closed side channels were absent in the Peace Canyon reach and open side channels were not recorded in the Pine River reach.

Table 4.1.4 Summary of channel zone characteristics (from Mainstream *et al.* 2012).

Reach Ch	**annel Type**	**Number[a]**	**Surface Area (ha)**	**Perimeter (km)**
Peace Canyon	Main Channel	1	202.0	20.8
	Open Side Channel	2	48.4	14.1
	Closed Side Channel	0		
	Tributary Confluence	1	0.2	0.2
	Total	*4*	*250.6*	*35.1*
Hudson's Hope	Main Channel	1	1,127.7	92.6
	Open Side Channel	7	282.6	56.4
	Closed Side Channel	4	95.1	28.8
	Tributary Confluence	17	20.3	11.9
	Total	*29*	*1,525.7*	*189.7*
Halfway River	Main Channel	1	1,694.7	149.9
	Open Side Channel	11	306.3	82.7
	Closed Side Channel	12	154.8	75.4
	Tributary Confluence	16	79.3	28.8
	Total	*40*	*2,235.2*	*336.9*
Pine River	Main Channel	1	52.1	6.3
	Open Side Channel	0		
	Closed Side Channel	1	15.4	9.2
	Tributary Confluence	1	35.0	6.4
	Total	*3*	*102.5*	*21.9*

[a] For side channel type (open and closed) the number represents zones that contains one or more individual units.

Main channels accounted for the largest percentage of surface area within each reach (Figure 4.1.1; 51% to 81%). Open side channels are second in importance in three of the four reaches (14% to 19%). Closed side channels and tributary confluences comprised < 15% of most reaches. In the Pine River reach, closed side channels and tributary confluences (i.e., Pine River confluence) accounted for 15% and 34% of the total surface area, respectively.

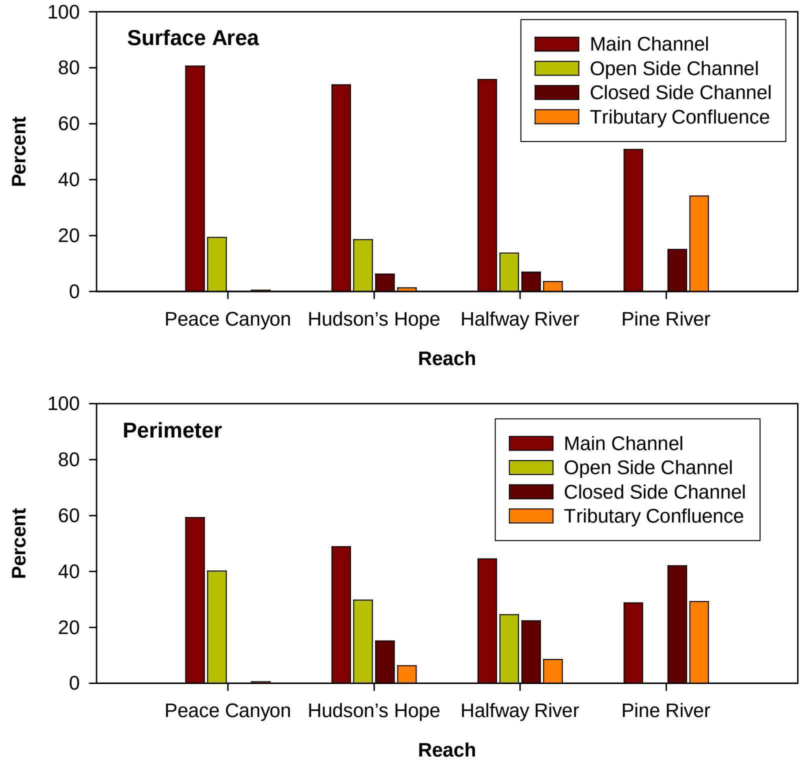


Figure 4.1.1 Percent surface area and perimeter of channel zones in study area reaches (from Mainstream *et al.* 2012).

Bank Type

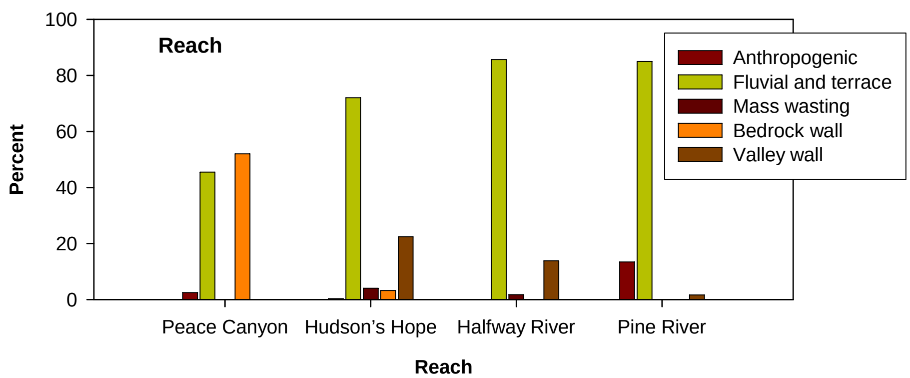
Bank type length differed by reach and channel type (Table 4.1.5, Figure 4.1.2). Anthropogenic bank types were not a significant component of any reach. In three of four reaches, fluvial and terrace bank was the dominant bank type - 118.2 km in Hudson's Hope, 259.1 km in Halfway River, and 15.2 km in Pine River reaches. Bedrock wall was the dominant bank type in the Peace Canyon reach followed closely by fluvial or terrace bank (16.6 km and 14.5 km, respectively). Bedrock walls were only observed in the Peace Canyon reach (16.6 km) and a small section of the Hudson's Hope reach (5.4 km). Valley wall was second in importance to the fluvial and terrace bank type in the Hudson's Hope reach and the Halfway River reach (36.7 km and 41.9 km, respectively).

Habitat Polygons

In total 1,185 habitat polygons representing 1,182.6 ha were recorded in the study area (Table 4.1.6). The number and surface area of habitat polygons varied by reach and channel type. The differences followed the amount of total wetted surface area available (see Table 4.1.4). The highest number and largest surface area of habitat polygons were recorded in the Hudson's Hope and Halfway River reaches.

Table 4.1.5 Summary of bank type lengths (from Mainstream *et al.* 2012).

Reach	Zone	Length (km)				
		Anthropo-genic	**Fluvial or Terrace Bank**	**Mass Wasting Deposit**	**Bedrock Wall**	**Valley Wall**
Peace Canyon	Main Channel	0.8	6.8		11.2	
	Open Side Channel		7.6		5.4	
	Closed Side Channel	0				
	Tributary Confluence		0.1			
	Total	*0.8*	*14.5*	*0.0*	*16.6*	*0.0*
Hudson's Hope	Main Channel	0.5	47.9	3.1	4.8	24.6
	Open Side Channel		37.4	0.1	0.6	11.9
	Closed Side Channel		26.8	0.1		0.2
	Tributary Confluence		6.1			
	Total	*0.5*	*118.2*	*3.3*	*5.4*	*36.7*
Halfway River	Main Channel	0.1	103.2	1.3		28.8
	Open Side Channel	0.1	67.1	0.1		9.3
	Closed Side Channel		66.5			3.6
	Tributary Confluence	0.0	22.3	0.0		0.2
	Total	*0.2*	*259.1*	*1.4*	*0.0*	*41.9*
Pine River	Main Channel	2.4	1.1			0.3
	Open Side Channel					
	Closed Side Channel		9.1			
	Tributary Confluence		5			
	Total	*2.4*	*15.2*	*0.0*	*0.0*	*0.3*



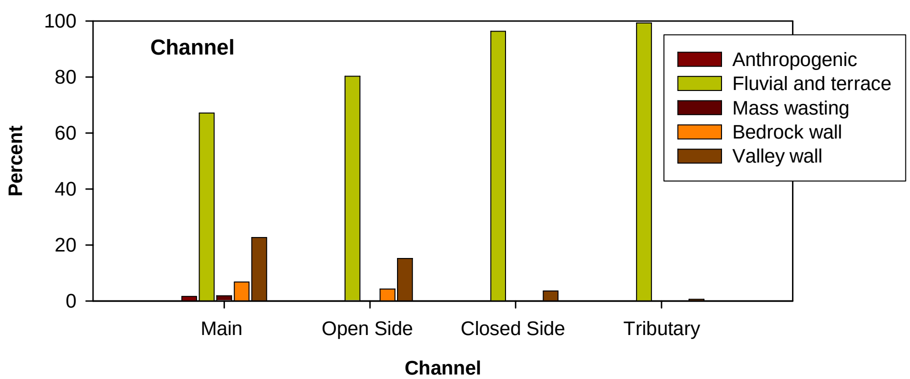


Figure 4.1.2 Percent length of bank type by reach and channel type (from Mainstream *et al.* 2012).

Habitat polygons represent the portion of the Peace River channel that is potentially influenced by BC Hydro operational discharge between the minimum 283 cms and maximum 1,982 cms target study flows. This information can therefore be used to identify reaches and channel types most affected by the operational flow regime.

The total area of habitat polygons (1,183 ha) represented 29% of the total available habitat (4,115 ha) within the study area. However, there are large spatial differences in habitat values. The data are summarized in Figure 4.1.3 and illustrations of surface area difference at each target flow for representative channel types are presented in Figures 4.1.4 to 4.1.7.

Table 4.1.6 Number and surface area of mapped habitat polygons (from Mainstream *et al.* 2012).

Reach	**Channel Type**	**Number**	**Surface Area (ha)**
Peace Canyon	Main Channel	95	33.6
	Open Side Channel	37	20.1
	Closed Side Channel	0	0.0
	Tributary Confluence	1	0.2
	Total	*133*	*53.9*
Hudson's Hope	Main Channel	229	234.3
	Open Side Channel	146	127.5
	Closed Side Channel	11	72.5
	Tributary Confluence	34	13.7
	Total	*420*	*448.0*
Halfway River	Main Channel	346	355.1
	Open Side Channel	184	141.2
	Closed Side Channel	40	96.7
	Tributary Confluence	36	53.2
	Total	*606*	*646.3*
Pine River	Main Channel	19	3.1
	Open Side Channel	0	0.0
	Closed Side Channel	4	10.4
	Tributary Confluence	3	21.0
	Total	*26*	*34.4*
Overall Total		**1,185**	**1,182.6**

Main channel habitat were least affected by variations in discharge over the investigated range of flows. The data indicate that the area of available habitat varied by 6% in the Pine River reach to 21% in the Halfway River reach. The percentage of affected area was much higher for open side channels (range of 42% to 46%). The range in area of closed side channels was greater than for open side channels (63% to 76%). The affected area of tributary confluences also was high and ranged between 60% and 91%. These results demonstrate the large effect of post-regulation changes in discharge on the area of fish habitats.

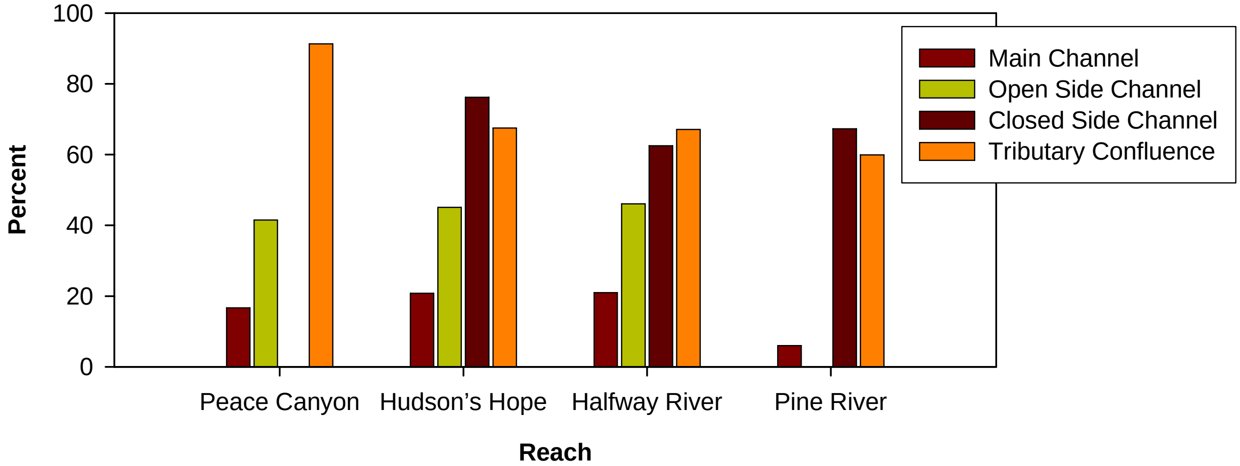
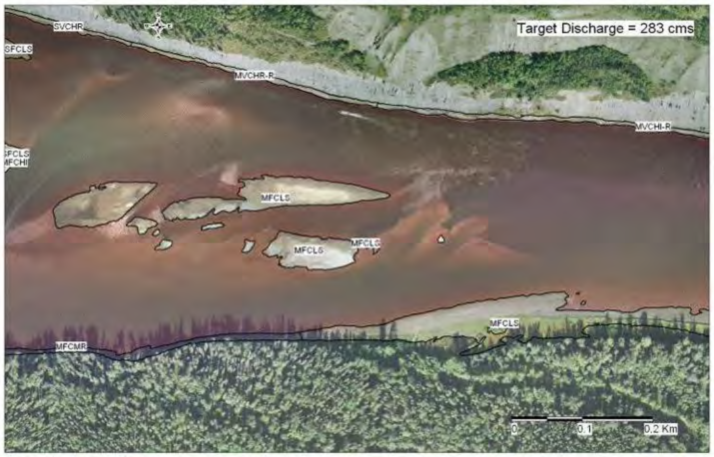
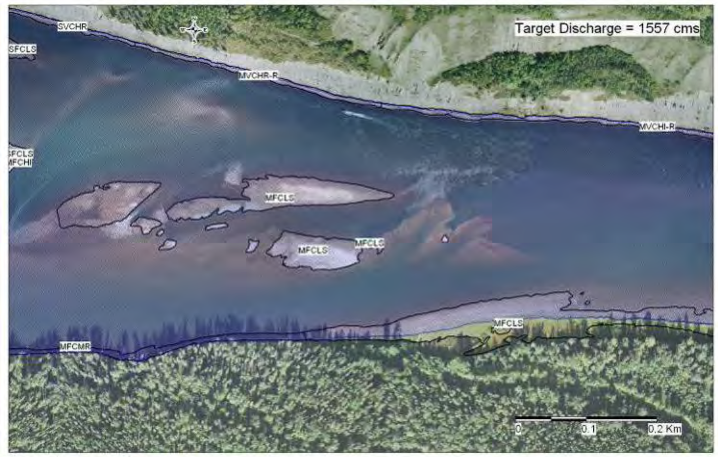
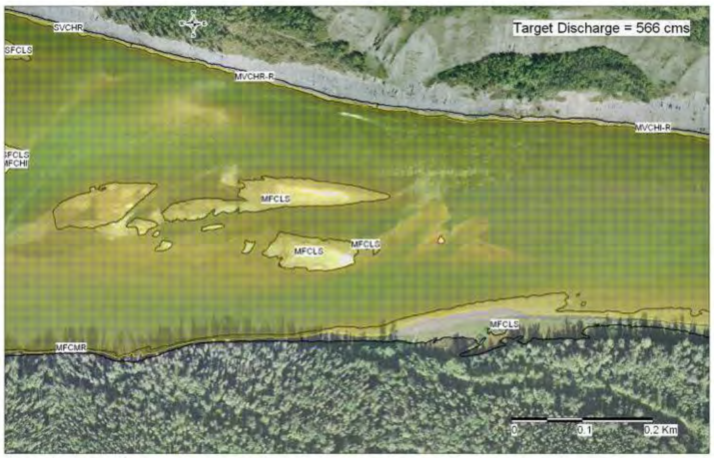
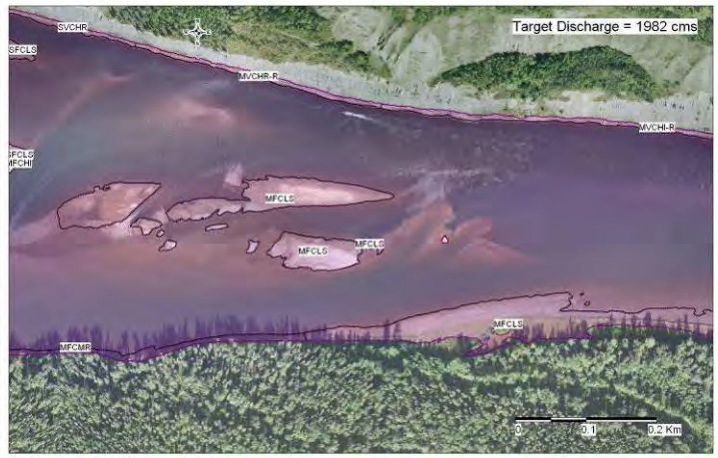


Figure 4.1.3 Percentage of available habitat area influenced by BC Hydro discharge operations (from Mainstream *et al.* 2012).









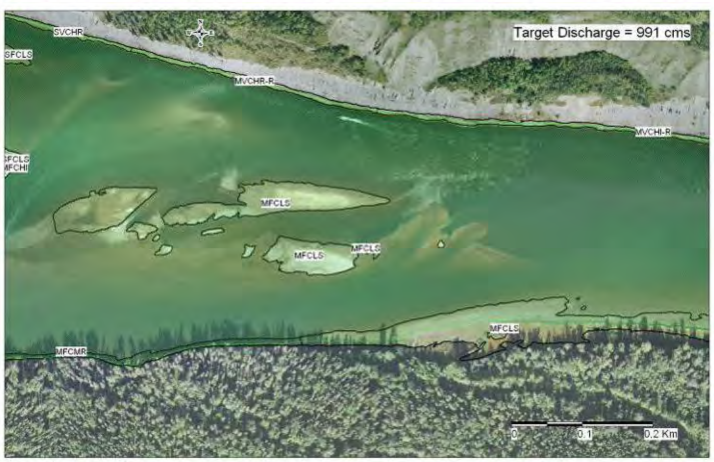


Figure 4.1.4 Habitat surface area at the five target flows for an example main channel area (River Km 88 from Peace Canyon Dam; solid colours indicate isolated ponds) (from Mainstream *et al.* 2012).

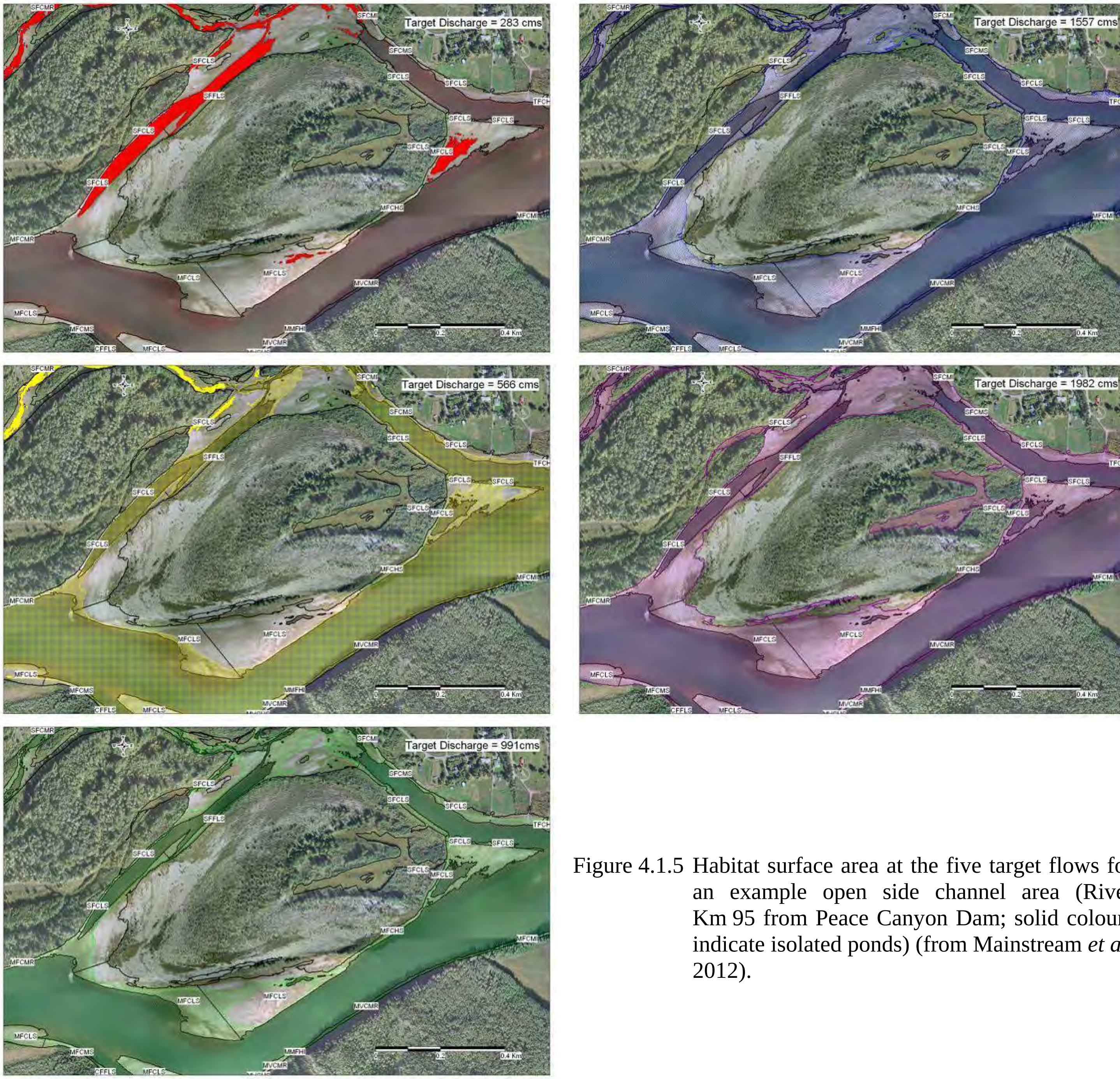


Figure 4.1.5 Habitat surface area at the five target flows for an example open side channel area (River Km 95 from Peace Canyon Dam; solid colours indicate isolated ponds) (from Mainstream *et al.* 2012).

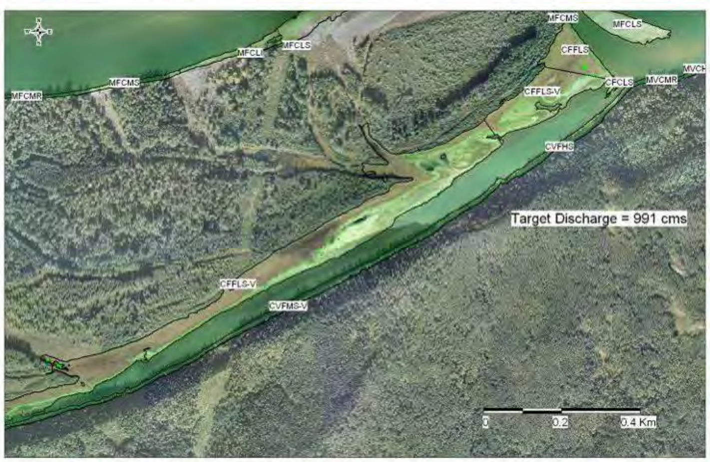


Figure 4.1.6 Habitat surface area at the five target flows for an example closed side channel area (River Km 95 from Peace Canyon Dam; solid colours indicate isolated ponds) (from Mainstream *et al.* 2012).

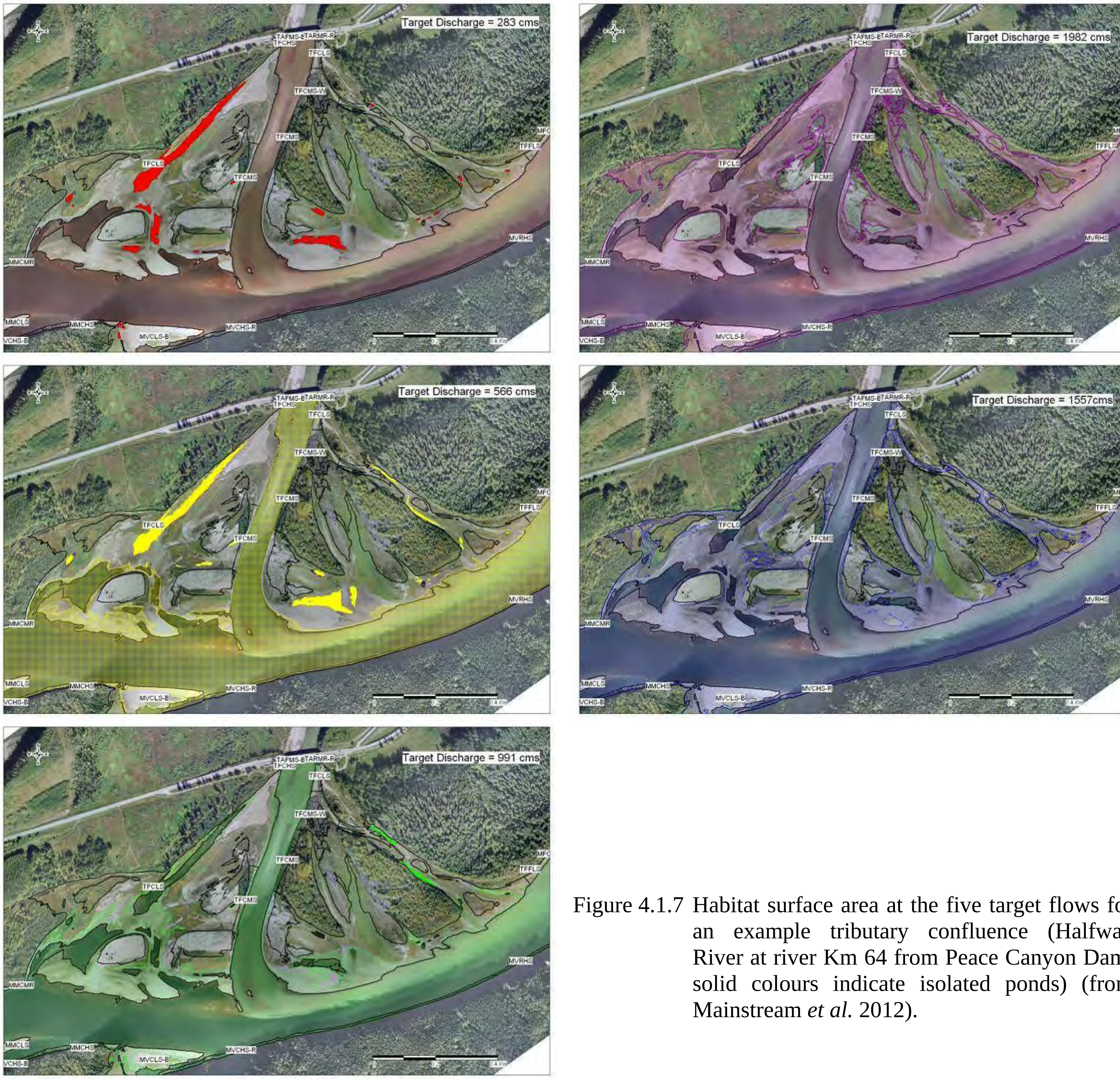


Figure 4.1.7 Habitat surface area at the five target flows for an example tributary confluence (Halfway River at river Km 64 from Peace Canyon Dam; solid colours indicate isolated ponds) (from Mainstream *et al.* 2012).

Habitat Types

Habitat polygons were represented by 79 combinations of the four descriptors used in the habitat classification system - bed material type, bank slope, bank configuration, and physical cover. The numerical contribution of each descriptor is presented in Table 4.1.7. The surface area contribution for each descriptor, expressed in terms of percent of total habitat, is summarized in Figures 4.1.8 to 4.1.11.

The frequency of occurrence of a habitat polygon feature did not always reflect the surface area of that feature. For example, polygons having a high foreshore slope were numerically prominent in the Peace Canyon reach ($n = 40$), but accounted for only 11% of habitat polygon surface area. This is because the surface area available for dewatering would be much less in a high slope habitat compared to low slope habitat.

The summaries indicated some general patterns. Coarse bed material, low foreshore slope, smooth bank, and absence of physical cover were the dominant habitat polygon features in all reaches. These characteristics also dominated in main channel and open side channel areas.

There were exceptions to the general pattern. Bedrock and boulders were important bed material types in the Peace Canyon reach. The apparent importance of boulders in the Pine River reach was caused by a substantial amount of rip rap (anthropogenic bank type). Closed side channels, and to a lesser extent tributary confluences, contained substantive areas of fine bed materials. These are indicative of areas where active sediment deposition is occurring. Tributary confluences tended to have a larger amount of rough and irregular bank configurations combined with the rock cover type compared to other channel types. This reflects the deposition zones which are present at the mouths of most Peace River tributaries. Aquatic vegetation, which included submergent and emergent forms, was a prominent cover type only in closed - side channels.

Table 4.1.7 Numerical contribution of habitat polygon descriptors (from Mainstream *et al.* 2012).

		Bed Material				Bed Slope			Bank Irregularities			Cover				
Reach	**Channel**	**Fines**	**Coarse**	**Boulder**	**Bedrock**	**Low**	**Moderate**	**High**	**Smooth**	**Rough**	**Irregular**	**None**	**Backwater**	**Roc k**	**LOD**	**Vegetation**
Peace Canyon	Main	1	28	12	54	42	13	40	74	5	16	48	6	40	1	
	Open Side	0	18	3	16	14	12	11	30	3	4	26	2	7	2	
	Closed Side															
	Tributary	0	1	0	0	1	0	0	1	0	0	0	1	0	0	
	Total	*1*	*47*	*15*	*70*	*57*	*25*	*51*	*105*	*8*	*20*	*74*	*9*	*47*	*3*	*0*
Hudson's Hope	Main	13	200	6	10	72	133	24	149	69	11	171	16	32	10	0
	Open Side	14	122	0	10	71	66	9	109	34	3	113	11	15	6	1
	Closed Side	4	6	1	0	7	3	1	10	1	0	5	2	1	0	3
	Tributary	16	18	0	0	22	11	1	22	10	2	22	5	5	2	0
	Total	*47*	*346*	*7*	*20*	*172*	*213*	*35*	*290*	*114*	*16*	*311*	*34*	*53*	*18*	*4*
Halfway River	Main	51	286	5	4	163	125	58	249	70	27	283	14	28	21	0
	Open Side	31	152	1	0	102	66	16	144	35	5	157	3	9	14	1
	Closed Side	26	14	0	0	31	6	3	40	0	0	24	1	0	1	14
	Tributary	12	22	0	2	11	16	9	22	11	3	29	3	2	2	0
	Total	*120*	*474*	*6*	*6*	*307*	*213*	*86*	*455*	*116*	*35*	*493*	*21*	*39*	*38*	*15*
Pine River	Main	2	11	6		4	10	5	16	2	1	12	3	3	1	0
	Open Side															
	Closed Side	2	2	0		4	0	0	4	0	0	2	0	0	0	2
	Tributary	2	1	0		2	0	1	3	0	0	2	0	0	1	0
	Total	*6*	*14*	*6*	*0*	*10*	*10*	*6*	*23*	*2*	*1*	*16*	*3*	*3*	*2*	*2*

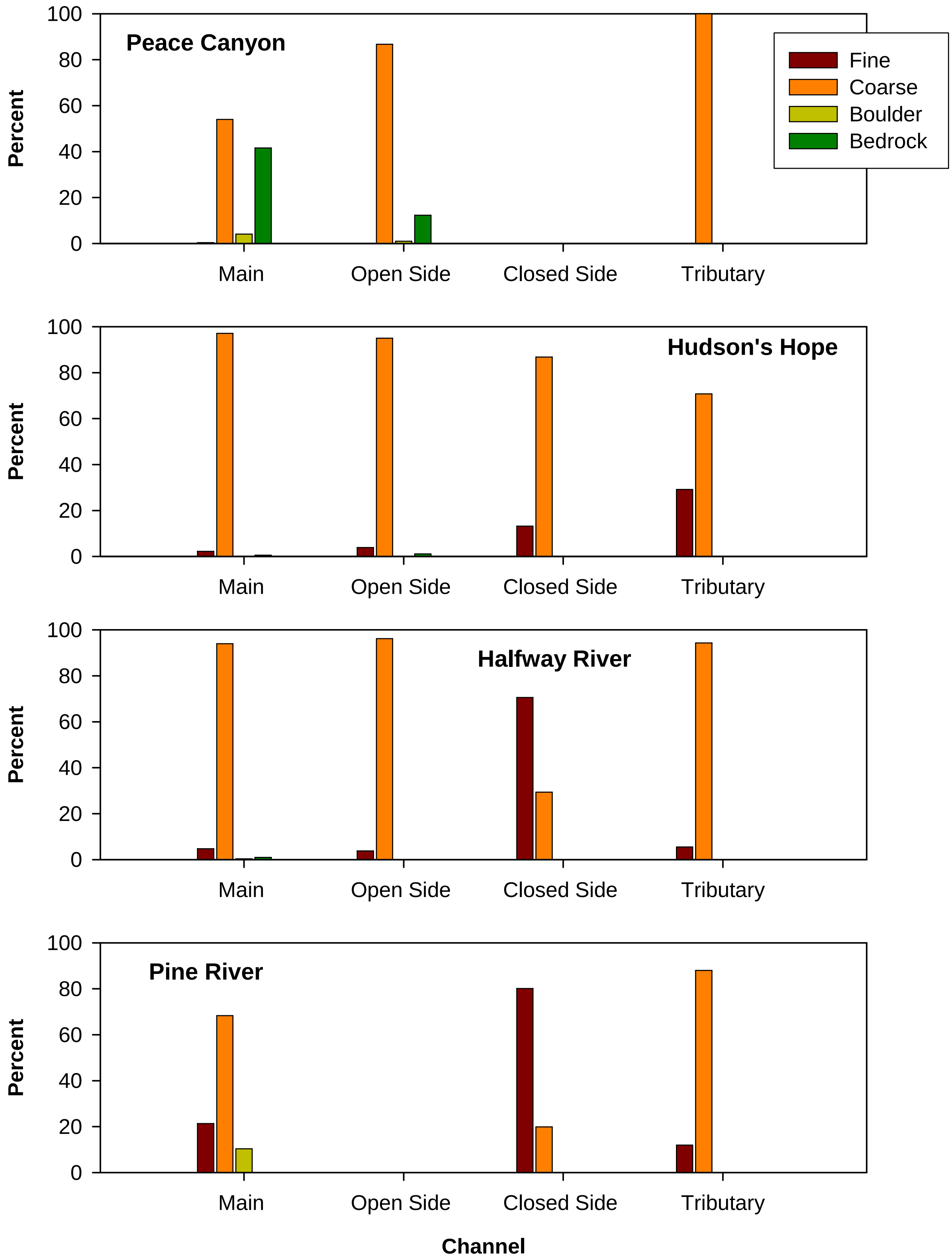


Figure 4.1.8 Percent contribution by surface area of habitat polygon bed material types by reach and channel type (from Mainstream *et al.* 2012).

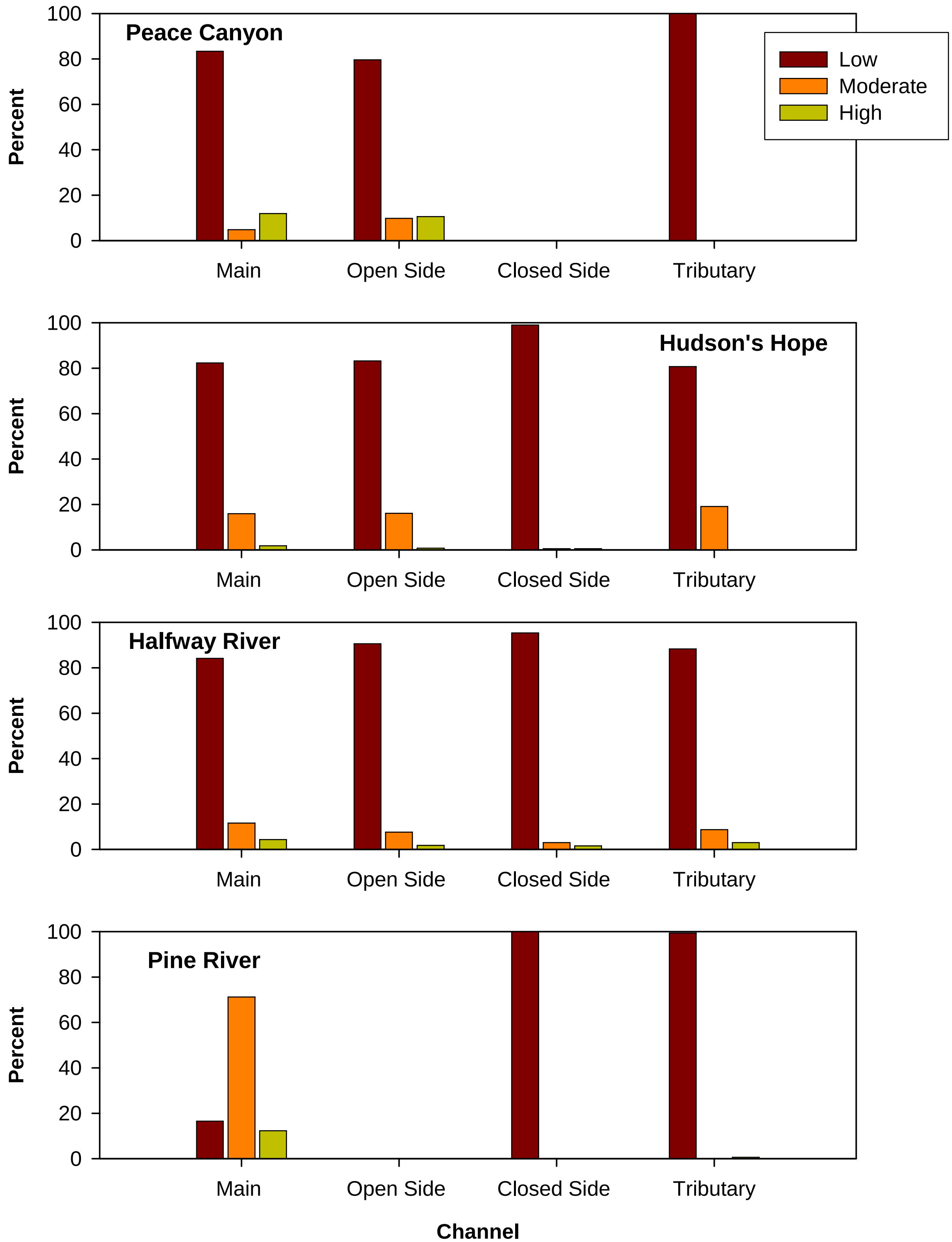


Figure 4.1.9 Percent contribution by surface area of habitat polygon slope type by reach and channel type (from Mainstream *et al.* 2012).

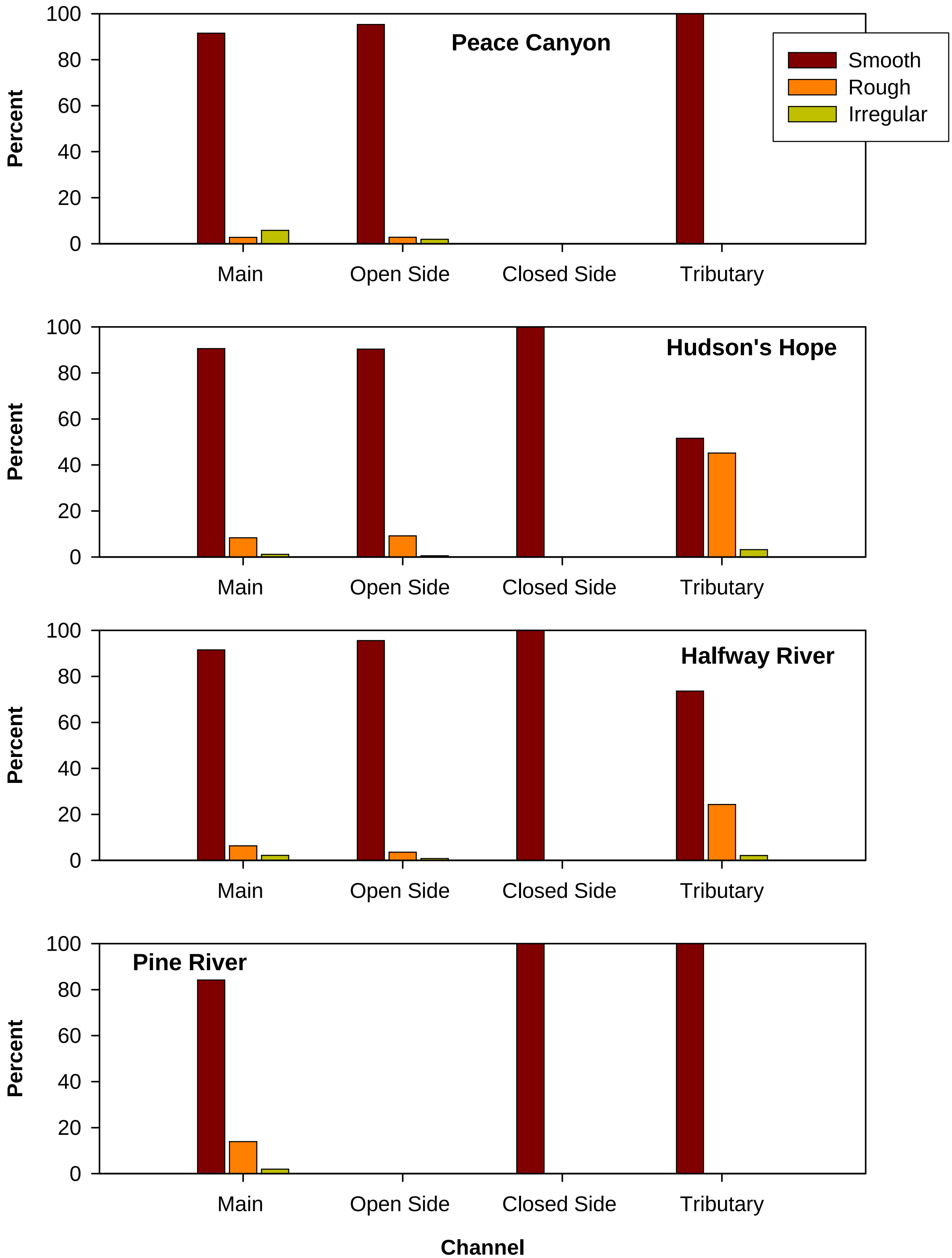


Figure 4.1.10 Percent contribution by surface area of habitat polygon bank irregularity type by reach and channel type (from Mainstream *et al.* 2012).

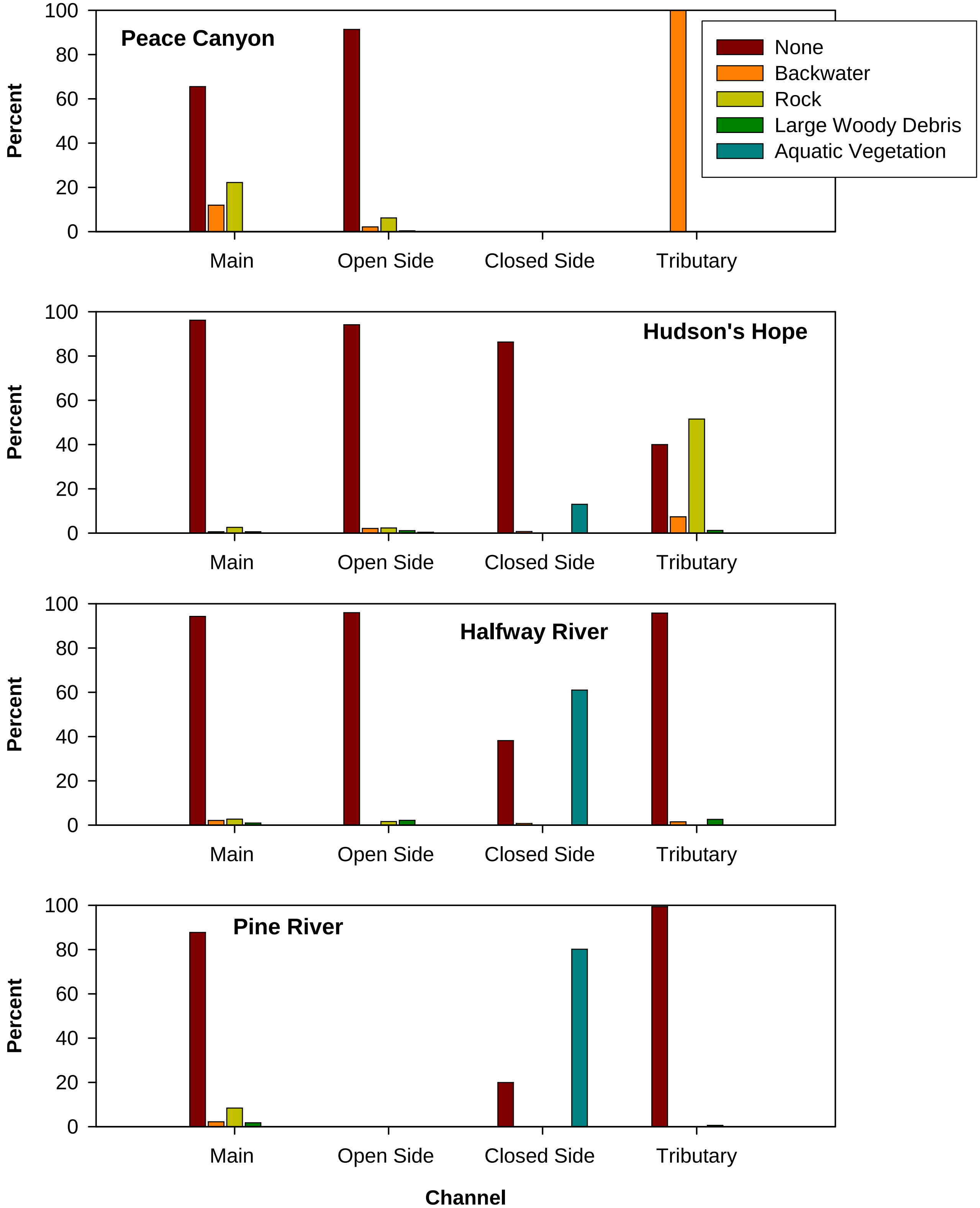


Figure 4.1.11 Percent contribution by surface area of habitat polygon cover type by reach and channel type (from Mainstream *et al.* 2012).

An important objective of Mainstream *et al.* (2012) was to quantify the relationship between discharge and habitat availability. Habitat models were developed based on a power function or a modification to the power function (i.e., shifted power, logistic power, and modified power). In most cases the power function was a good fit to the data (i.e., $r^2 < 0.9$). The results of Mainstream *et al.* (2012) are presented below.

<u>Habitat Model for the Study Area</u>

The available hydraulic habitat, considering all habitat units, in the study reach is estimated by the equation:

$$\text{Habitat Area (sq. m)} = 7.93 \times 10^5 x^{0.31} \ (r^2 = 0.998)$$

Where: x is flow rate (cfs)

The model is shown in Figure 4.1.12.

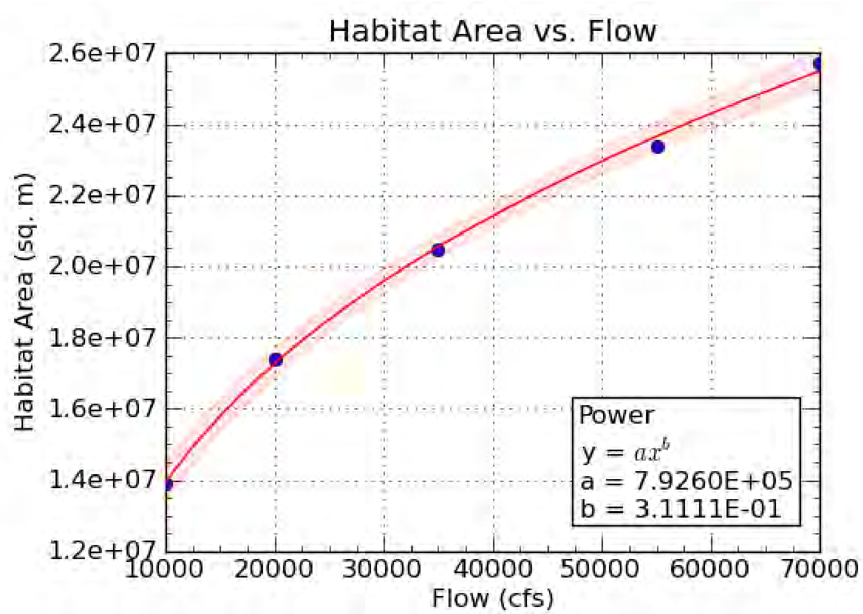


Figure 4.1.12 Hydraulic habitat model for the study reach. Data points are represented by dots, function by red line and pink bands are the 95% confidence area (from Mainstream *et al.* 2012).

Habitat Model by Reach

Models describing the hydraulic habitat area in different river reaches are described in Table 4.1.8. The models are shown in Figure 4.1.13 (Peace Canyon), Figure 4.1.14 (Hudson's Hope), Figure 4.1.15 (Halfway River), and Figure 4.1.16 (Pine River).

Table 4.1.8 River Reach Hydraulic Habitat Models (from Mainstream *et al.* 2012).

Reach	**Model Type**	**Model Parameters**				r^2
		a b		**c**	**d**	
Peace Canyon	Power	97,677.77	0.24			1.000
Hudson's Hope	Power	202,248.45	0.34			0.997
Halfway River	Power	517,097.08	0.30			0.998
Pine River	Modified Power	346,920.97	1.00			0.975

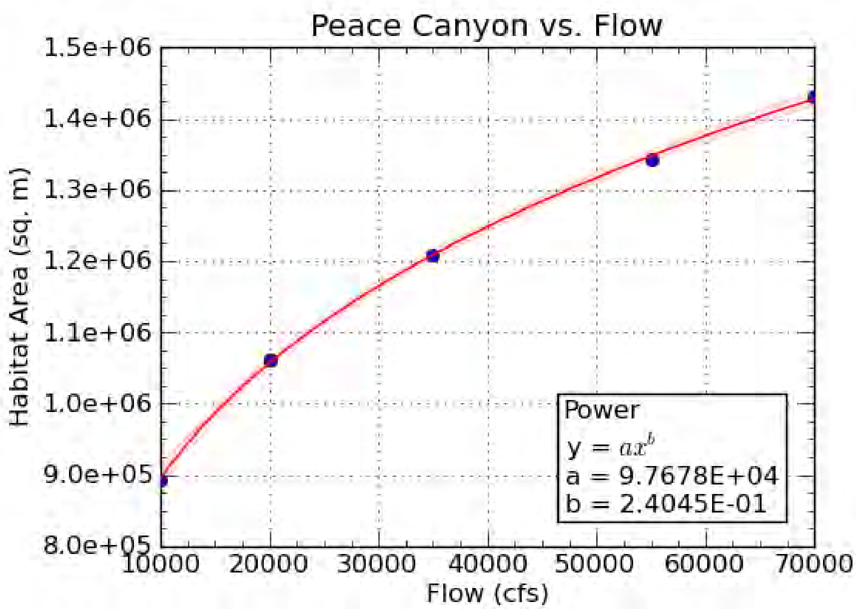


Figure 4.1.13 Hydraulic habitat model for the Peace Canyon reach. Data points are represented by dots, function by red line and pink bands are the 95% confidence area (from Mainstream *et al.* 2012).

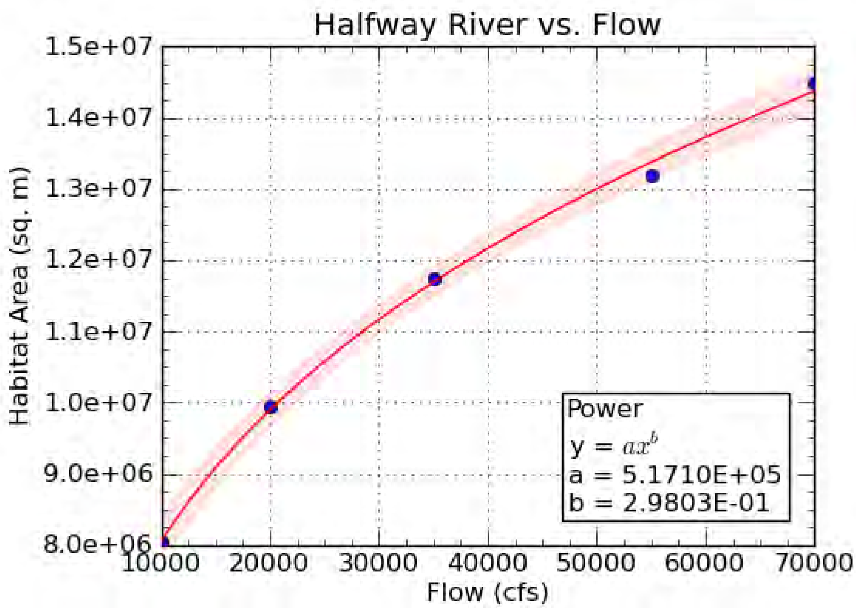


Figure 4.1.14 Hydraulic habitat model for the Halfway River reach. Data points are represented by dots, function by red line and pink bands are the 95% confidence area (from Mainstream *et al.* 2012).

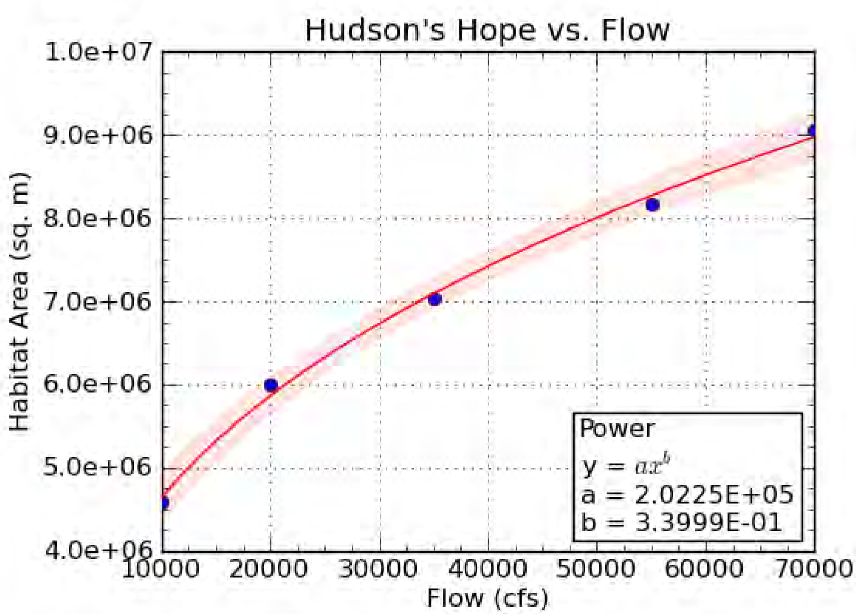


Figure 4.1.15 Hydraulic habitat model for the Hudson's Hope reach. Data points are represented by dots, function by red line and pink bands are the 95% confidence area (from Mainstream *et al.* 2012).

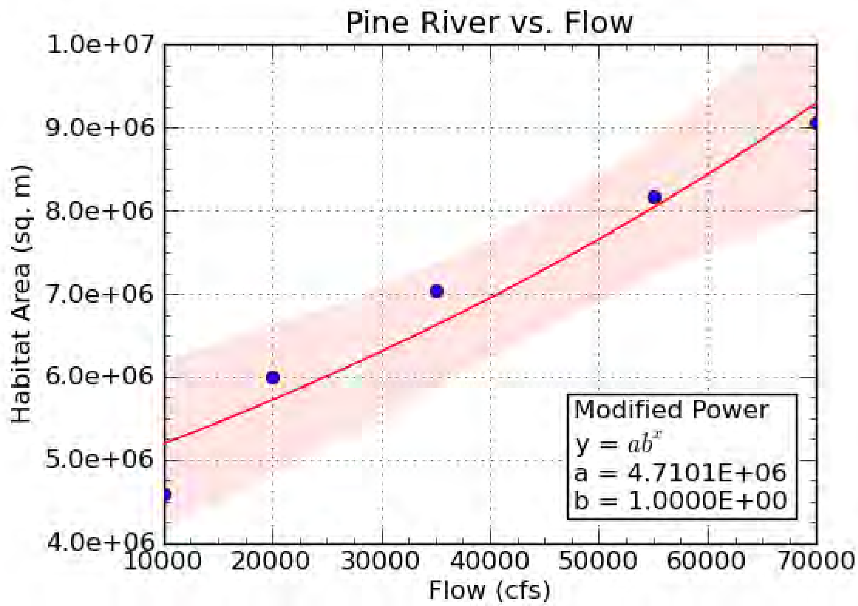


Figure 4.1.16 Hydraulic habitat model for the Pine River reach. Data points are represented by dots, function by red line and pink bands are the 95% confidence area (from Mainstream *et al.* 2012).

Habitat Model by Channel Type

Models describing the change in habitat surface area by channel type with flow are provided in Table 4.1.9.

Table 4.1.9 River Channel Type Hydraulic Habitat Models (from Mainstream *et al.* 2012).

Channel Type	Model Type	Model Parameters				r^2
		a b		c	d	
Main Channel	Power	56.78	0.29			0.995
Open Side Channel	Power	22.55	0.30			0.999
Closed Side Channel	Exponential	145.88	1.00			0.998
Tributary Confluence	Power	2.35	0.39			0.983

Habitat Model by Habitat Type

Models describing the change in habitat types with flow are provided in Appendix Tables C1 (main channel), C2 (open side channels), C3 (closed side channel), and C4 (tributary confluence) of Mainstream *et al.* (2012.)

To estimate the available habitat area of a specific habitat unit type, the individual estimations of the main channel, open side channel, closed side channel, and tributary can be summed.

The habitat mapping by Mainstream *et al.* (2012) identified isolated waterbodies, or ponds. The ponds may have formed as water levels dropped due to changes to river discharge associated with BC Hydro operations. However, factors outside of river discharge influence the formation and persistence of ponds. These include the duration of the dewatered period, rainfall events immediately preceding photo acquisition, subsurface flow, tributary inflow, and changes to channel topography over the duration of the study. As such, ponds identified during habitat mapping can potentially be attributed to changes in river discharge, but the data may not be a reliable measure of this effect.

In total, 1,136 ponds ≥ 5 m^2 were recorded within the active river channel that was exposed between target flows of 283 cms and 1,982 cms (Table 4.1.10). This value represents the combined number of ponds recorded from the orthophoto sets. It has been assumed that ponds located outside the wetted area at 1,982 cms were not influenced by BC Hydro operations investigated by the study. The surface area of included ponds varied substantially from 5 m^2 to 69,572 m^2. Median pond surface area ranged from 5 m^2 to 29,116 m^2.

Table 4.1.10 Number and surface area of isolated ponds (from Mainstream *et al.* 2012).

Reach	**Channel Type**	**Number**	**Surface Area (m^2)**		
			Median	**Range**	**Total**
Peace Canyon	Main Channel	20	29	5 – 420	1,506
	Open Side Channel	1	162	162	162
	Closed Side Channel	0			
	Tributary Confluence	0			
	Total	*21*	*30*	*5 – 420*	*1,668*
Hudson's Hope	Main Channel	60	50	5 - 5,005	15,944
	Open Side Channel	35	32	7 - 10,585	17,306
	Closed Side Channel	51	176	5 - 46,857	219,341
	Tributary Confluence	4	7	5 – 15	34
	Total	*150*	*56*	*5 – 46,857*	*252,625*
Halfway River	Main Channel	244	33	5 - 24,615	110,229
	Open Side Channel	214	32	5 - 50,276	236,352
	Closed Side Channel	321	145	5 - 69,572	759,390
	Tributary Confluence	123	34	5 - 12,090	48,423
	Total	*902*	*50*	*5 – 69,572*	*1,154,394*
Pine River	Main Channel	2	227	23 – 430	453
	Open Side Channel	0			
	Closed Side Channel	31	225	16 - 29,116	128,739
	Tributary Confluence	30	42	5 - 13,099	17,371
	Total	*63*	*140*	*5 – 29,116*	*146,563*
Overall Total		**1,136**	**53**	**5 – 29,116**	**1,555,250**

The number, median area and total area of ponds differed between reaches (Table 4.1.10). In general, the greater the surface area available for dewatering, the higher the number and the greater the surface area of ponds. The Halfway River reach contained a much higher number of ponds (*n* = 901) and total surface area of ponds (1,154,394 m^2) when compared to the remaining reaches. Total area of ponds also differed between channel types (Table 4.1.10). Within each reach, the closed side channel type consistently had the greatest surface area of ponds.

The number of ponds and total pond surface area was influenced by discharge (Figure 4.1.17). The number of ponds and surface area of ponds in the four channel types decreased with declining discharge; however, the relationship was not linear. The threshold of greatest change appeared to occur between 566 cms and 991 cms.

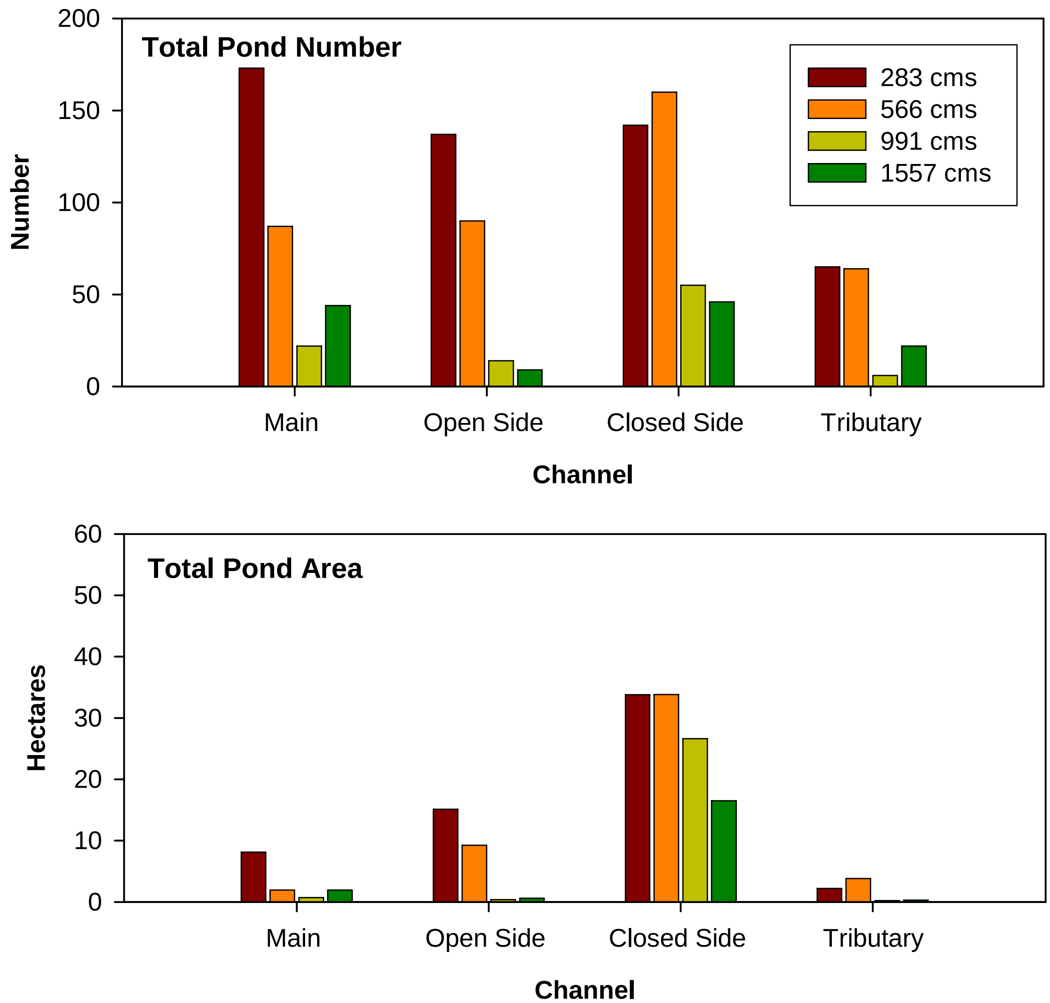


Figure 4.1.17 Pond number and pond surface area by channel type at each target discharge (target discharge of 1,982 cms assumed to have no isolated ponds) (from Mainstream *et al.* 2012).

In summary, the results of Mainstream *et al.* (2012) indicated that large scale air photos could be used to map the water line boundary at each of the five flows at a high level of precision. And, the habitat classification system could reliably identify and delineate near shore habitats using the same large scale air photos. They were able to calculate habitat surface area by combining the digital habitat boundaries with the wetted area of the river at each flow. The habitat surface area data allowed quantification of habitat availability at several spatial scales. Habitat availability was related to river reach, channel type, and habitat type. Habitat availability was strongly related to discharge. Modeling established that there was a high correlation between habitat surface area and discharge, the relationship was curvilinear, and was most often expressed by a power function.

4.2 TRIBUTARIES

4.2.1 General Characteristics

In total, ten named tributaries to the Peace River between the Peace Canyon Dam and the B.C./AB boundary were investigated. They include seven tributaries upstream of the Site C dam location and three main tributaries downstream of the Site C dam location. A fourth tributary located downstream of the Site C dam location was not investigated (Alces River which flows into the Peace River 142.4 km downstream of the Peace Canyon Dam). From upstream to downstream the tributaries are -- Maurice Creek, Lynx Creek, Farrell Creek, Halfway River, Cache Creek, Wilder Creek, Moberly River, Pine River, Beatton River, and Kiskatinaw River (Table 4.2.1).

Table 4.2.1 Characteristics of Peace River tributaries.

Location Relative to Site C dam	Tributary	Distance from Peace Canyon Dam (km)	Total Length (km)	Drainage Area (km^2)
Upstream	Maurice Creek	7.3	31.0	266
	Lynx Creek	13.6	46.7	307
	Farrell Creek	23.7	134.4	640
	Halfway River	45.2	303.6	9,389
	Cache Creek	61.7	48.8	899
	Wilder Creek	72.6	-	100
	Moberly River	84.5	213.4	1,851
Downstream	Pine River	101.0	289.6	13,499
	Beatton River	122.5	500.0	15,948
	Kiskatinaw River	135.5	305.0	4,101

Mainstream (2009c) completed a survey of Peace River tributaries located upstream of the Site C dam in summer 2008 that included a discussion of the characteristics of each watercourse. The following is a summary of that discussion.

Water Quality

Water quality parameters measured during the summer survey (29 July to 7 August) were generally consistent among study tributaries and tributary sections. Water pH in all streams ranged between 7.6 and 9.0, which indicated neutral to slightly alkaline conditions within the range that is considered acceptable for the protection of aquatic life (Anonymous 2006). Water conductivity values in the small tributaries were elevated. Values ranged from 418 µS/cm in Maurice Creek to 2450 µS/cm in Red Creek. There are currently no water quality guidelines for the protection of aquatic life (CCME 2005); however, the high values likely were an indication of groundwater inputs. Lower water conductivities (< 310 µS/cm) were recorded on the larger tributaries (Moberly River and Halfway River).

Water clarity was moderate to high during the summer survey. Water was clear in most tributaries in most sections. Exceptions included Lynx Creek, the Upper Section of Cache Creek, and the Halfway River. Clarity on those systems appeared to be influenced by sediment inputs from source streams (Brenot Creek on Lynx Creek), beaver activity (Cache Creek), and highly erodable materials from slumping banks (Halfway River).

It should be noted that pH, conductivity, and water clarity were largely influenced by the low flow conditions at the time of the survey. As such, they do not reflect water quality conditions throughout the entire year.

Water Temperature

Water temperatures were monitored between May and October 2008. With the exception of Lynx Creek and the Halfway River, most tributaries exhibited a wide range of seasonal water temperatures from a low of 3.4^{o}C (Maurice Creek) to a high of 27.3^{o}C (Farrell Creek). Several tributaries also exhibited a wide range of temperatures within a particular day. Daily temperatures varied by as much as 10.8^{o}C during the warm summer period.

Of note was maximum water temperatures recorded in some tributaries during the study. Water temperatures exceeded the cold-water fish species critical tolerance threshold of 22^{o}C (Oliver and

Fidler 2001) in Maurice Creek, Farrell Creek, Cache Creek, and the Moberly River. Although not monitored, high water temperatures likely occurred in Red Creek and Wilder Creek. The frequency of high water temperatures varied between streams. Temperatures above 22°C were recorded on 6 days in Maurice Creek, 16 days in the Moberly River, 42 days in Cache Creek, and 49 days in Farrell Creek. These conditions exceeded the tolerance levels of cold-water fish species.

Recorded water temperatures were lower in the Halfway River and Lynx Creek during the monitored period. The water volume of the Halfway River likely had a moderating effect on water temperature in that system. Lynx Creek was a small tributary similar in size to Maurice Creek and Farrell Creek; therefore, lower water temperatures were not expected. Lower water temperatures recorded in this stream may have reflected groundwater inputs and/or shading from the tree canopy and steep valley walls. Visual observations during the program indicated that both factors likely contributed to maintaining lower water temperatures in this tributary.

Discharge

The discharge regime during 2008 was similar among the small tributaries. A strong freshet was recorded during May, followed by a rapid decrease of discharge to base flow conditions by early summer. Seasonal changes in discharge of the large tributaries was generally similar to that of the smaller systems; however, changes were more gradual and base flow conditions were not reached until later in the summer. All study tributaries exhibited flow patterns that reflected a rapid response to inputs such as snow melt and rainfall events. For example, the spring freshet in the small tributaries exhibited two modal peaks. The first presumably was related to snow melt, while the second was in response to a rain event. The Halfway River, which receives a portion of its flow from the mountains, exhibited a large peak in August after the spring freshet period. This peak likely was caused by a strong rain event in the mountains – it was not recorded in any other surveyed tributary.

4.2.2 Fish Habitat of Small Tributaries

Habitats in Peace River tributaries upstream of the Site C dam were inventoried in 2005 by AMEC and LGL (2008a). Surveyed sections were separated into a lower and upper area of approximately equal length separated by the predicted upstream limit of Site C reservoir at full supply level. Mainstream (2009c) completed similar work on smaller tributaries in 2008 and then expanded the study area in 2010 to include upper watersheds of smaller tributaries thought to support coldwater sportfish (Mainstream 2011e). Descriptions of tributary habitat characteristics are summarized below.

4.2.1.1 Maurice Creek

Maurice Creek is a small watercourse. It has a total length of 31 km and drains 266 km^2 of rolling forested terrain located south of the Peace River. Maurice Creek can be divided into two regions. The lower 3 km section is separated from the upper section by a series of impassible barriers to upstream fish passage.

The major habitat types recorded at sampled sites on Maurice Creek were pools, riffles, and runs (Table 4.2.2; Photograph 4.2.1). Other habitats recorded included a flat and a falls in the Upper Section.

Table 4.2.2 Physical characteristics of fish habitats (mean ± SE) in Lower and Upper sections of Maurice Creek, 2008 tributaries juvenile fish summer survey (from Mainstream 2009c).

Section	Habitat Type	*n*	Bankfull Width (m)	Wetted Width (m)	Water Depth (m)	Water Velocity (m^3/s)
Lower (Sites = 1)	Flat	0				
	Pool	5	11.0 ± 0.3	5.4 ± 0.4	0.47 ± 0.09	< 0.01
	Riffle	5	12.8 ± 1.0	5.9 ± 1.4	0.10 ± 0.03	0.21 ± 0.07
	Run	5	13.9 ± 1.5	5.3 ± 0.8	0.15 ± 0.02	0.04 ± 0.01
	Falls	0				
	Average[a]	15	12.5 ± 0.7	5.5 ± 0.5	0.24 ± 0.05	0.08 ± 0.03
Upper (Sites = 2)	Flat	1	12.9	8.5	0.54	0.00
	Pool	8	15.4 ± 1.4	6.5 ± 1.0	0.39 ± 0.04	0.01 ± 0.002
	Riffle	7	14.7 ± 1.0	5.2 ± 1.2	0.07 ± 0.01	0.18 ± 0.09
	Run	8	16.5 ± 1.5	5.3 ± 0.7	0.13 ± 0.02	0.07 ± 0.04
	Falls	1	17.5	15.3	0.12	0.04
	Average[a]	23	15.5 ± 0.8	5.7 ± 0.6	0.20 ± 0.03	0.08 ± 0.03

[a] Includes data from pool, run, and riffle.

Photograph 4.2.1 Riffle/run complex on Maurice Creek, summer 2008 (from Mainstream 2009c).

Wetted channel width was approximately 40% of bankfull width, water depth was generally less than 0.25 m, and water velocities were generally low. As expected, pool habitats exhibited greater water depths (0.40 m). These values were indicative of base flow conditions during the survey.

Cobbles and/or boulders/bedrock dominated the bed materials in most habitats (Table 4.2.3). The primary exception was the large percentage of fines (clays, silts, and sands) in pool habitat. D90 exceeded 22 cm in all habitats except flat in the Upper Section, which indicated substantial stream power at high flows.

Table 4.2.3 Bed material characteristics of fish habitats (mean ± SE) in Lower and Upper sections of Maurice Creek, 2008 tributaries juvenile fish summer survey (from Mainstream 2009c).

Section	Habitat Type	*n*	D90 (cm)	Bed Material Type (%)				Condition	
				Fines	PE/GR	CO	BO/BE	Embedd.	Compact.
Lower (Sites = 1)	Flat	0							
	Pool	5	23.0 ± 1.6	49 ± 8	9 ± 3	9 ± 4	33 ± 8	1.8 ± 0.2	1.4 ± 0.4
	Riffle	5	30.2 ± 2.0	27 ± 4	17 ± 5	37 ± 3	19 ± 5	1.6 ± 0.2	1.8 ± 0.4
	Run	5	35.0 ± 6.2	27 ± 4	18 ± 3	27 ± 3	28 ± 6	1.6 ± 0.4	1.4 ± 0.2
	Falls	0							
	Average[a]	*15*	*29.4 ± 2.5*	*34 ± 1*	*15 ± 2*	*24 ± 4*	*27 ± 4*	*1.7 ± 0.2*	*1.5 ± 0.2*
Upper (Sites = 2)	Flat	1	14	75	10	10	5	3	1
	Pool	8	23.4 ± 7.9	33 ± 6	15 ± 3	12 ± 2	40 ± 8	2.4 ± 0.3	1.3 ± 0.2
	Riffle	7	41.4 ± 12.3	15 ± 6	21 ± 5	33 ± 7	30 ± 11	1.2 ± 0.2	1.8 ± 0.3
	Run	8	24.6 ± 4.0	16 ± 5	19 ± 5	38 ± 7	27 ± 7	1.9 ± 0.3	2.0 ± 0.2
	Falls	1	39	5	0	10	85	3	2
	Average[a]	*23*	*29.3 ± 4.9*	*22 ± 1*	*19 ± 2*	*27 ± 4*	*32 ± 5*	*1.9 ± 0.2*	*1.7 ± 0.1*

[a] Includes data from pool, run, and riffle.

Bed material embeddedness and compaction was low to moderate (1 to 2) in surveyed sections.

The physical and bed material characteristics of the Lower Section and Upper Section were very similar (Figure 4.2.1). The only apparent differences were bankfull width (12.5 m versus 15.5 m, respectively) and percentage of fines (34% versus 22%, respectively).

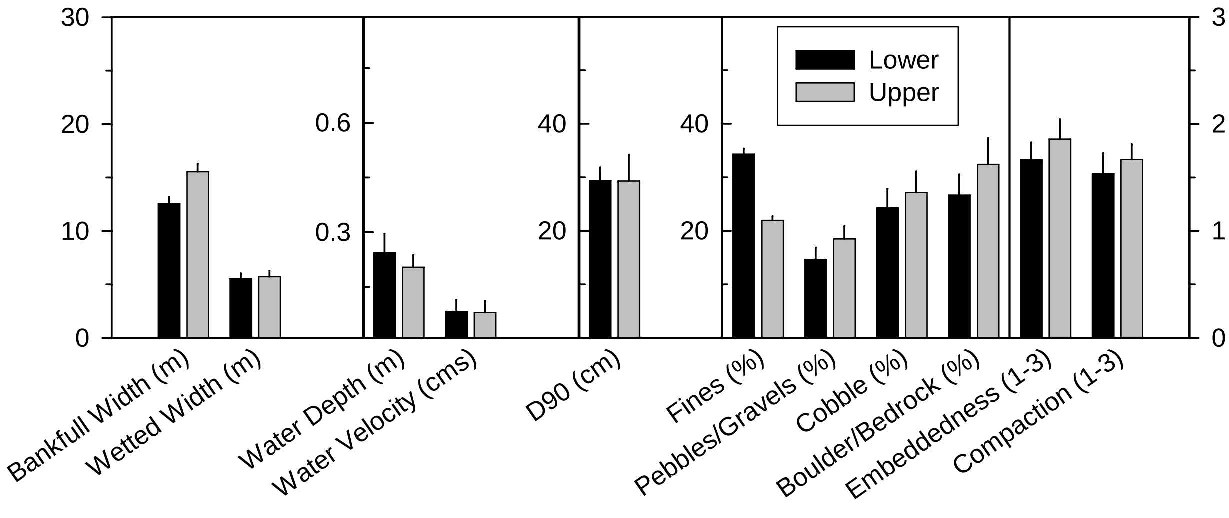


Figure 4.2.1 Physical and bed material characteristics (mean ± SE) of Lower and Upper sections of Maurice Creek, 2008 tributaries juvenile fish summer survey (includes pool, run, and riffle data) (from Mainstream 2009c).

Mainstream (2011e) extended habitat surveys into the upper watershed of Maurice Creek in 2010. The study found that habitat features were generally similar to habitats in lower reaches, but there was a higher prevalence of beaver dams and impoundments

AMEC and LGL (2008a) presented a summary of habitat types inventoried in 2005 as follows:

Habitat Type	Percent by Length	
	Lower Area	Upper Area
Riffle	70.2	40.6
Pool	29.8	25.3
Run		34.1
Other		

4.2.1.2 Lynx Creek

The Lynx Creek watershed originates next to Butler Ridge and flows north west, then south west entering the north side of the Peace River approximately 6 km downstream of the town of Hudson’s Hope. Lynx Creek mainstem is 46.7 km in length and drains an area of 307 km^2.

Habitat in Lynx Creek consists of glide/riffles with boulder substrates (ARL 1991a). Approximately 2 km upstream from the confluence, the channel becomes entrenched in a shale valley. Channel width was approximately 8 m while the average water depth was 0.25 m. A series of waterfalls 2 to 4 m in height were located approximately 10 km upstream from the confluence. These falls may act as barriers to upstream movement of fish. Beaver impoundments are prevalent in the middle and upper sections (Mainstream 2009c, 2011e).

The Lynx Creek watershed can be divided into four regions:

- The Lower Mainstem region extends from the confluence with the Peace River to a series of waterfalls located approximately 9.9 km to 10.2 km upstream of the confluence.
- The Middle Mainstem region extends from Km 10.2 (upstream of the waterfalls) to the mouth of Mackie Creek, approximately 18.0 km upstream.
- The Upper Mainstem region corresponds to the steep section of the watershed located between the mouth of Mackie Creek and the headwaters.
- Brenot Creek originates at Butler Ridge and enters Lynx Creek less than one kilometer downstream of the waterfalls at Km 9.9.

The major habitat types recorded at sampled sites on Lynx Creek were pools, riffles, and runs (Table 4.2.4; Photographs 4.2.2 and 4.2.3). There were also five flats in the Upper Section and three flats in the sampled Lower Section. Although not specifically sampled in Lynx Creek, beaver impoundments were prevalent in the Upper Section.

Table 4.2.4 Physical characteristics of fish habitats (mean ± SE) in Lower and Upper sections of Lynx Creek, 2008 tributaries juvenile fish summer survey (from Mainstream 2009c).

Section	**Habitat Type**	***n***	**Bankfull Width (m)**	**Wetted Width (m)**	**Water Depth (m)**	**Water Velocity (m^3/s)**
Lower (*n*=3)	Flat	3	9.6 ± 2.4	6.3 ± 0.1	0.18 ± 0.01	0.12 ± 0.03
	Pool	14	10.7 ± 0.8	5.1 ± 0.7	0.29 ± 0.03	0.12 ± 0.02
	Riffle	22	10.2 ± 0.4	6.3 ± 0.4	0.13 ± 0.03	0.45 ± 0.03
	Run	16	10.0 ± 0.6	5.1 ± 0.3	0.15 ± 0.01	0.24 ± 0.02
	Average[a]	*52*	*10.3 ± 0.3*	*5.6 ± 0.3*	*0.18 ± 0.02*	*0.29 ± 0.02*
Upper (*n*=3)	Flat	5	8.9 ± 0.6	5.9 ± 0.8	0.19 ± 0.03	0.14 ± 0.02
	Pool	16	10.6 ± 0.9	7.2 ± 1.2	0.33 ± 0.04	0.14 ± 0.03
	Riffle	23	10.0 ± 0.4	6.6 ± 0.3	0.12 ± 0.01	0.46 ± 0.04
	Run	21	9.6 ± 0.3	5.8 ± 0.3	0.17 ± 0.01	0.29 ± 0.03
	Average[a]	*60*	*10.0 ± 0.3*	*6.5 ± 0.4*	*0.19 ± 0.02*	*0.33 ± 0.03*

[a] Includes data from pool, run, and riffle.

Photograph 4.2.2 Riffle/run complex on Lynx Creek summer 2008 (from Mainstream 2009c).

Photograph 4.2.3 Beaver impoundment on Lynx Creek, summer 2008 (from Mainstream 2009c).

Wetted channel width was approximately 60% of bankfull width, water depth was generally less than 0.20 m (pools > 0.30 m), and water velocities were less than 0.30 m/s (riffles > 0.45 m/s). Fines dominated the bed materials in most habitats (Table 4.2.5). The percentage of fines was less in riffles and runs. D90 exceeded 38 cm in all habitats, which indicated substantial stream power at high flows. Bed material embeddedness and compaction was variable (range of 1 to 3). Embeddedness was higher in flat and pool habitats which were characterized by lower water velocities.

The physical and bed material characteristics of the Lower Section and Upper Section were very similar (Figure 4.2.2). The only distinct differences were D90 (48.6 cm versus 64.4 cm, respectively), and compaction (1.7 versus 2.5, respectively).

Table 4.2.5 Bed material characteristics of fish habitats in Lower and Upper sections of Lynx Creek, 2008 tributaries juvenile fish summer survey (from Mainstream 2009c).

Section	**Habitat Type**	***n***	**D90 (cm)**	**Bed Material Type (%)**				**Substrate Condition**	
				Fines	**PE/GR**	**CO**	**BO/BE**	**Embedd.**	**Compact.**
Lower (*n*=3)	Flat	3	45.7 ± 21.2	60 ± 5	15 ± 3	15 ± 3	10 ± 5	3.0	1.0
	Pool	14	46.7 ± 7.8	60 ± 5	14 ± 2	15 ± 2	11 ± 3	2.8 ± 0.1	1.4 ± 0.1
	Riffle	22	57.6 ± 9.6	29 ± 2	20 ± 2	25 ± 2	26 ± 4	1.2 ± 0.1	2.1 ± 0.2
	Run	16	38.3 ± 6.3	38 ± 3	24 ± 1	24 ± 1	14 ± 3	2.1 ± 0.1	1.4 ± 0.1
	Average[a]	*52*	*48.6 ± 4.9*	*40 ± 1*	*20 ± 1*	*22 ± 1*	*18 ± 2*	*1.9 ± 0.1*	*1.7 ± 0.1*
Upper (*n*=3)	Flat	5	42.4 ± 11.2	54 ± 3	18 ± 2	20 ± 2	8 ± 3	2.4 ± 0.2	2.0 ± 0.3
	Pool	16	71.4 ± 15.0	46 ± 3	17 ± 2	19 ± 1	19 ± 3	2.8 ± 0.1	2.2 ± 0.2
	Riffle	23	58.2 ± 11.6	33 ± 2	22 ± 1	26 ± 1	19 ± 2	1.1 ± 0.1	2.7 ± 0.1
	Run	21	65.9 ± 19.7	41 ± 2	20 ± 1	21 ± 1	18 ± 2	1.7 ± 0.1	2.5 ± 0.1
	Average[a]	*60*	*64.4 ± 9.0*	*39 ± 1*	*20 ± 1*	*23 ± 1*	*18 ± 1*	*1.8 ± 0.1*	*2.5 ± 0.1*

[a] Includes data from pool, run, and riffle.

Wetted channel width was approximately 60% of bankfull width, water depth was generally less than 0.20 m (pools > 0.30 m), and water velocities were less than 0.30 m/s (riffles > 0.45 m/s). Fines dominated the bed materials in most habitats (Table 4.2.5). The percentage of fines was less in riffles and runs. D90 exceeded 38 cm in all habitats, which indicated substantial stream power at high flows. Bed material embeddedness and compaction was variable (range of 1 to 3). Embeddedness was higher in flat and pool habitats which were characterized by lower water velocities.

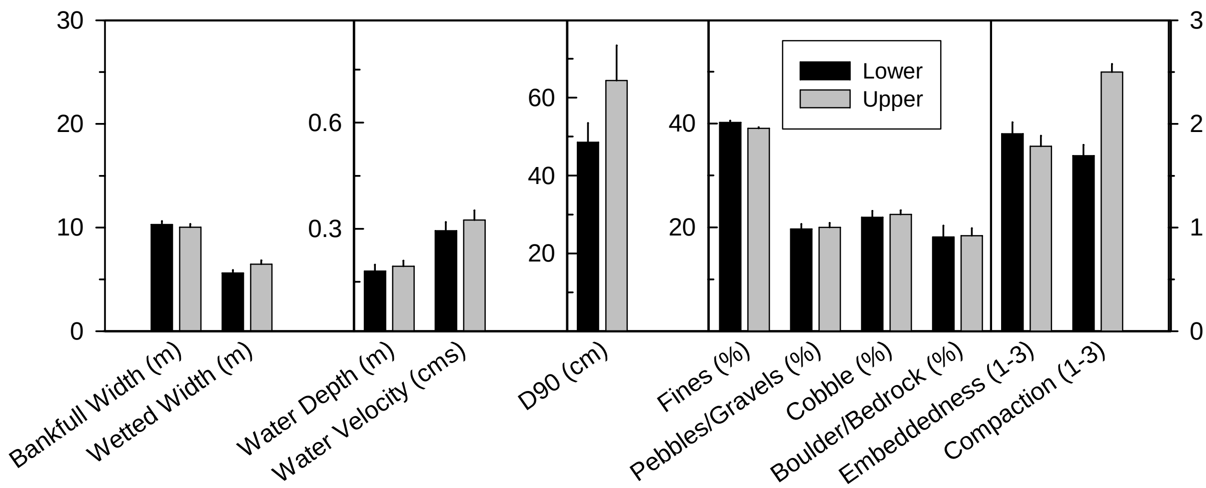


Figure 4.2.2 Physical and bed material characteristics (mean ± SE) of in Lower and Upper sections of Lynx Creek, 2008 tributaries juvenile fish survey (includes pool, run, and riffle data) (from Mainstream 2009c).

Mainstream (2011e) extended habitat surveys into the upper watershed of Lynx Creek in 2010. The study found that habitat features were generally similar to habitats in lower reaches, but beaver impoundments were prevalent at the most upstream sites on Lynx Creek and on Brenot Creek. An important feature documented on Brenot Creek was an active land slide that was contributing significant amounts of suspended sediments (Photograph 4.2.4).

Photograph 4.2.4 Landslide with runoff into Brenot Creek, 16 September 2010 (from Mainstream 2011e).

AMEC and LGL (2008a) presented a summary of habitat types inventoried in 2005 as follows:

Habitat Type	Percent by Length	
	Lower Area	Upper Area
Riffle	90.3	59.2
Pool	9.7	23.4
Run		14.6
Other		

4.2.1.3 Farrell Creek

Farrell Creek originates near Butler Ridge located approximately 24 km north west of Hudson's Hope and flows east then south to its confluence with the Peace River approximately 22 km downstream of the town of Hudson's Hope. The mainstem channel is 134.4 km in length and the watershed drains 640 km^2.

Farrell Creek is confined by steep banks up to 30 m high (ARL 1991a). Channel width is 25 m and wetted width at the time of survey was 7 m. The channel becomes increasingly braided moving upstream. The stream had a high percentage of riffle habitat with boulder cover. There are no barriers to fish movement in Farrell Creek.

The Farrell Creek watershed can be divided into three regions:

- The Lower Mainstem region extends from the confluence with the Peace River to approximately 22 km upstream. This area exhibits higher stream gradient as the creek incises into the Peace River valley wall.
- The Upper Mainstem region extends from approximately 22 km upstream of the Peace River confluence to the foothills of Butler Ridge. Headwater sources include Chinaman Lake, Ruby Creek, and Beany Creek.

The major habitat types recorded in sampled sections on Farrell Creek were pools, riffles, and runs (Table 4.2.6; Photograph 4.2.5). Other habitats recorded included a cascade and three flats in the Lower Section and a beaver impoundment (Photograph 4.2.6) and one flat in the Upper Section.

Table 4.2.6 Physical characteristics of fish habitats (mean ± SE) in Lower and Upper sections of Farrell Creek, 2008 tributaries juvenile fish summer survey (from Mainstream 2009c).

Section	**Habitat Type**	***n***	**Bankfull Width (m)**	**Wetted Width (m)**	**Water Depth (m)**	**Water Velocity (m^3/s)**
Lower (*n*=3)	Flat	3	14.5 ± 1.2	8.7 ± 0.6	0.32 ± 0.06	< 0.01
	Pool	13	16.2 ± 0.9	8.7 ± 0.9	0.45 ± 0.04	0.04 ± 0.01
	Riffle	15	18.3 ± 0.7	10.4 ± 1.1	0.1 ± 0.01	0.24 ± 0.03
	Run	15	15.9 ± 1.0	7.2 ± 0.5	0.19 ± 0.02	0.10 ± 0.02
	Cascade	1	18.4	6.0	0.22	0.22
	Impoundment	0				
	Average[a]	*43*	*16.9 ± 0.5*	*8.8 ± 0.5*	*0.24 ± 0.03*	*0.13 ± 0.02*
Upper (*n*=3)	Flat	1	17.2	8.0	0.14	0.02
	Pool	15	16.1 ± 0.9	7.6 ± 0.4	0.39 ± 0.04	0.04 ± 0.01
	Riffle	16	17.5 ± 1.3	9.5 ± 0.8	0.08 ± 0.01	0.17 ± 0.02
	Run	14	17.8 ± 1.2	6.6 ± 0.5	0.19 ± 0.01	0.10 ± 0.01
	Cascade	0				
	Impoundment	1	21.3	16.2	0.44	< 0.01
	Average[a]	*45*	*17.1 ± 0.6*	*7.9 ± 0.4*	*0.22 ± 0.02*	*0.10 ± 0.01*

[a] Includes data from pool, run, and riffle.

Wetted channel width was approximately 50% of bankfull width, water depth averaged less than 0.25 m, and water velocities were generally low (< 0.10 m/s). As expected, pool habitats exhibited greater water depths (approximately 0.40 m) and higher water velocities were recorded in riffles (> 0.15 m/s). These values were indicative of base flow conditions at the time of the survey.

Photograph 4.2.5 Typical Riffle/Pool/Run complex on Farrell Creek, summer 2008 (from Mainstream 2009c).

Photograph 4.2.6 Beaver Impoundment on Farrell Creek, summer 2008 (from Mainstream 2009c).

Smaller rock bed materials (i.e., pebbles and gravels) dominated in all habitats including the impoundment (Table 4.2.7), while pool and flat habitats exhibited a high percentage of fines (> 25%).

Table 4.2.7 Bed material characteristics of fish habitats (mean ± SE) in Lower and Upper sections of Farrell Creek, 2008 tributaries juvenile fish summer survey (from Mainstream 2009c).

Section	**Habitat Type**	***n***	**D90 (cm)**	**Bed Material Type (%)**				**Substrate Condition**	
				Fines	**PE/GR**	**CO**	**BO/BE**	**Embedd.**	**Compact.**
Lower (*n*=3)	Flat	3	17.3 ± 4.3	38 ± 12	38 ± 4	10 ± 6	13 ± 6	2.3 ± 0.3	3.0
	Pool	13	28.8 ± 3.3	26 ± 4	27 ± 4	16 ± 3	30 ± 6	1.6 ± 0.2	1.5 ± 0.2
	Riffle	15	28.9 ± 1.8	20 ± 1	42 ± 4	23 ± 2	15 ± 4	1.5 ± 0.1	1.5 ± 0.2
	Run	15	27.3 ± 2.3	24 ± 3	35 ± 4	21 ± 3	20 ± 5	1.8 ± 0.2	1.7 ± 0.2
	Cascade	1	42	10	20	15	55	1	1
	Impoundment	0							
	Average[a]	*43*	*28.3 ± 1.4*	*23 ± 1*	*35 ± 3*	*20 ± 2*	*21 ± 3*	*1.6 ± 0.1*	*1.6 ± 0.1*
Upper (*n*=3)	Flat	1	19	30	55	10	5	2	2
	Pool	15	19.3 ± 1.3	38 ± 3	44 ± 3	11 ± 2	6 ± 4	2.1 ± 0.1	2.1 ± 0.2
	Riffle	16	20.1 ± 1.5	24 ± 2	51 ± 3	19 ± 2	6 ± 1	2 ± 0.2	2.2 ± 0.2
	Run	14	19.6 ± 1.5	28 ± 2	55 ± 4	13 ± 2	4 ± 1	2.4 ± 0.1	2.4 ± 0.2
	Cascade	0							
	Impoundment	1	15	45	40	10	5	2	2
	Average[a]	*45*	*19.7 ± 0.8*	*30 ± 1*	*50 ± 2*	*15 ± 1*	*6± 1*	*2.2 ± 0.1*	*2.2 ± 0.1*

[a] Includes data from pool, run, and riffle.

D90 exceeded 15 cm in all habitats and bed material embeddedness and compaction was low to moderate (1 to 2) in most habitats. The only exception was high embeddedness and compaction recorded in the flat habitat of the Lower Section.

The physical and bed material characteristics of the Lower Section and Upper Section were very similar (Figure 4.2.3). The apparent differences were D90 (28.3 cm versus 19.7 cm, respectively), percentage of small rock (35% versus 50%, respectively), and percentage of large rock (21% versus 6%, respectively). These values were indicative of the average rock width being higher in the Lower Section compared to the Upper Section.

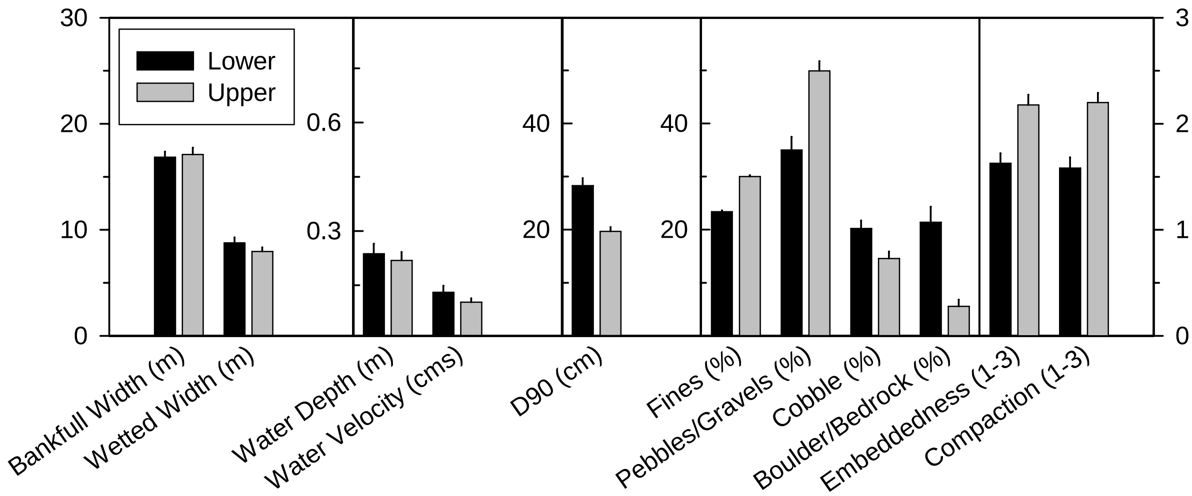


Figure 4.2.3 Physical and bed material characteristics (mean ± SE) of Lower and Upper sections of Farrell Creek, 2008 tributaries juvenile fish summer survey (includes pool, run, and riffle data) (from Mainstream 2009c).

Mainstream (2011e) extended habitat surveys into the upper watershed of Farrell Creek in 2010. The study found that habitat features were generally similar to habitats in lower reaches.

AMEC and LGL (2008a) presented a summary of habitat types inventoried in 2005 as follows:

Habitat Type	**Percent by Length**	
	Lower Area	**Upper Area**
Riffle	51.9	49.9
Pool	35.9	34.0
Run	12.1	15.0
Other		

4.2.1.4 Cache Creek

The Cache Creek watershed is larger than the Maurice Creek, Lynx Creek, and Farrell Creek watersheds. It drains 899 km^2. The Cache Creek mainstem is 78.8 km in length and enters the Peace River approximately 95 km west of Fort St. John and approximately 25 km upstream of the Site C dam.

Cache Creek can be divided into two regions:

- The Lower Mainstem region extends from the confluence with the Peace River to the Peace River valley wall, approximately 4 km upstream.
- The Upper Mainstem region extends from the Peace River valley wall to the headwaters. Major tributaries include Red Creek, East Cache Creek, and West Cache Creek.

The lower sections of Cache Creek consist of a series of large shallow pools connected by short riffle sections (ARL 1991a). Riffles lacked boulder cover and runs had silt-embedded substrates with no cover for fish. Spawning gravels were observed in Cache Creek. Red Creek, a tributary to Cache Creek, contained significant iron deposits. Approximately 20 km upstream from the confluence, Cache Creek consists of largely beaver ponds (ARL 1991a).

Sampling of Cache Creek occurred during zero surface water flow, which affected the results of the survey. The major habitat types recorded at sampled sites on Cache Creek were pools, riffles, and runs (Table 4.2.8; Photographs 4.2.7 and 4.2.8). Other recorded habitats included two flats in the Lower Section.

Table 4.2.8 Physical characteristics of fish habitats (mean ± SE) in Upper and Lower sections of Cache Creek, 2008 tributaries juvenile fish summer survey (from Mainstream 2009c).

Section	Habitat Type	*n*	Bankfull Width (m)	Wetted Width (m)	Water Depth (m)	Water Velocity (m^3/s)
Lower (*n*=4)	Flat	2	20.2 ± 2.2	3.7 ± 0.5	0.60 ± 0.46	0.00
	Pool	23	11.7 ± 0.7	5.6 ± 0.4	0.39 ± 0.05	0.00
	Riffle	22	15.6 ± 1.0	5.6 ± 0.8	0.04 ± 0.01	0.01 ± 0.01
	Run	23	13.3 ± 0.8	5.2 ± 0.6	0.19 ± 0.05	0.00
	Average[a]	*68*	*13.5 ± 0.5*	*5.5 ± 0.3*	*0.21 ± 0.03*	*< 0.01*
Upper (*n*=3)	Flat	0				
	Pool	18	11.2 ± 0.8	5.3 ± 0.4	0.33 ± 0.03	0.00
	Riffle	18	11.6 ± 1.3	4.9 ± 0.7	0.06 ± 0.02	0.05 ± 0.02
	Run	16	11.9 ± 0.9	5.8 ± 0.7	0.14 ± 0.02	0.01 ± 0.01
	Average[a]	*52*	*11.5 ± 0.6*	*5.3 ± 0.3*	*0.18 ± 0.02*	*0.02 ± 0.01*

[a] Includes data from pool, run, and riffle.

Photograph 4.2.7 Riffle/run complex in Cache Creek, summer 2008 (from Mainstream 2009c).

Photograph 4.2.8 Isolated pool in Cache Creek, summer 2008 (from Mainstream 2009c).

Wetted channel width was approximately 40% of bankfull width, water depth averaged less than 0.20 m, and water velocities were generally nil. As expected, pool habitats exhibited greater water depths (approximately 0.30 to 0.40 m), as did flat habitat (approximately 0.60 m).

Fines dominated the bed material in most habitats (Table 4.2.9). Riffle and run habitats had higher percentages of pebble/gravel and cobble. Bed material embeddedness and compaction was low to moderate (1 to 2) in most habitats.

Table 4.2.9 Bed material characteristics of fish habitats in Upper and Lower sections of Cache Creek, 2008 tributaries juvenile fish summer survey (from Mainstream 2009c).

Section	Habitat Type	*n*	D90 (cm)	Bed Material Type (%)				Substrate Condition	
				Fines	PE/GR	CO	BO/BE	Embedd.	Compact.
Lower (*n*=4)	Flat	2	30.5 ± 12.5	40	20	20	20	2.0	2.5 ± 0.5
	Pool	23	12.8 ± 3.1	58 ± 3	22 ± 3	17 ± 1	4 ± 1	2.6 ± 0.1	1.3 ± 0.1
	Riffle	22	20.3 ± 3.8	34 ± 3	31 ± 3	23 ± 2	12 ± 2	1.4 ± 0.2	1.8 ± 0.2
	Run	23	15.5 ± 2.4	45 ± 3	28 ± 3	20 ± 2	7 ± 2	2.4 ± 0.1	1.7 ± 0.1
	Average[a]	*68*	*16.2 ± 1.8*	*46 ± 1*	*27 ± 2*	*20 ± 1*	*8 ± 1*	*2.1 ± 0.1*	*1.6 ± 0.1*
Upper (*n*=3)	Flat	0							
	Pool	18	16.5 ± 2.1	49 ± 3	19 ± 1	22 ± 1	10 ± 2	2.8 ± 0.1	1.7 ± 0.1
	Riffle	18	17.8 ± 1.6	35 ± 2	23 ± 1	26 ± 1	16 ± 2	1.3 ± 0.1	1.6 ± 0.1
	Run	16	17.8 ± 1.7	41 ± 2	19 ± 2	24 ± 1	16 ± 1	2.3 ± 0.1	1.8 ± 0.1
	Average[a]	*52*	*17.3 ± 1.0*	*42 ± 1*	*20 ± 1*	*24 ± 1*	*14 ± 1*	*2.1 ± 0.1*	*1.7 ± 0.1*

[a] Includes data from pool, run, and riffle.

The physical and bed material characteristics of the Upper Section and Lower Section were very similar (Figure 4.2.4).

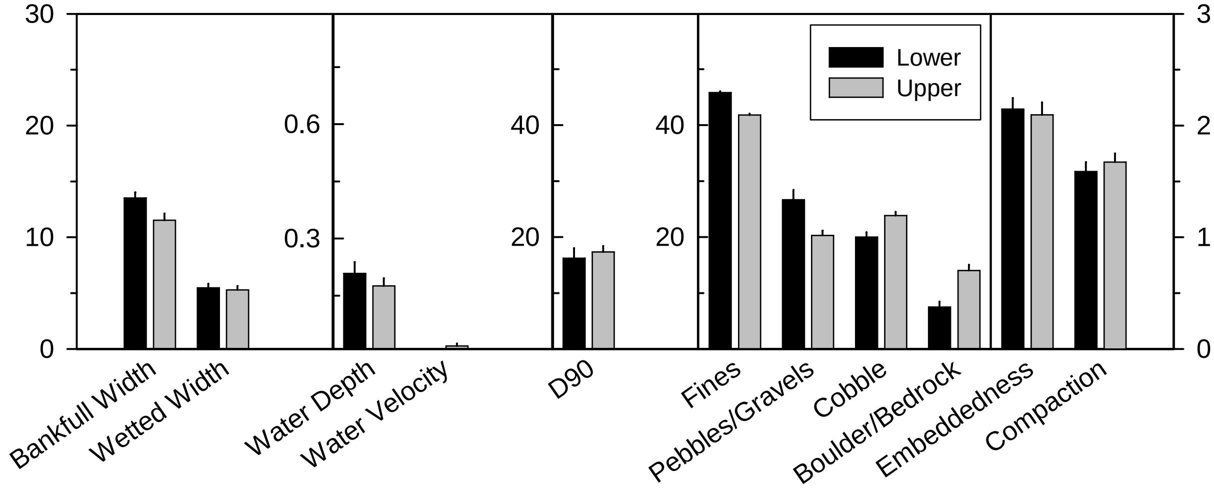


Figure 4.2.4 Physical and bed material characteristics (mean ± SE) of Lower and Upper sections of Cache Creek, 2008 tributaries juvenile fish summer survey (includes pool, run, and riffle data) (from Mainstream 2009c).

AMEC and LGL (2008a) presented a summary of habitat types inventoried in 2005 as follows:

Habitat Type	Percent by Length	
	Lower Area	Upper Area
Riffle	30.2	30.3
Pool	52.2	46.1
Run	16.6	19.2
Other		

4.2.1.5 Wilder Creek

Wilder Creek flows into the Peace River from the north approximately 12.5 km upstream of the Site C dam. Wilder Creek is deeply entrenched in a valley with 150 m high banks comprised of fines (ARL 1991a). During surveys by ARL (1991a) the stream consisted of shallow glide/riffle habitat with average depths of 0.03 m and pool depths of 0.2 m. Approximately 9 km upstream from the confluence, there was extensive beaver activity. AMEC and LGL (2008a) indicated that a shallow channel 5 m in width is present between the beaver ponds. Gravel substrates are present in Wilder Creek and may be utilized by spring spawning species. AMEC and LGL (2008a) characterized Wilder Creek as a small stream with a heavily aggraded channel, minimal surface flow, and no useful habitat for fish at the time of the fall survey. Mainstream (2009c) documented the same features during a survey in summer 2008. A survey of the stream in May 2008 recorded a discharge of 0.07 m^3/s (Mainstream 2009b).

AMEC and LGL (2008a) presented a summary of habitat types inventoried in 2005 as follows:

Habitat Type	Percent by Length	
	Lower Area	Upper Area
Riffle	59.2	70.5
Pool	10.2	
Run	20.4	29.5
Other	10.1	

4.2.3 Fish Habitats of Larger Tributaries

4.2.3.1 Halfway River

The Halfway River is the largest Peace River tributary in the technical study area upstream of the Site C dam. The watershed drains 9,402 km^2. The river originates at Robb Lake between Mount Robb and Mount Kenny in the Muskwa Range of the Rocky Mountains. From its headwaters, the river flows south for 303.6 km to the confluence with the Peace River approximately 40 km downstream of the town of Hudson's Hope. The watershed can be divided into four regions:

- The Lower Mainstem region of the Halfway River begins at the confluence of the Peace River and extends in a northerly direction along the front ranges of the Rocky Mountains.
- The Upper Mainstem region represents the headwater area of the Halfway River, the majority of which is located in mountainous terrain, and is oriented in an east-west direction.
- The Western Tributaries encompasses tributary drainages situated west and south of the mainstem Halfway River. It includes coldwater tributaries draining east from the foothills. Many of these tributaries have their headwaters located in mountain alpine areas. Major tributaries in this region include Ground Birch, Blue Grave, Kobes, and Cypress Creeks, and the Graham and Chowade Rivers.
- The Eastern Tributaries encompasses tributary drainages situated east of the mainstem Halfway River. It includes the Cameron River and its tributaries that drain the low, rolling foothills area.

Lower Mainstem Region

The main channel is wide (80 m to > 100 m) and is increasingly braided upstream (ARL 1991a). The Halfway River upstream of the Cameron River is a relatively unstable meandering channel containing clean rock substrates (Mainstream 2011a). The Halfway River downstream of the Cameron River is largely confined by steep valley walls and is influenced by sediment inputs from the Cameron River, bank erosion, and active valley wall slumping. There are no barriers to fish movement in the Lower Mainstem Region.

Upper Mainstem Region

Habitats in the Upper Mainstem region are generally characterized by riffles and pools with coarse granular substrates (Diversified Environmental Services 2002a). Side channel habitats and cobble margins provide juvenile rearing habitat, while runs and deep pools associated with large woody debris and bedrock provide holding and feeding habitat for adult salmonids (Diversified Environmental Services 2002a). Diversified Environmental Services (2002a) described a barrier to upstream fish movement at river Km 215.

Western Tributaries Region

Ground Birch Creek is a low-gradient, moderate turbidity drainage system that originates on plateau uplands (Diversified Environmental Services 2002b). The lower Ground Birch Creek is moderately incised but streams in the upper portion of the watershed are only slightly incised and typically have gradients of 1% to 2% (Diversified Environmental Services 2002b). The banks in Ground Birch Creek have a moderate degree of instability and erodibility, resulting in low to moderate levels of suspended solids and turbidity (Diversified Environmental Services 2002b).

Kobes Creek is a relatively wide, meandering channel with a low gradient and an average bankfull width of 30 m. The upper reaches of Kobes Creek has two main branches and below the confluence of these branches the gradient is low (0.4%) (LGL 2001).

The Graham River is a major tributary to the Halfway River. It is a moderate-gradient, low turbidity system. Near the mouth, the channel has an average width of 63 m and is occasionally confined between steep shale banks up to 40 m high (ARL 1991a). Upstream of Km 35, the river becomes entrenched and the average stream gradient increases gradually. Near Christina Falls (Km 87) the channel width is 25 m and the stream gradient is steep (ARL 1991a).

Horseshoe Creek is another low-gradient system which flows through a wide, flat-bottomed valley. The channel is occasionally confined by steep banks 20-30 m high (ARL 1991a). The channel width varies from 60 m at the mouth to 30 m 16 km upstream. High erosion on some of the banks results in abundant scattered debris (ARL 1991a).

Streams in the Blue Grave Creek upper watershed typically have a moderate gradient, low turbidity and appear to provide rearing habitat for juvenile sportfish (Diversified Environmental Services 1997a). Near the confluence, the river flows unconfined through a flat bottom valley. The channel width is 35 m. Further upstream, the channel width is 10 m and the banks are mostly flat and aggrading. Eroding banks were also reported in some areas (ARL 1991a).

The Chowade River is a major tributary to the Halfway River. It is a low to moderate gradient system with no major barriers to fish movement (Baxter, 1996). The channel is mostly unconfined and meanders over the valley bottom. Near the confluence, the channel is very unstable, the average channel width is 50 m, and eroding banks result in increased sediment load in the water (ARL 1991a). When moving upstream, the water is clearer and the river is mostly confined to one channel. At Km 42, the channel width was 15 m (ARL 1991a).

Cypress Creek is a moderate-gradient, low-turbidity system, flowing east from the Rocky Mountains. Fisheries values within the Cypress Creek watershed are considered high (Diversified Environmental Services, 1997a). In the lower section, the channel is 60 m wide, unconfined and frequently braided. Approximately 23 km upstream, the stream gradient increases slightly and the creek becomes confined to one channel. The channel width is 26 m. A series of 2-3 m falls is located near Km 45. Upstream of these falls, the creek splits in several channels in marsh habitat and is no longer well defined (ARL 1991a).

In the Western Inputs region, a large number of culverts are present on Ground Birch Creek, Kobes Creek, Blue Grave Creek, and in the Graham River system. These culverts may create a barrier to fish movement. Christina Falls located approximately 87 km upstream of the confluence with the Halfway River is the largest of three impassable barriers on the Graham River (Diversified Environmental Services 2002a). The other two barriers are located further upstream near Horn Creek. A 5 m fall is located on Cypress Creek approximately 46 km upstream of the confluence with the Halfway River (Diversified Environmental Services 2002b).

Eastern Tributaries Region

Habitats in the Eastern Tributaries were mostly riffle/pool and fines were the dominate substrate. A survey completed in 1998 on the Cameron River noted that stream banks and valley slopes were largely comprised of erodible materials with a moderate degree of natural instability (Diversified Environmental Services 1999b). Stream channels had substrates comprised of cobble and gravel with a significant proportion of fines and moderate beaver activity.

Mainstream (2011a) completed a survey during August 2010 of the mainstem Halfway River from the Chowade River to the confluence of the Peace River, which was distance of 128 km. Based on this assessment Mainstream (2011a) divided the surveyed river into four reaches.

Reach 1

Reach 1 (Km 0 to Km 12) represents the potential area of inundation by the proposed Site C reservoir. The physical characteristics of Reach 1 are similar to Reach 2; however, this section of river contains extended runs interspersed by short riffle/rapid sections containing boulders. Reach 1 contains similar habitats as Reach 2, but the effect of sedimentation on rock substrates is greater.

Reach 2

The upstream boundary of Reach 2 is the confluence of the Cameron River, which represents a major reach break. The Halfway River in this reach (Km 12 to Km 43) exhibits characteristics of a system affected by fine sediments. This reach receives sediment laden water from the Cameron River. It is largely confined by high valley walls and the river frequently abuts the valley walls resulting in bank erosion causing introduction of fine sediments. There also is a large active slump at Km 14 of this reach. Unlike upstream reaches, no permanent tributaries enter the Halfway River and side channels are much less abundant. The bed material in Reach 2 consists of cobbles, gravels, interspersed with sands and silts. The material typically is highly embedded in low velocity areas.

Reach 3

Reach 3 is located from Km 43 to Km 92, between the Graham River confluence and the Cameron River confluence. With the exception of being a larger system (due to inputs from the Graham River) and the presence of a short section dominated by bedrock sills immediately downstream of the Graham River, Reach 3 physical characteristics and fish habitats are similar to those recorded in Reach 4. This reach contained an abundance of rearing, feeding, and overwintering habitats for fish species found in the Halfway River.

Reach 4

Reach 4 (Km 92 to Km 128) includes the section of river between the confluence of the Chowade River and the confluence of the Graham River. Reach 4 represents a smaller watercourse than other reaches of the Halfway River because it is located upstream of the Graham River, which contributes a large amount of water to the system. Portions of the channel in Reach 4 are laterally unstable and the bed material is dominated by clean gravels and cobbles. This reach also contains several small named and unnamed tributaries. The dominant habitats in this reach are long runs interspersed with riffles, although there are numerous side channels that provide protected areas for rearing fish. This reach has the potential to provide high quality habitats for species such as Arctic grayling, bull trout, mountain whitefish, and rainbow trout (*Oncorynchus mykiss*).

AMEC and LGL (2008a) presented a summary of habitat types inventoried in 2005 as follows:

Habitat Type	**Percent by Length**	
	Lower Area	**Upper Area**
Riffle	9.2	20.7
Pool	20.1	21.2
Run	70.7	58.2
Other		

4.2.3.2 Moberly River

The Moberly River watershed is the second largest watershed upstream of the Site C dam. The watershed drains 1,833 km^2 and the mainstem is 213.4 km in length originating near Rosetta Ridge in the Rocky Mountains approximately 65 km west of Chetwynd. It flows east into a large waterbody known as Moberly Lake. Downstream of Moberly Lake, the river flows north east to its confluence with the Peace River immediately south of Fort St. John and immediately upstream of the proposed Site C dam. The Moberly River watershed can be divided into three regions:

- The Lower Mainstem region extends from the confluence with the Peace River to approximately 46 km upstream. This region is characterized by a higher stream gradient as the river incises the Peace River valley wall.
- The Middle Mainstem region extends from approximately 46 km upstream of the Peace River confluence to the outlet of Moberly Lake.
- The Upper Mainstem region includes Moberly Lake and the Moberly River upstream of Moberly Lake to the headwaters. The Moberly River in this region is known as West Moberly River.

Mainstream (2011a) completed a survey during August 2010 of the mainstem Moberly River from just downstream of Moberly Lake to the confluence of the Peace River, a distance of 116 km. Based on this assessment Mainstream (2011a) divided the surveyed river into four reaches.

<u>Reach 1A</u>

Reach 1A is a short section between the Peace River and Km 10, which includes the inundation zone of the proposed Site C reservoir. Channel characteristics in this reach are identical to Reach 1B. The river channel is unstable, there is large scale bank erosion, woody debris accumulations are common, and valley wall slumps are present. Similar to Reach 1B, the physical characteristics of Reach 1A generate a large amount of habitat complexity and several of the sampled sites were considered good quality habitat.

Reach 1B

Reach 1B represents a distinct transition from a stable singular channel in Reach 2, to a higher gradient, laterally unstable, braided channel located within an incised valley. Unlike Reaches 2, 3, and 4, extensive sections of the Moberly River in Reach 1B are unstable, exhibit large scale bank erosion, and contain numerous secondary channels. Woody debris accumulations are common in Reach 1B. Bed material also changes to small and medium sized cobble with boulders located in high velocity zones. These features become progressively more pronounced from upstream to downstream. One other feature that occurs in the lower section of Reach 1B, but is not present in Reaches 2, 3, and 4, is active valley wall slumping into the channel. Highly erodible materials of these slumps introduce sands and silts into the river during high flows. The physical characteristics of Reach 1B generated a large amount of habitat complexity and many of the sampled sites are considered good quality habitat for fluvial species.

Reach 2

The irregular channel in Reach 2, located between Km 43 and Km 81, traverses a valley floor dominated by mature forest. This reach exhibits a higher gradient than Reach 3 and contains extended runs interspersed with short riffle/rapid sections. Gravels and sands are the dominant bed material in the run sections, whereas cobbles and boulders are prominent in the riffle/rapid sections. Fish habitats potentially used by fluvial species such as Arctic grayling and mountain whitefish are widespread and abundant. Many areas sampled within this reach could be characterized as high quality, spawning, rearing, feeding, and overwintering habitats.

Reach 3

Reach 3, located between Km 81 to Km 101, is characterized by a well-defined, low gradient, meandering channel dominated by a sand bed. Short higher gradient sections characterized by riffle/runs and rock substrates also are present, but are infrequent. A unique feature of Reach 3 is the presence of numerous protected cutoff side channels containing emergent and submergent vegetation. These areas provide high quality spawning and rearing habitat for northern pike (*Esox lucius*).

Reach 4

Reach 4, the uppermost reach, exhibits a moderate gradient containing frequent riffle/rapid sections interspersed with flats and slow runs. The bed material is dominated by sand and gravels, but riffle/rapid contains an abundance of cobbles and small boulders. The reach also contains numerous small side channels. Many areas sampled within this reach could be characterized as high quality, spawning, rearing, feeding, and overwintering habitats for fluvial species such as Arctic grayling and mountain whitefish.

Mainstream 2011a also discussed the effects of a recent flood event on fish habitats, as follows. Superimposed on these general characteristics is the ongoing effect of a recent major flood event in June 2007. Field observations in 2008 (Mainstream 2009b,c) and 2009 (Mainstream 2010c) indicated substantial bank erosion and removal of mature woody vegetation from the riparian zone, which has resulted in deposition of large amounts of woody debris into the river channel and shifting of the river channel within the valley floor. Major disturbances by the flood were largely restricted to Reach 1, which has a high gradient. Upstream of this point (Reaches 2, 3, and 4) riparian vegetation was largely intact and most of the channel was stable**.** The effects of the 2007 flood were evident during the present study, and as such, continue to affect fish habitats of the Moberly River.

AMEC and LGL (2008a) presented a summary of habitat types inventoried in 2005 as follows:

Habitat Type	**Percent by Length**	
	Lower Area	**Upper Area**
Riffle	32.3	39.7
Pool	13.1	17.3
Run	40.8	33.6
Other	9.0	

4.2.3.3 Pine River

The Pine River is the second largest watershed in the study area, after the Beatton River. It drains 13,504 km^2 and has 4,499 tributary streams. The mainstem, which originates at Azouzetta Lake between Mount Murray and Azu Mountain, flows north west for 289.6 km to the confluence with the Peace River near the town of Taylor. The Pine River confluence is approximately 16 km downstream of the proposed Site C dam.

The Pine River watershed can be divided into three regions:

- The Lower Mainstem region extends from the confluence with the Peace River to the mouth of the Murray River, approximately 90 km upstream.

- The Upper Mainstem region extends from the mouth of the Murray River to the headwaters. Larger tributaries in the region include Lemoray Creek, Falling Creek, Halser Creek, Beaudette Creek, the Sukunka River, and the Burnt River.
- The Eastern Tributaries region includes the Murray River and its tributaries.

In the Upper Mainstem region, the Pine River meanders within a well-defined channel through actively eroding cut banks (AGRA 1997, AXYS *et al.* 1994). Lemoray Creek, Falling Creek, and Halser Creek generally flow from V-shaped valleys at higher elevations to U-shaped valleys in the mid to lower elevations and lastly, through the Pine River flood plain (Hatfield Consultants Ltd. 1999). In the East Inputs region, the southern and western portions of the lower Murray River and associated tributaries flow through low-lying foothills with forested ridges (Diversified Environmental Services 2002d). In the north and east, the foothills change to a flatter topography of the Alberta Plateau. The upper Murray River and associated tributaries are partially or completely confined and flow through mountainous regions and high foothills.

Within the Lower Mainstem region, Stewart Creek is the largest tributary. The general morphology of Stewart Creek is confined, with cobbles in riffle/pool complexes (AXYS 1998). A number of hill slope failures were recorded throughout the Stewart Creek watershed resulting in increased sediment load in the creek.

The Upper Mainstem region is complex and contains braided channels, debris jams, overhanging vegetation and riffle/pool areas with clean pebble/cobble substrate (AGRA 1997, AXYS *et al.* 1994). The Sukunka River is a major tributary to the Pine River. In the lower reaches of the Sukunka River watershed, Dickebusch Creek and Zonnebeke Creek provide the majority of salmonid rearing and spawning habitat in the watershed (Hatfield Consultants Ltd. 1999). Both creeks have riffle/pool and step pool habitats and a variety of cover and substrates. Smaller tributaries in the lower Sukunka River have poor quality habitat for fish (Hatfield Consultants Ltd. 1999).

The overview identified several barriers to fish movement in the Pine River watershed, especially in the Upper Mainstem and East Inputs regions. Persistent debris is the dominant barrier type found in the watershed. Falls and cascades are also numerous and are typically found on the lower reaches of small tributaries.

Of note is the 60 m Kinuseo Falls located on the Murray River mainstem approximately 150 km upstream of the mouth, which separates the upper and lower fish communities of the Murray River.

4.2.3.4 Beatton River

The Beatton River is a low-gradient system that drains the Alberta plateau uplands east of the Rocky Mountain Foothills. The river originates at Lily Lake near Pink Mountain and flows 500 km east and then south to the confluence with the Peace River, 19 km downstream of the town of Taylor and 37 km downstream of the proposed Site C dam. The Beatton River watershed is the largest in the study area, covering 14,266 km^2.

The Beatton River basin can be divided into five regions:

- The Lower Mainstem region extends from the confluence with the Peace River to the mouth of Blueberry River, which is the largest tributary in the watershed.
- The Middle Mainstem region extends from the Blueberry River confluence to approximately 80 km upstream where the Beatton River enters the foothills of the mountains.
- The Upper Mainstem region extends to the headwaters.
- The Eastern Tributaries region includes the Doig River, Milligan Creek, Big Arrow Creek, Black Creek, and their tributaries
- The Western Tributaries region includes Montney Creek, the Blueberry River, Nig Creek, and their tributaries.

The Beatton River watershed is largely dominated by forest; however agriculture is a prominent land use in the Lower Mainstem and West Inputs regions. The Middle Mainstem and East Inputs regions have less agriculture and contain more wetland area. The Upper Mainstem region contains the least amount of anthropogenic land use.

Habitat data have not been collected in the Lower and Middle mainstem regions. Upper Mainstem regions data was collected by Diversified Environmental Services (2001). The Beaton River is relatively large with low gradient and meandering channel. Tributaries typically originate on well-drained, undulating plateau topography and have incised channels with gradients of 1% to 5%. Stream banks and valley slopes have high instability resulting in slumps and associated high total suspended solids. No macro habitat information exists for the East Inputs region.

Mesohabitat information for the Upper Mainstem region was described by Diversified Environmental Services (2001) as riffle/pool habitat with rearing cover provided by deep pools and large woody debris. Substrates consisted of cobbles and gravel with a significant portion of fines, which result in moderate to high turbidity. Bratland Creek was described as low to moderate gradient with high potential for Arctic grayling spawning and rearing habitat. In the Eastern Inputs region, Milligan Creek contained moderate-gradient, riffle/pool habitats with granular substrates, which offered spawning and seasonal rearing habitat suitable for Arctic grayling. The Beatton River mainstem contained riffle/pool habitat in a moderately incised channel to a point south west of Chinchaga Lakes, where the gradient decreases and is less confined. In the Western Region inputs the mainstem stream bed substrates are generally composed of cobble and gravel with significant proportion of fines. Habitat consists of riffle/pool complexes with rearing cover provided by deep pools, large woody debris, and high turbidity (Diversified Environmental Services 2002e).

No major barriers to fish movement have been recorded along the mainstem Beatton River. Barriers to fish movement generally consist of beaver dams, which are found throughout the upper watershed.

4.2.3.5 Kiskatinaw River

The Kiskatinaw River originates at Bearhole Lake in the foothills of the Rocky Mountains and flows 305 km north to the confluence with the Peace River. The confluence is located approximately 52 km downstream of the proposed Site C dam. The Kiskatinaw River watershed covers 4,097 km^2 and has 776 tributary streams.

The Kiskatinaw River watershed can be divided into four regions:

- The Lower Mainstem region extends from the confluence with the Peace River to approximately 60 km upstream (5 km upstream of the Highway 97 bridge), at the Peace River valley wall.
- The Middle Mainstem region lies between the edge of the Peace River valley wall and the confluence of the West Kiskatinaw River.
- The Upper East region includes the Kiskatinaw River and its tributaries.
- The Upper West region includes the West Kiskatinaw River and its tributaries.

In the Lower Mainstem region, the Kiskatinaw River is deeply incised in the Peace River valley wall creating a canyon in some sections. In the Middle Mainstem region, the river channel is characterized by tortuous meanders. No macro habitat information was available for the Upper East and Upper West regions. No mesohabitat data were available for the Lower and Middle Mainstem and Upper East regions. The middle and lower reaches in the tributaries to Kiskatinaw River and West Kiskatinaw River contain good spawning and rearing habitats for rainbow trout. Only the largest of streams provide adequate water levels and slopes for fish, although these feeder streams may be utilized by spawning rainbow trout at higher water levels in spring (Hatfield Consultants Ltd. 1998). Oetata Creek, which flows from west to east into the Kiskatinaw River, was characterized as meandering and turbid and well suited to coarse fish species. The inventory studies completed by Hatfield Consultants Ltd. (1998) resulted in a large capture of cyprinids. The steeper tributaries to Oetata Creek may provide better habitats for sportfish, but neither the 1997 nor previous work indicated the presence of sportfish species (Hatfield Consultants Ltd. 1998).

There are a number of barriers to fish movement in the Kiskatinaw River watershed. Of note is a weir used by the City of Dawson Creek. The weir contains a fishway to facilitate fish passage, but its condition and effectiveness are not known.

4.2.4 Riparian Areas

Assessments of riparian areas (vegetation type and stage) were completed by AMEC 2008 and LGL (2008a) in 2005 as part of the fish and habitat tributary studies program. Riparian area assessments were completed on Maurice Creek, Lynx Creek, Farrell Creek, Halfway River, Cache Creek, Wilder Creek, and Moberly River.

In 2011, MacInnis *et al.* (2011) completed Year 1 of the Peace River Riparian Habitat Assessment. The purpose was to assess the current state of riparian habitats along the Peace River from the Peace Canyon Dam downstream to the confluence of the Pine River. The study area included the lower sections of Peace River tributaries. The project was completed under the direction of Water License Requirements as specified by the Peace Water Use Plan: the Peace Spill Protocol and the Peace Flood Pulse Plan (BC Hydro 2007). The results of the project will create a baseline inventory of riparian habitats that can be used to assess distributions of riparian vegetation.

The results of the study were discussed by MacInnis *et al.* (2011) as follows:

A total of 32 riparian habitat classes were identified in the study area from photo interpretation. Habitat classifications included unvegetated, herbaceous and shrub cover, anthropogenic modification, wetland, standing water, and deciduous and coniferous forest types. A subset of habitat classes are widespread and compose most of the riparian habitat in the study area. The remaining habitat classes tend to be smaller polygons sparsely distributed throughout the study area. A general trend in the distribution of habitat classes was observed from the river’s edge to upland areas during photo interpretation. The polygons closest to the water were usually identified as mineral (gravel, etc.), followed by an herbaceous polygon, then a shrub-dominant polygon, transitioning eventually to the forest edge.

5.0 FISH COMMUNITY

5.1 SPECIES PRESENT IN STUDY AREA

5.1.1 Regulatory and Social Status

In total, 32 fish species have been recorded in the technical study area (Table 5.1.1).

Table 5.1.1 Fish species recorded in the technical study area and their provincial status.

Group	Species			Provincial Status	
	Common Name	Latin Name	Label	B.C.[a]	AB[b]
Sportfish (cold-clear water)	Arctic grayling	*Thymallus arcticus*	GR	Yellow	Sensitive
	Bull trout	*Salvelinus confluentus*	BT	Blue	Sensitive
	Brook trout	*Salvelinus fontinalis*	AEB	Exotic	Exotic
	Kokanee	*Oncorhynchus nerka*	KO	Yellow	Not assessed
	Lake whitefish	*Coregonus clupeaformis*	LT	Yellow	Secure
	Lake trout	*Salvelinus namaycush*	LW	Yellow	Sensitive
	Mountain whitefish	*Prosopium williamsoni*	MW	Yellow	Secure
	Pygmy whitefish	*Prosopium coulteri*	PW	Yellow	May be at risk
	Rainbow trout	*Oncorhynchus mykiss*	RB	Yellow	At risk
Sportfish (cool-turbid water)	Burbot	*Lota lota*	BB	Yellow	Secure
	Goldeye	*Hiodon alosoides*	GE	Blue	Secure
	Northern pike	*Esox lucius*	NP	Yellow	Secure
	Yellow perch	*Perca flavescens*	~~W~~YP	Yellow	Secure
	Walleye	*Sander vitreus*	~~Y~~WP	Yellow	Secure
Suckers	Largescale sucker	*Catostomus macrocheilus*	CSU	Yellow	Sensitive
	Longnose sucker	*Catostomus catostomus*	LSU	Yellow	Secure
	White sucker	*Catostomus commersoni*	WSC	Yellow	Secure
Minnows	Brook stickleback	*Culea inconstans*	BSB	Yellow	Secure
	Finescale dace	*Chrosomus neogaeus*	FDC	Unknown	Undetermined
	Flathead chub	*Platygobio gracilis*	FHC	Yellow	Secure
	Lake chub	*Couesius plumbeus*	LKC	Yellow	Secure
	Longnose dace	*Rhinichthys cataractae*	LNC	Yellow	Secure
	Northern pikeminnow	*Ptychocheilus oregonensis*	NSC	Yellow	Sensitive
	Northern redbelly dace	*Phoxinus eos*	RDC	Unknown	Sensitive
	Peamouth	*Mylcheilus caurinus*	PCC	Yellow	
	Pearl dace	*Margariscus margarita*	PDC	Blue	Undetermined
	Redside shiner	*Richardsonius balteatus*	RSC	Yellow	Secure
	Spottail shiner	*Notropis hudsonius*	STC	Red	Secure
	Trout-perch	*Percopsis omiscomaycus*	TP	Yellow	Secure
Sculpins	Prickly sculpin	*Cottus asper*	CAS	Yellow	Not assessed
	Slimy sculpin	*Cottus cognatus*	CCG	Yellow	Secure
	Spoonhead sculpin	*Cottus ricei*	CRI	Yellow	May be at risk

[a] Red - Indigenous species or subspecies that have- or are candidates for- Extirpated, Endangered, or Threatened status.
Blue - Indigenous species or subspecies considered to be of Special Concern.
Yellow - Species that are apparently secure and not at risk of extinction.
Unknown - Designation highlights species where more inventory and/or data gathering is needed
Exotic - Species that have been moved beyond their natural range as a result of human activity.

None of the 32 species are officially listed as endangered, threatened, or a special concern under Schedule 1 of *SARA*, or are being considered for official listing under Schedule 2 or 3 of *SARA*.[1]

Although B.C. and Alberta have strategies and legislation designed to protect fish species, neither province has specialized endangered species legislation. Species are assigned special protection based on the findings of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). In 2003, the federal *Species at Risk Act (SARA)* was proclaimed and COSEWIC was established as an advisory body. Under SARA, the federal government takes COSEWIC's designations into consideration when establishing the legal list of wildlife species at risk. B.C. and Alberta are represented on COSEWIC and therefore participate in species designation under COSEWIC.

In B.C., the Conservation Framework (CF) provides a set of science-based tools and actions for conserving species and ecosystems in B.C. The Conservation Data Center (CDC) maintains a database of species and ecosystems of concern.

In British Columbia, of the 32 fish species found in the technical study area one species is listed as "red" (endangered or threatened); spottail shiner (*Notropis hudsonius*), and three are listed as "blue" (special concern); bull trout, goldeye (*Hiodon alosoides*), and pearl dace (*Margariscus margarita*). (http://a100.gov.bc.ca/pub/eswp/; 30-Sep-12) The remaining species are designated as "yellow", described as secure and not at risk of extinction.

The species at risk program in Alberta is described in the document *Alberta's Strategy for the Management of Species at Risk (2009 – 2014).* (http://www.srd.alberta.ca/FishWildlife/SpeciesAtRisk/AlbertasSpeciesAtRiskStrategy/Default.aspx; 30-Sep-12). Alberta takes an active role in The Committee for the Recovery of Nationally Endangered Wildlife (RENEW), which was established in order to comply with the United Nations Conservation on Biological Diversity of 1992. SARA applies to lands under federal jurisdiction. In Alberta, the Wildlife Act remains the dominant legislation for management of species at risk. Alberta uses different nomenclature to describe species designations under COSEWIC, than does B.C. Regardless, the designations are based on the same system, that of COSEWIC.

In Alberta, of the 32 fish species found in the technical study area two are identified as "may be at risk" -- pygmy whitefish (*Prosopium coulterii*) and spoonhead sculpin (*Cottus ricei*). A total of 6 species have "sensitive" designations including; bull trout, Arctic grayling, lake trout (*Salvelinus namaycush*), brook

[1] *http://www.sararegistry.gc.ca/sar/listing/default_e.cfm; 30* September, 2012

stickleback (*Culea inconstans),* northern pikeminnow (*Ptychocheilus oregonensis),* and northern redbelly dace (*Phoxinus eos*). The rainbow trout designation as "at risk" refers to the Athabasca River population. The remaining fish species are "secure", "not assessed", or "not determined".

The DRAFT Fish, Wildlife and Ecosystem Resources and Objectives for the Lower Peace River Watershed Site C Project Area (B.C. Government 2011) identified six Indicator Species that are useful to monitor the environmental sustainability and ecological integrity of Key Values. The following lists the six species and the reasons for selection that were provided by B.C. Government (2011).

Species		**Reasons for Selection as Indicator**
Common Name	**Scientific name**	
Arctic grayling	*Thymallus arcticus*	• high value target for anglers; sensitive to harvest pressure • relatively well studied within Lower Peace River Watershed and elsewhere • representative of cool/cold water fauna; very sensitive to habitat degradation • representative of Beringia origin[a]
Bull trout	*Salvelinus confluentus*	• high value target for anglers • relatively well studied within Lower Peace River Watershed and elsewhere • representative of cold water fauna; highly migratory; noteworthy headwater populations; not tolerant of high turbidity; global level conservation concerns; top predator • representative of Pacific origin[a]
Burbot	*Lota lota*	• high value target for anglers • not well studied within Lower Peace River Watershed and elsewhere • representative of cool/coldwater fauna; tolerant of turbidity; omnivore • representative of Pacific, Beringia and Great Plains origins[a]
Goldeye	*Hiodon alosoides*	• not well studied within Lower Peace River Watershed and elsewhere • representative of coolwater fauna; tolerant of turbidity; highly migratory • representative of Great Plains origin[a]
Mountain whitefish	*Prosopium williamsoni*	• relatively well studied within Lower Peace River Watershed and elsewhere • representative of cold water fauna; not tolerant of turbidity • an important insectivore prey species for piscivorous fish • representative of Pacific origin[a]
Rainbow trout	*Oncorhynchus mykiss*	• high value target for anglers • relatively well studied within Lower Peace River Watershed and elsewhere • representative of cool/coldwater fauna; not tolerant of turbidity • representative of Pacific and Beringia origins[a]
Walleye	*Sander vitreus*	• high value target for anglers • relatively well studied within Lower Peace River Watershed and elsewhere • representative of warm/coolwater fauna; tolerant of turbidity; highly migratory • representative of Great Plains origins[a]

[a] Refers to location(s) of ice-free refugia during the last glaciation from which the species is thought to have originated (McPhail 2007).

The 32 species can be grouped based on environmental requirements and social value (i.e., traditional, commercial, or recreational use). The sportfish group consists of fourteen species that have traditional/commercial/recreational value. The group includes nine species that typically inhabit cold, clear water environments (subsequently referred to as coldwater sportfish) and five species that typically are more tolerant of warmer water temperatures and turbid water environments (subsequently referred to as coolwater sportfish).

The sucker group includes three species that have traditional value. All three species are tolerant of a broad range of environmental conditions and are typically found in a large number of fish habitats (McPhail 2007) (subsequently referred to as suckers).

The minnows group consists of twelve species, the trout-perch (*Percopsis omiscomaycus)* (Family Percopsidae), the brook stickleback (Family Gasterosteida) and ten species of true minnows (Family Cyprinidae) (subsequently referred to as minnows). Fish in this group typically are small (i.e., < 200 mm length) and are forage for larger fish species. The only exception to this description are northern pikeminnow that can attain sizes up to 600 mm in the study area. The final category includes the sculpin group that consists of three species; prickly sculpin (*Cottus asper*), slimy sculpin (*Cottus cognatus*), and spoonhead sculpin (subsequently referred to as sculpins).

5.1.2 Ecological Status

The technical study area fish community can be divided in two categories based on maximum fish size – large and small-fish species (Table 5.1.2). Large-fish species generally attain a length of at least 200 mm at maturity, but are also represented by smaller age classes (i.e., young-of-the-year and juveniles). The large-fish category in the study area includes sportfish and suckers. In the small-fish group, all age classes are typically smaller than 150 mm. The only exception to this description is northern pikeminnow in the minnows group. This category includes minnows and sculpins.

The rationale for the size distinction relates to the relative difference between large-fish species and small-fish species in their ability to move extended distances. Adults of large-fish species are capable of migrating large distances. Given their small size, small-fish species typically undertake much smaller movements. The exception to this statement is downstream dispersal of small-fish species, which can involve large distances.

The ecological status (i.e., importance to the fish community) of fish species recorded in the technical study area can be categorized based on general patterns of distribution and abundance (Table 5.1.2). Seven species are incidental to the technical study area fish community. They were rarely or never present in recent fish collections.

Table 5.1.2 Fish species size categories and numerical status in the technical study area and downstream into Alberta.

Category	Group	Species	Numerical Status in technical study area and Alberta Peace River to Many Islands[a,b]			
			British Columbia		Alberta	
			Peace R.	Tribs.	Peace R.	Tribs.
Large-fish	Sportfish (cold/clear water)	Arctic grayling	S	R	I	I
		Bull trout	A	R	R	I
		Brook trout	I	I	I	I
		Kokanee	R	I	I	I
		Lake whitefish	S	I	R	I
		Lake trout	R	I	I	I
		Mountain whitefish	A	A	A	I
		Pygmy whitefish	I	I	I	I
		Rainbow trout	A	R	I	I
	Sportfish (cool/turbid water)	Burbot	S	R	A	A
		Goldeye	R	R	A	I
		Northern pike	R	R	A	A
		Yellow perch	R	I	I	I
		Walleye	R	R	A	A
	Suckers	Largescale sucker	A	A	A	A
		Longnose sucker	A	A	A	A
		White sucker	R	R	R	R
Small-fish	Minnows	Brook stickleback	I	I	I	I
		Finescale dace	I	I	I	I
		Flathead chub	R	R	A	A
		Lake chub	R	A	A	A
		Longnose dace	A	A	A	A
		Northern pikeminnow	R	A	I	I
		Northern redbelly dace	I	I	I	I
		Peamouth	I	I	I	I
		Pearl dace	I	I	I	I
		Redside shiner	A	A	A	A
		Spottail shiner	R	R	A	A
		Trout-perch	R	R	A	A
	Sculpins	Prickly sculpin	A	A	I	I
		Slimy sculpin	A	A	R	R
		Spoonhead sculpin	R	R	A	A

[a] Many Islands area located 59 km downstream of B.C./AB boundary.
[b] I - Incidental (rarely or not encountered).
S - Scarce (limited to a few areas and not abundant).
R - Restricted (restricted distribution but can be abundant).
A - Abundant (widespread and abundant).

These species include brook trout (*Salvelinus fontinalis*) that may have originated from hatchery fish stocked in Inga Lake, which is a headwater source of Cache Creek via Coplin Creek (Province of British Columbia 2010), pygmy whitefish, which is thought to originate from the Williston Reservoir watershed (McPhail and Zemlak 2001), brook stickleback, finescale dace (*Phoxinus neogaeus*), northern redbelly dace, and pearl dace, which may be present throughout the study area, but were not prevalent in sampled watercourses. Peamouth (*Mylocheilus caurinus*) which is abundant in Dinosaur Reservoir (Diversified and Mainstream 2011a), is rarely encountered downstream of the Peace Canyon Dam.

The relative importance of a number of species in the technical study area can be spatially stratified based on the provincial boundary. Most of the nine coldwater water sportfish species are numerically important on the British Columbia side and not on the Alberta side. The only exception is mountain whitefish. In contrast, all five of the coolwater water species are restricted within the British Columbia portion of the study area, but most (all but yellow perch, *Perca flavescens*) are prominent in the Alberta portion of the study area. In the suckers group, longnose suckers (*Catostomus catostomus*) and largescale sucker (*Catostomus macrocheilus*), are widespread and abundant throughout the study area.

The same pattern that has been observed for sportfish can be seen for most species in the sculpin group versus most species in the minnows group. Sculpins tend to be more widespread and abundant in British Columbia than in Alberta and the reverse is true for minnows. Exceptions to this pattern include increased prevalence of spoonhead sculpin in Alberta and the widespread importance of longnose dace (*Rhinichthys cataractae*) and redside shiner (*Richardsonius balteatus*) in both the British Columbia and Alberta portions of the technical study area.

The fish community in the Peace River can be divided into three general fish assemblages based on habitat requirements: cold-clear water (11 species), cool-turbid water (16 species), and unique (5 species).

The cold-clear water fish assemblage, which consists of primarily of salmonid (trout and whitefish) and cottid (sculpins) species, dominates the fish community in the mainstem river within the study area. Mountain whitefish is the numerically dominant and most widespread large-fish species in this assemblage, while slimy sculpin is the most numerically important species in the small-fish group. Populations in this group are found in side channels and in near-shore areas along channel margins in the mainstem river. They are very flexible in their habitat needs. If appropriate conditions are present, either in side channels or the mainstem, species in this group likely will utilize these habitats.

The cool-turbid water fish assemblage contains a diverse group of large-fish and small-fish species that reside in the mainstem river, but most of these fish are largely restricted to tributary confluence areas and/or the lower portion of the study area (i.e., downstream of the Pine River confluence). The only exceptions to this pattern are redside shiners, which are abundant and widely distributed throughout the study area. The restricted distribution of most cool-turbid water species is largely due to the requirement for warmer water temperatures and low water clarity. For example, populations of goldeye and walleye reside primarily downstream of the Pine River, but will use habitats upstream of the Pine River confluence opportunistically if appropriate conditions exist (i.e., warm water and high turbidity). Others such as suckers, northern pikeminnow, and most of the minnow species rely heavily on tributaries to provide appropriate habitats, and therefore, do not venture far from these focal points. Despite the restricted distribution of most species, side channels are the preferred habitat when they are available, but near-shore areas along channel margins in the mainstem river can also be used.

The unique fish assemblage represents five species that are almost entirely restricted to side channels (i.e., lake whitefish, northern pike, yellow perch, white sucker, and spottail shiner). All occur in a select number of side channels that exhibit specific physical characteristics. The side channel must be sheltered from high water velocities (i.e., one inlet at the downstream end), have low water turbidity during much of the year, and support growth of aquatic vegetation. These side channel habitats are restricted in distribution; therefore, the unique fish populations that rely on them are also restricted in distribution.

5.2 PEACE RIVER

Fish inventories were completed on the Peace River in 2009 (Mainstream 2010a), 2010 (Mainstream 2011f), and 2011 (Mainstream 2012a). The purpose of the studies was to collect baseline information to describe the fish community in the Peace River study area. The studies used several fish capture methods in a variety of fish habitats during three seasons. The studies examined environmental conditions, fish community structure, catch rate, population characteristics, and fish health. Sample methods included large fish boat electrofisher, small fish boat electrofisher, gill net, backpack electrofisher, and beach seine. The following summarizes the results of that work.

The study area extended from the Peace Canyon Dam to as far downstream as 63 km downstream of the British Columbia/Alberta boundary and included a total of nine sections (Table 5.2.1, Figure 5.2.1). Study sections in Alberta were added to the program each year as follows: 2009 – 0 sections, 2010 – one section, 2011 – 2 sections. For analytical purposes, sections were grouped into one of two zones relative to the position of the Site C dam – Zone 1 (Upstream) and Zone 2 (Downstream).

Table 5.2.1 Study area zones and sections, Peace River Fish Inventory studies (from Mainstream 2010a, 2011f, 2012a).

Zone[a]	Section	Section Location	Section Location[b] (km)
1 Upstream	1A	Peace River Canyon area	Km 150.0 to 145.2
	1	Maurice Creek area	Km 137.0 to 145.2
	2	Farrell Creek area	Km 119.7 to 125.2
	3	Halfway River area	Km 89.8 to 99.2
2 Downstream	5	Moberly River area[c]	Km 53.4 to 64.8
	6	Pine River area	Km 46.8 to 35.7
	7	Beatton River area	Km 26.7 to 13.6
	8	Pouce Coupe River area	Km -6.0 to -20.4
	9	Many Islands area	Km -50.5 to -63.2

[a] Position relative to proposed Site C dam.
[b] Based on distance from British Columbia/Alberta boundary.
[c] A small portion of Section 5 is located upstream of proposed Site C dam location (see Appendix A, Figures A5A and A5B in Mainstream 2011f).

Four criteria were used to determine the section boundaries. They included good spatial coverage of the study area, representation of major reaches, representation of major tributary confluences, and inclusion of previously sampled sites.

Sampling occurred in three major habitats described by RL&L (2001) and P&E (2002) as follows:

Main channel - Portion of active channel that is permanently wetted and that is characterized by moving water under the typical flow regime, and the dominance of rock (i.e., gravel, pebble, cobble, boulder, and/or bedrock) bed materials. This includes the thalweg channel and smaller channels that exhibit similar characteristics.

Side channel - Portion of the active channel that is permanently wetted and that is characterized by slow moving or still water under the typical flow regime, and the presence of silt and sand bed materials. Includes channels protected from the main river flow that exhibit unique features such as standing water and emergent/submergent vegetation.

Tributary confluence - Portion of the tributary confluence that is within the immediate influence of the Peace River flow regime. The habitat can be divided into the tributary channel proper and the confluence zone within the active Peace River channel. The confluence zone includes an upstream area that exhibits higher water velocities and is dominated by rock bed materials (i.e., riffle section) and a downstream area that exhibits low water velocities and bed materials dominated by silts and sands (i.e., backwater section).

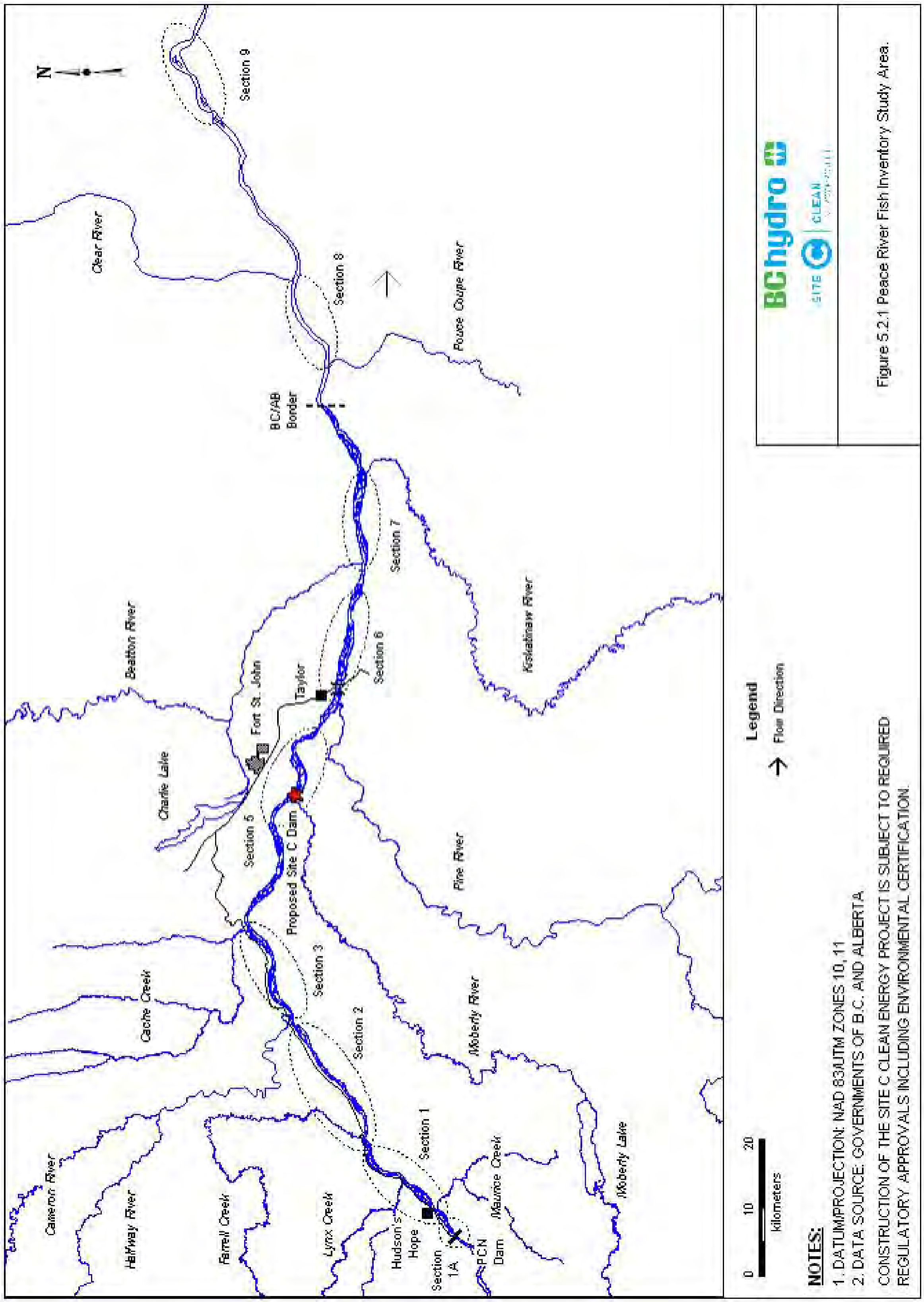


Figure 5.2.1 Peace River Fish Inventory Study Area.

5.2.1 Species Composition

Information from Mainstream 2010a, 2011f, 2012a demonstrated consistent patterns in species composition. The numerically dominant fish species in the coldwater sportfish group and the most numerous fish recorded during the study was mountain whitefish (Table 5.2.2).

Table 5.2.2 Composition of enumerated fish species, Peace River Fish Inventory (all capture methods and sample events combined) (from Mainstream 2010a, 2011f, 2012a).

Group	Species	2009 2		010		2011	
		Total	Percent	Total	Percent	Total	Percent
Sportfish (coldwater)	Arctic grayling	337	1.4	272	0.5	135	0.3
	Bull trout	302	1.3	285	0.6	247	0.5
	Kokanee	173	0.7	537	1.1	234	0.5
	Lake trout	6	*< 0.1*	2	< 0.1	9	< 0.1
	Lake whitefish	16	0.1	31	0.1	54	0.1
	Mountain whitefish	13,167	56.1	21,023	42.3	15,253	29.8
	Pygmy whitefish	0		1	< 0.1	0	
	Rainbow trout	502	2.1	285	0.6	356	0.7
	Subtotal	*14,503*	*61.8*	*22,436*	*45.1*	*16,288*	*31.8*
Sportfish (coolwater)	Burbot	45	0.2	51	0.1	170	0.3
	Goldeye	37	0.2	82	0.2	49	0.1
	Northern pike	190	0.8	338	0.7	200	0.4
	Walleye	107	0.5	332	0.7	322	0.6
	Yellow perch	158	0.7	635	1.3	131	0.3
	Subtotal	*537*	*2.3*	1,438	*2.9*	*872*	*1.7*
Suckers	Largescale sucker	870	3.7	1,085	2.2	1,054	2.1
	Longnose sucker	2,691	11.5	4,165	8.4	7,214	14.1
	White sucker	299	1.3	271	0.5	278	0.5
	Subtotal	*3,860*	*16.4*	*5,521*	*11.1*	*8,546*	*16.7*
Sculpins	Prickly sculpin	377	1.6	256	0.5	154	0.3
	Slimy sculpin	929	4.0	1,517	3.1	3,113	6.1
	Spoonhead sculpin	5	*< 0.1*	3	< 0.1	47	0.1
	Subtotal	*1,311*	*5.6*	*1,776*	3.6	*3,314*	*6.5*
Minnows[b]	Brook stickleback	1	*< 0.1*	1	< 0.1	1	< 0.1
	Finescale dace	21	0.1	2	< 0.1	3	< 0.1
	Flathead chub	141	0.6	272	0.5	609	1.2
	Lake chub	491	2.1	5,531	11.1	2,988	5.8
	Longnose dace	345	1.5	2,170	4.4	3,701	7.2
	Northern pikeminnow	285	1.2	620	1.2	1,438	2.8
	Northern redbelly dace	5	*< 0.1*	10	< 0.1	11	< 0.1
	Peamouth	2	*< 0.1*	2	< 0.1	2	< 0.1
	Pearl dace	2	*< 0.1*	0		3	< 0.1
	Redside shiner	1,331	5.7	6,935	14.0	10,767	21.0
	Spottail shiner	287	1.2	2,386	4.8	1,476	2.9
	Trout-perch	344	1.5	603	1.2	1,223	2.4
	Subtotal	*3,255*	*13.9*	*18,532*	*37.3*	*22,222*	*43.4*
Total		**23,466**	**100.0 4**	**9,703**	**100.0 5**	**1,242**	**100.0**

[a] Includes true minnows (Family Cyprinidae), trout-perch (Family Percopsidae) and sticklebacks (Family Gasterosteidae).

The next most numerically important coldwater sportfish species were rainbow trout, bull trout, and Arctic grayling. In 2010, kokanee (*Oncorhynchus nerka*) was also a prominent coldwater sportfish. All other coldwater sportfish were scarce. These included lake trout, lake whitefish (*Coregonus clupeaformis*), and pygmy whitefish. Overall coolwater sportfish were less abundant than coldwater sportfish.

The numerically dominant fish species in the coolwater sportfish group were northern pike, walleye (*Sander vitreus*), and yellow perch. The two remaining coolwater sportfish, burbot and goldeye were less numerous. An exception to this trend was burbot in 2011. Burbot numbers were higher in 2011 due to expansion of the study area downstream to Many Islands, Alberta. This region contains habitats that are known to support burbot elsewhere in the Peace River (Mainstream 2010e).

Longnose sucker was the numerically dominant species in the sucker group followed by largescale sucker and white sucker (*Catostomus commersonii*). Slimy sculpin was the numerically dominant species in the sculpins group followed by prickly sculpin. Spoonhead sculpin were scarce, except in 2011, when the study area extended downstream to Many Islands, Alberta

Redside shiner was the numerically dominant species in the minnow group. Lake chub (*Couesius plumbeus*), longnose dace, spottail shiner, and northern pikeminnow were well represented. The importance of trout-perch and flathead chub (*Platygobio gracilis*) increased from year to year as the study area expanded downstream into Alberta. Each of the remaining species in this group, which included brook stickleback, finescale dace, northern redbelly dace, and peamouth were scarce.

A comparison to historical data collected in 1989 by Pattenden *et al.* 1990 suggests a shift in species composition between the late 1980s and the present (Table 5.2.3). That study employed boat electrofisher to survey the large-fish community during three seasons in an area similar to work completed in 2009 by Mainstream (2010a).

The total number of fish collected was similar (12,132 fish in 1989 versus 13,420 fish in 2009). In both sets of data, mountain whitefish numerically dominated. Species such kokanee, northern pike, largescale sucker, and white sucker were present, but did not represent a large percentage of the catch. Species such as lake trout, burbot, and goldeye were scarce.

In the coldwater sportfish group there was a substantial decline in the contribution of Arctic grayling between 1989 and 2009 (5.7% to 1.5%). Lake whitefish exhibited a large decline since 1989 (it is largely absent from the 2009 boat electrofisher catch (4.0% to 0.1%). Rainbow trout also dropped from 4.2% to 2.2%. At the same time bull trout increased from 0.8% of the catch to 2.8% of the catch. In the coolwater sportfish group walleye exhibited a large decline (68.9% to 31.0%) and burbot exhibited a large increase (2.2% to 15.0%).

There are several reasons for these differences. One reason may simply be annual variation in abundance; however, results of other studies completed subsequent to those presented in Table 5.2.3 by Pattenden *et al.* (1990) and Mainstream (2011f, 2012a) exhibited similar patterns.

Table 5.2.3 Composition of enumerated large-fish fish species collected in spring, summer, and fall by boat electrofisher in 1989 (Pattenden *et al.* 1990) and 2009 (Mainstream 2010a).

Group	Species	1989 2		009	
		Total	**Percent of Group**	**Total**	**Percent of Group**
Sportfish (coldwater)	Arctic grayling	606	5.7	169	1.5
	Bull trout	89	0.8	283	2.6
	Kokanee	80	0.8	41	0.4
	Lake trout	1	0.0	5	0.0
	Lake whitefish	418	4.0	8	0.1
	Mountain whitefish	8,938	84.5	10,211	93.1
	Rainbow trout	444	4.2	245	2.2
	Subtotal	*10,576*	*87.2*	*10,962*	*81.7*
Sportfish (coolwater)	Burbot	7	2.2	43	15.0
	Goldeye	21	6.6	31	10.8
	Northern pike	71	22.3	83	28.9
	Walleye	219	68.9	89	31.0
	Yellow perch	-	0.0	41	14.3
	Subtotal	*318*	*2.6*	*287*	*2.1*
Suckers	Largescale sucker	333	26.9	422	3.1
	Longnose sucker	806	65.1	1,646	75.8
	White sucker	99	8.0	103	4.7
	Subtotal	*1,238*	*10.2*	*2,171*	*16.2*
	Large-fish Species Total	**12,132**	100.0	**13,420**	100.0

Another reason for the difference may include a change in recruitment levels. Lake whitefish, a pelagic species that recruits from upstream of Peace Canyon Dam, has exhibited a large decline in abundance in Williston Reservoir and has been replaced by kokanee as the dominant pelagic species (Sebastian *et al.* 2009). Historically, the rainbow trout population in Dinosaur Reservoir was supplemented with hatchery stock. With the exception of 1998, rainbow trout were stocked annually between 1982 and 2003

(Diversified and Mainstream 2011a). At least until 1989, hatchery rainbow trout were marked using fin clips. Marked and unmarked rainbow trout captured in the technical study area were enumerated by Pattenden *et al.* (1990). Of the 442 rainbow trout examined 28% were marked. In the reach located immediately downstream of Peace Canyon Dam 54% were marked (Pattenden *et al.* (1990). The results presented in Table 5.2.3 suggest a 45% decline in rainbow trout contribution to the catch. Based on this information the historical changes illustrated by lake whitefish and rainbow trout in the technical study area are most likely explained by changes in recruitment levels from upstream sources.

The decline in Arctic grayling numbers may reflect a decrease in recruitment or a change in recruitment source. In 1989 and 1990, taggable Arctic grayling (≥ 250 mm fork length) were found primarily in the section of the Peace River between Farrell Creek to approximately 10 km upstream of the Moberly River (Figure 4.7 in Pattenden *et al.* 1991). The authors hypothesized that the Halfway River was the primary recruitment source of Arctic grayling recorded in the study area. Annual studies completed by Mainstream and Gazey (2004 to 2012) consistently demonstrate that taggable Arctic grayling are largely restricted to the section of the Peace River downstream of the Moberly River, suggesting that the Moberly River is now the primary recruitment source for the population. This hypothesis has been corroborated by elemental signature work (i.e., otolith microchemistry analysis) by Earth Tone Environmental and Mainstream (2012). The authors established that Arctic grayling sampled from the Peace River recruited primarily from the Moberly River (55% of samples with a known origin) compared to the Halfway River (13% of samples with a known origin). Results indicate that there has been a shift in the recruitment source of Arctic grayling from the Halfway River in the late 1980s to the Moberly River.

The increased importance of bull trout in the Peace River sample since 1989 reflects a reduction in mortality rate of this population. The Halfway River watershed is a critical spawning and rearing area for the Peace River bull trout population (Diversified and Mainstream 2011b). As part of the provincial char conservation plan, bull trout retention quotas in the Peace River watershed, downstream of the W.A.C. Bennett Dam, were reduced to zero in 1995. Seasonal closures to angling at the Peace-Halfway confluence and in the upper Chowade River also protected staging and spawning bull trout from harassment and potential hooking mortality. Additional protection for the population is offered by the Identified Wildlife Management Strategy (IWMS) of the Forest and Range Practices Act (formerly the Forest Practices Code). In 2002, under the IWMS, bull trout Wildlife Habitat Areas (WHAs) were established to encompass critical sections of stream habitat where bull trout spawning activity is concentrated or where significant numbers of pre-spawning bull trout migrants are known to stage.

Monitoring of bull trout spawner and redd numbers in the Halfway River watershed since 2002 have documented a large increase in adult bull trout abundance and expansion of bull trout spawning areas, based on numbers and locations of redds (Diversified and Mainstream 2011b). The authors attributed this increase to the implementation of conservative measures with particular reference to reduction of the legal harvest of bull trout to zero as well as seasonal and permanent angling closures. The authors concluded that these measures have resulted in increased survival of adult bull trout.

The decline in walleye numbers between 1989 and 2009 may reflect an increase in mortality caused by increased angler harvest. Walleye are consistently recorded at the confluence of the Beatton River and Peace River during fish inventories (Pattenden *et al.* 1990, 1991, Mainstream 2010a, 2011f, 2012a). This location is used by anglers (Robichaud *et al.* 2009) and anecdotal observations during historical and current fish inventories indicate an increase in the number of anglers targeting walleye at this location (personal observations by author).

5.2.2 Species Diversity and Distribution

Species distribution on the Peace River in the technical study area is illustrated by work presented in Mainstream (2011f). In total, 30 fish species were recorded during the 2010 study, but the number of species differed between sections (Table 5.2.4). The number of species increased from upstream to downstream. Seven species were recorded in Section 1A, which is located immediately below the Peace Canyon Dam. In Sections 1, 2, and 3 which are located upstream of the Moberly River, 15, 16, and 19 species were recorded, respectively. The number of species recorded increased to ≥ 24 species in the remaining four sections (Sections 5, 6, 7, and 8).

The majority of fish species recorded during the study were widely distributed. In total, 16 species were recorded in 6 or more sections. These included Arctic grayling, bull trout, kokanee, mountain whitefish, rainbow trout, northern pike, longnose sucker, largescale sucker, white sucker, prickly sculpin, slimy sculpin, lake chub, longnose dace, northern pikeminnow, redside shiner, and spottail shiner.

Of the 14 species that exhibited a more restricted distribution (present in ≤ 5 sections), most (13 species) were located only in Zone 2 and/or in the lower portion of Zone 1 (Section 3). These included pygmy whitefish, burbot, goldeye, walleye, yellow perch, spoonhead sculpin, brook stickleback, finescale dace, flathead chub, northern redbelly dace, peamouth, and trout-perch. Lake whitefish was located in five sections (Section 1 to Section 6).

Table 5.2.4 Distribution of fish species by section and zone recorded on the Peace River, 2010 Peace River Fish Inventory (from Mainstream 2011f).

Group Species		**Zone 1 – Upstream**				**Zone 2 – Downstream**			
		1A	**1 2**		**3**	**5**	**6 7**		**8[b]**
Sportfish (coldwater)	Arctic grayling			+	+	+	+	+	+
	Bull trout	+	+	+	+	+	+	+	+
	Kokanee	+	+	+	+	+	+	+	+
	Lake trout		+		+				
	Lake whitefish		+	+	+	+	+		
	Mountain whitefish	+	+	+	+	+	+	+	+
	Pygmy whitefish					+			
	Rainbow trout	+	+	+	+	+	+	+	+
Sportfish (coolwater)	Burbot				+	+	+	+	+
	Goldeye					+	+	+	+
	Northern pike			+	+	+	+	+	+
	Walleye					+	+	+	+
	Yellow perch					+	+	+	+
Suckers	Longnose sucker		+	+	+	+	+	+	+
	Largescale sucker	+	+	+	+	+	+	+	+
	White sucker		+		+	+	+	+	+
Sculpins	Prickly sculpin	+	+	+	+	+	+	+	+
	Slimy sculpin	+	+	+	+	+	+	+	+
	Spoonhead sculpin						+	+	
Minnows[a]	Brook stickleback								+
	Finescale dace								+
	Flathead chub						+	+	+
	Lake chub		+	+	+	+	+	+	+
	Longnose dace		+	+	+	+	+	+	+
	Northern pikeminnow		+	+	+	+	+	+	+
	Northern redbelly dace					+	+	+	+
	Peamouth							+	
	Redside shiner		+	+	+	+	+	+	+
	Spottail shiner			+	+	+	+	+	+
	Trout-perch					+	+	+	+
Total Number of Species		**7**	**15**	**16**	**19**	**24**	**25**	**25**	**25**

[a] Includes true minnows (Family Cyprinidae), trout-perch (Family Percopsidae), and sticklebacks (Family Gasterosteidae).
[b] Section is located in Alberta.

Species distributions were generally similar among survey years (Mainstream 2010a, 2012a); however, some species differences were recorded. During 2011, which represented a year with very high tributary flows and turbid water (Mainstream 2012a) several coolwater species exhibited an extended upstream distribution. These included the large-fish species burbot (Section 1), northern pike (Section 1A), and walleye (Section 3) and the small-fish species flathead chub (Section 3).

5.2.3 Fish Assemblages

Fish assemblages on the Peace River in the technical study area are illustrated by work presented in Mainstream (2011f). The fish assemblage was not constant among sections (Figure 5.2.2). The coldwater sportfish group accounted for the majority of the sample in each section; however, their contribution decreased from upstream to downstream. A high of 87.1% recorded in Section 1A declined to 58.0% in Section 3. Downstream of the proposed Site C dam (Zone 2) coldwater sportfish accounted for ≤ 28.0% of the sample in each section. A similar pattern was recorded for the sculpin group. The contribution of sculpins ranged from 12.6% in Sections 1A to 7.8% in Section 3. The percentage of sculpins in each section was ≤ 2.0 in each section located in Zone 2.

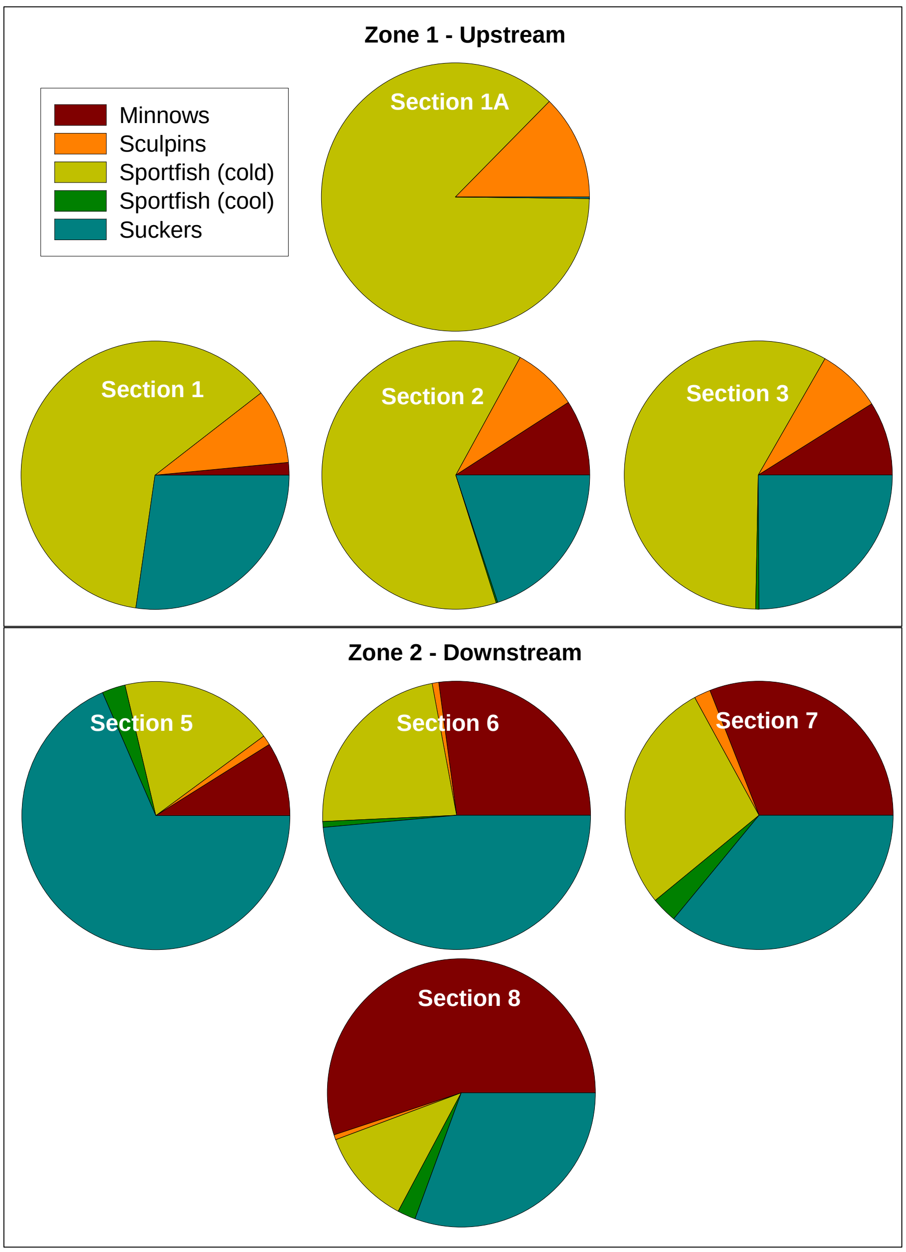


Figure 5.2.2 Relative contribution of fish groups by section and zone, 2010 Peace River Fish Inventory (all capture methods and sample events combined) (from Mainstream 2011f).

The spatial trends recorded for the coolwater sportfish, sucker, and minnow groups were the reverse of trends for the coldwater sportfish and sculpin groups. There was an increase in the numerical contribution from upstream to downstream. Coolwater sportfish were largely absent from all sections in Zone 1. In Zone 2 their contribution ranged from 0.7% (Section 6) to 2.8% (Section 5). For the sucker group, a low of 0.2% recorded in Section 1A increased to ≥ 36.0% in Zone 2 sections. The largest change occurred between Section 3 (24.9%) and Section 5 (68.5%). Similarly, the minnow group accounted for a small percentage of the sample in Sections 1A through to Section 5 (≤ 8.9%). The contribution of this group was ≥ 27.1% in Section 6 to Section 8.

The fish assemblage also differed by habitat type (Figure 5.2.3). In Zone 1, upstream of the Site C dam location, the contribution of coldwater sportfish was higher in the main channel area (79.6%) compared to side channel (33.1%) and tributary confluence areas (24.2%). A similar pattern was recorded for the sculpin group in Zone 1. In contrast, suckers were more prominent in side channels (37.3%) and tributary confluence areas (54.1%) compared to main channel areas (9.8%). The results for minnows were similar to the sucker results. The contribution of the minnow group was higher in side channels and tributary confluences than in main channel areas. Coolwater sportfish were rarely encountered in Zone 1.

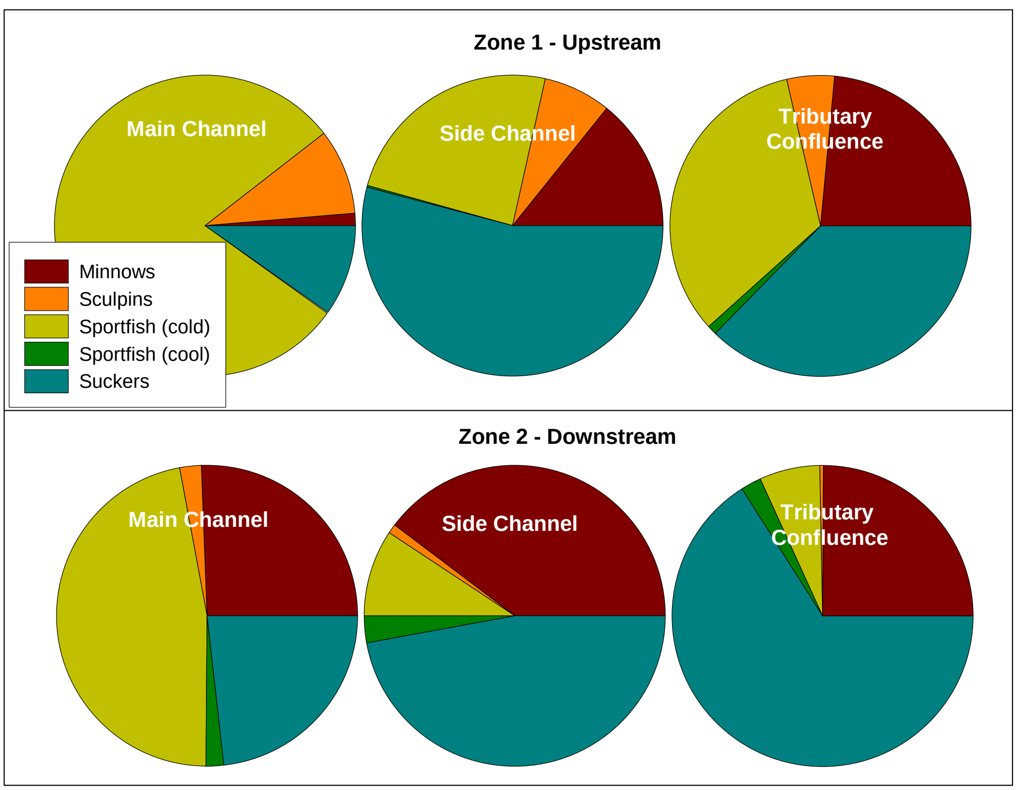


Figure 5.2.3 Relative contribution of fish groups by habitat type and zone, 2010 Peace River Fish Inventory (all capture methods and sample events combined) (from Mainstream 2011f).

The relative contribution of each group changed in Zone 2. Within each habitat type, the contribution of coldwater sportfish and sculpins was lower in Zone 1 compared to Zone 2. The reverse was true for coolwater sportfish, suckers, and minnows. This shift reflects the spatial differences within the study area illustrated by Figure 5.2.2.

Although the relative contribution of each group differed by Zone, the pattern within each habitat remained the same. The coldwater sportfish group and the sculpin group were most prominent in main channel areas, while the contribution of minnows was generally higher in side channel and tributary confluence areas. Coolwater sportfish and suckers were also more prominent in these two areas.

These patterns were also recorded by Mainstream (2010a, 2012a)

5.2.4 Fish Abundance

5.2.4.1 Catch Rates

Catch rate, which is an index of fish abundance, was used to describe the seasonal and spatial distribution of fish in the Peace River study area. Several fish collection methods were used in a variety of habitats in order to accurately characterize fish abundance. The results from Mainstream (2011f) are presented here. Similar results were recorded by Mainstream (2010a, 2012a)

<u>Arctic grayling</u>

In total, 272 Arctic grayling were enumerated in the study area. Arctic grayling were recorded in main channel areas; this species was not encountered in side channels and was recorded at only one tributary area (Figure 5.2.4). Catch rates of small Arctic grayling were higher than for large Arctic grayling. Mean catch rates of small Arctic grayling reached 3.0 fish/km, while mean catch rates for large Arctic grayling did not exceed 1.0 fish/km.

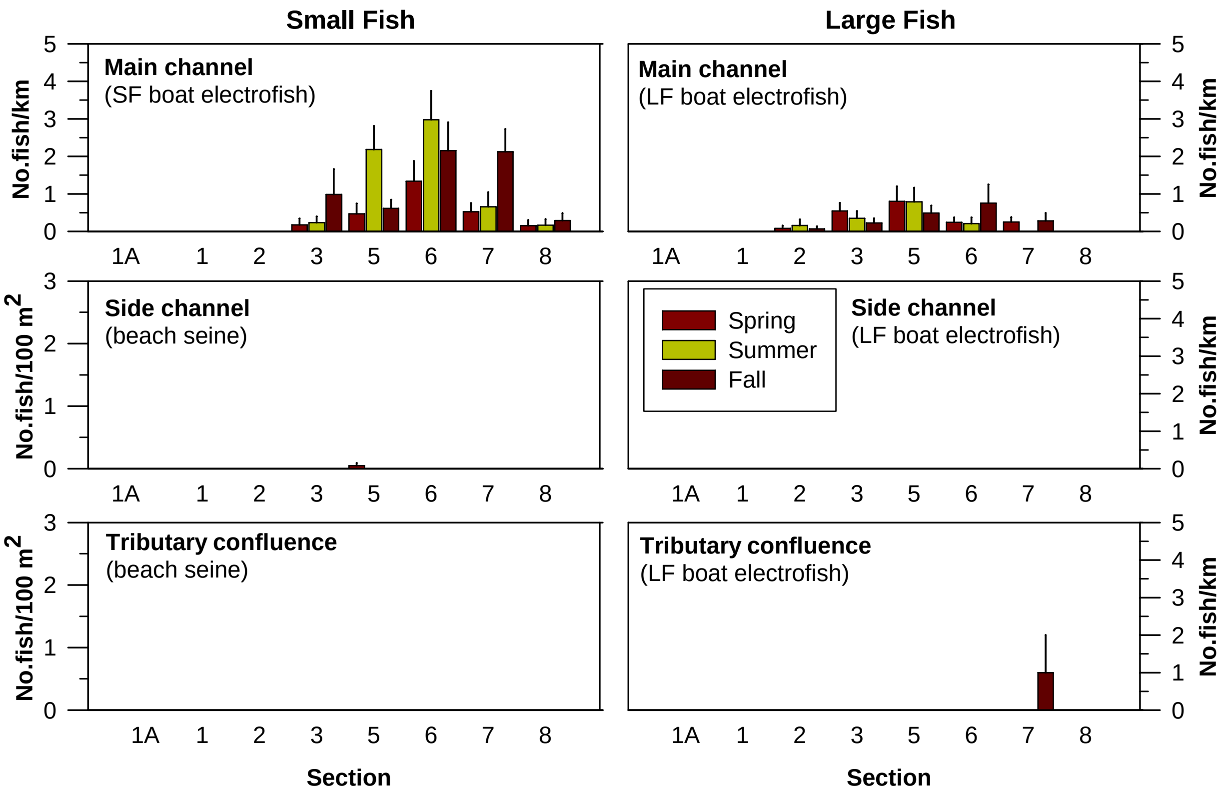


Figure 5.2.4 Average catch rates (± SE) of Arctic grayling in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Catch rates of large Arctic grayling were highest in Section 3 to Section 6, while the catch rates of small Arctic grayling were highest in Section 3 to Section 7. These spatial patterns may reflect the distribution of recruitment sources of small Arctic grayling (Sections 3 to 7 are located in immediate vicinities of major tributaries to the Peace River), as well as the distribution of habitats preferred by Arctic grayling.

Generally, there were no substantial differences in seasonal catch rates of large Arctic grayling. However, catch rates of small Arctic grayling were highest in summer and fall. The elevated small fish catch rates in summer and fall suggest an influx of fish to the Peace River from tributaries or an increase in catchability.

<u>Bull trout</u>

In total, 285 bull trout were enumerated in the study area. Bull trout were encountered in main channel areas, side channel areas, and tributary confluence areas, but the catch was almost entirely composed of larger fish (> 200 mm fork length) (Figure 5.2.5). Mean catch rates of large bull trout in main channel areas and side channel areas rarely exceeded 1.5 fish/km.

Higher mean catch rates were recorded at tributary confluence areas in Sections 1, 2, and 3 during spring and/or fall. In all cases the high catch rates were caused by the presence of 2 to 4 fish. The high catch rate recorded in Section 3 in spring occurred in the Halfway River confluence area, where 16 adult bull trout were recorded. A concentration of adult bull trout also was recorded in the same location in spring 2008 (Mainstream 2009b) and spring 2009 (Mainstream 2010a).

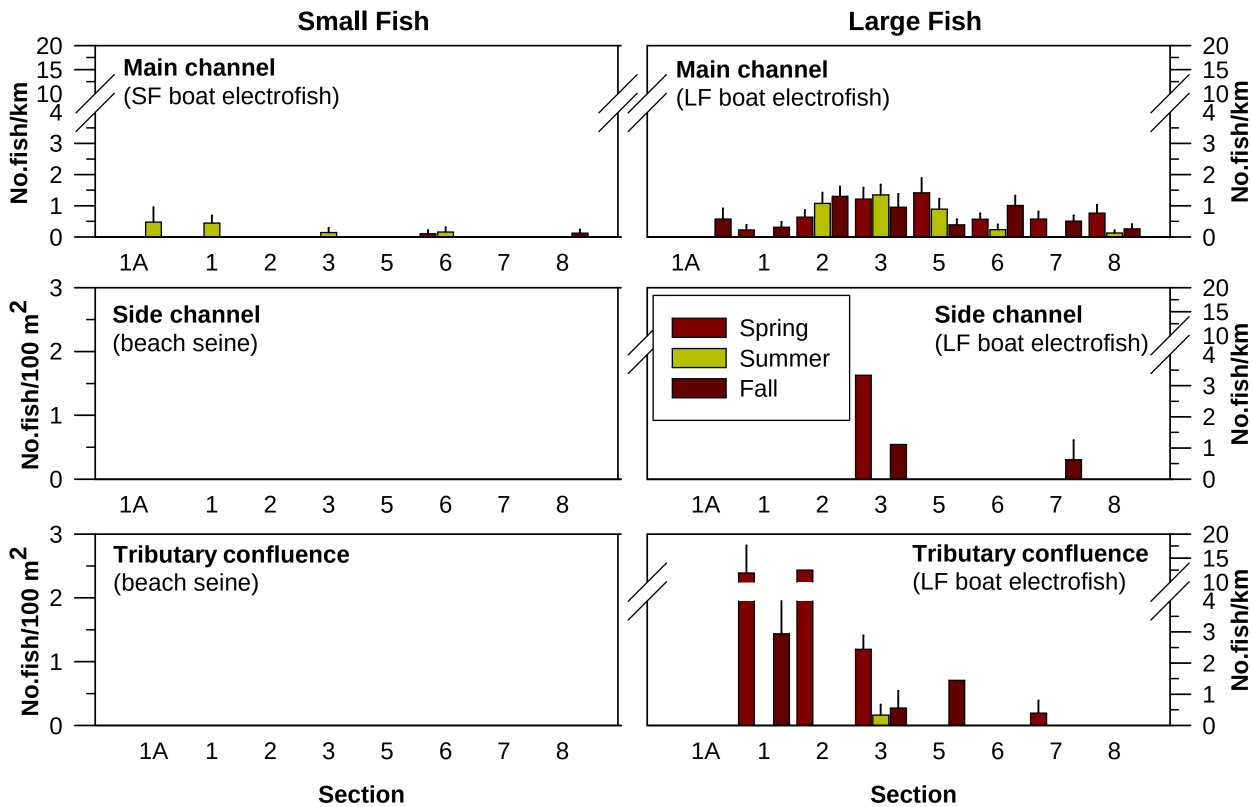


Figure 5.2.5 Average catch rates (± SE) of bull trout in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Large bull trout were recorded in all sections during the study, but catch rates were highest in Sections 2 to 6. Small bull trout were encountered in several sections during the study (Sections 1A, 1, 3, 6, and 8), but no more than one fish was recorded at any one time. There were no strong seasonal differences in bull trout catch rates.

Kokanee

In total, 537 kokanee were enumerated in the study area. Kokanee catch rates were highest in main channel areas. This species was rarely encountered in side channel or tributary confluence areas (Figure 5.2.6). The only exception occurred in spring in Section 1 when large and small kokanee were recorded at confluences of Maurice Creek and Lynx Creek.

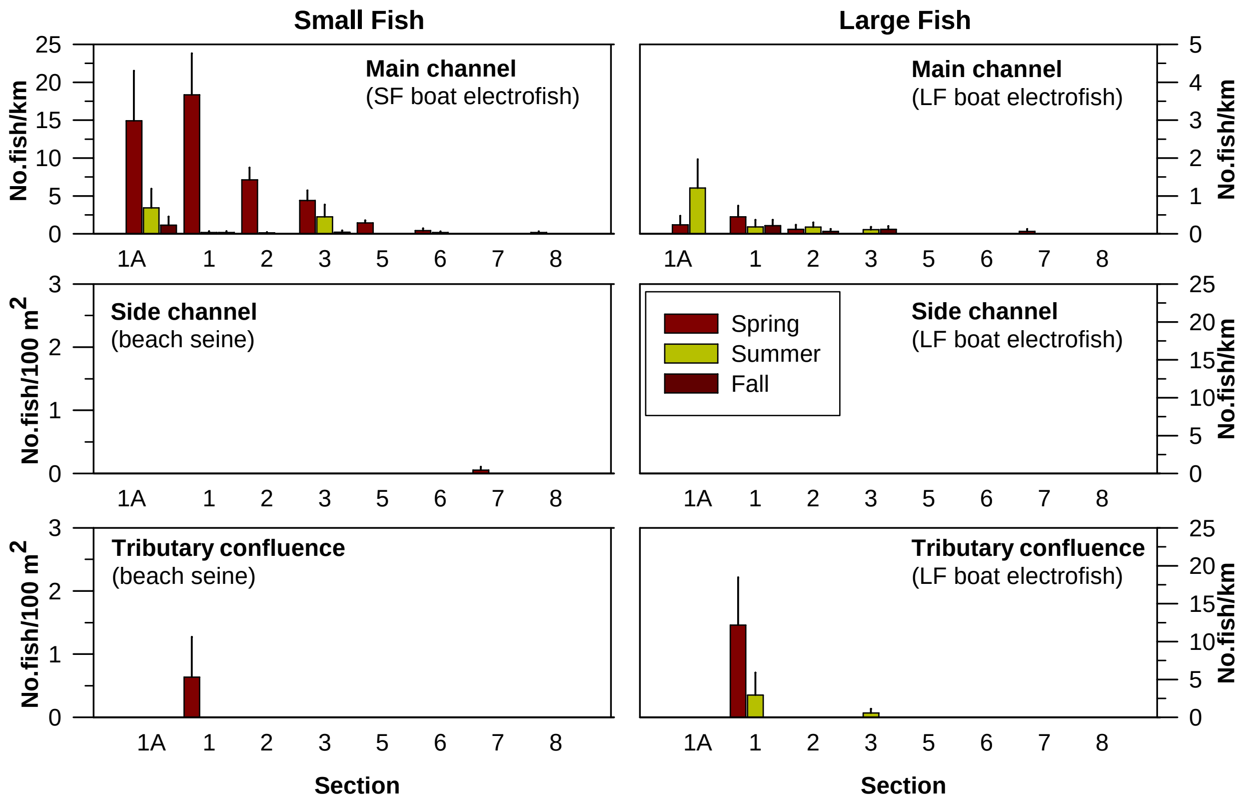


Figure 5.2.6 Average catch rates (± SE) of kokanee in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Mean catch rates of small kokanee in main channel areas were highest in Sections 1A and 1 (> 14 fish/km), but declined rapidly in downstream sections. Large kokanee also were most abundant in upstream sections, but catch rates did not exceed 1.4 fish/km. The spatial pattern of kokanee catch rate may reflect recruitment of fish from upstream of the Peace Canyon Dam.

There was a distinct seasonal difference in kokanee catch rates. Catch rates were highest in spring and low in summer. Small and large kokanee were infrequently encountered in fall.

Mountain whitefish

Mountain whitefish catch rates were very high in the Peace River study area (Figure 5.2.7). Small and large mountain whitefish were found in all sections and all habitat areas, but catches of both size groups were highest in main channel areas. Catch rates of large and small mountain whitefish exhibited distinct spatial patterns. Average catch rates of large mountain whitefish in main channel areas increased from approximately 40.0 fish/km in Section 1A, to peak levels in Section 1 and 2 (approximately 60 fish/km), and then gradually declined to approximately 10 fish/km in Section 8. This spatial pattern was consistent among seasons, although there was a trend of decreasing rates from spring to fall in Sections 1A and 1.

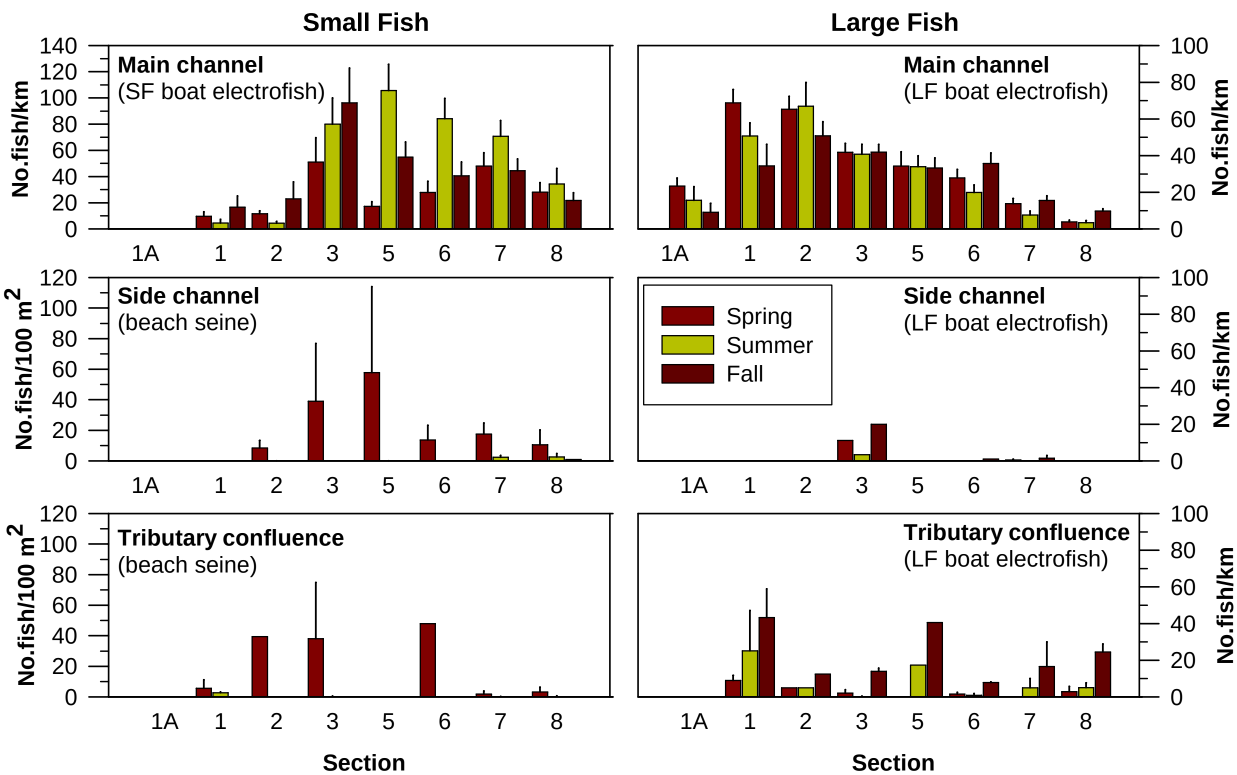


Figure 5.2.7 Average catch rates (± SE) of mountain whitefish in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Small mountain whitefish exhibited a different spatial trend. Catch rates were lowest in the uppermost Sections 1A, 1, and 2 (≤ 16.6 fish/km), then increased in Section 3 and Section 5 reaching 105.6 fish/km. Catch rates of small mountain whitefish then declined farther downstream to approximately 25 fish/km in Section 8.

Catch rates of small mountain whitefish exhibited seasonal differences. In spring, highest catch rates were recorded in Sections 3 to 7. In summer, catch rates were highest in Sections 5 to 8. In fall the highest mean catch rate was in Section 3 (96.3 fish/km).

The patterns of large and small mountain whitefish catch rates suggest spatial segregation of younger and older cohorts of the Peace River population. Small (younger) fish occur primarily from Section 3 downstream, while large (older) fish are most abundant from Section 2 upstream.

Rainbow trout

In total, 285 rainbow trout were enumerated during the study. Rainbow trout catch rates were highest in main channel areas and fish were rarely encountered in side channel and tributary confluence areas (Figure 5.2.8). Average catch rates of small and large rainbow trout were generally similar and did not exceed 2.9 fish/km. Catch rates of both size groups of rainbow trout were highest in Sections 1A to Section 3 although both large and small fish were recorded in all study sections. There was a general trend for catch rates of rainbow trout to decline from upstream to downstream.

There were seasonal differences in rainbow trout catch rate. In fall, small individuals were found only in Section 1.

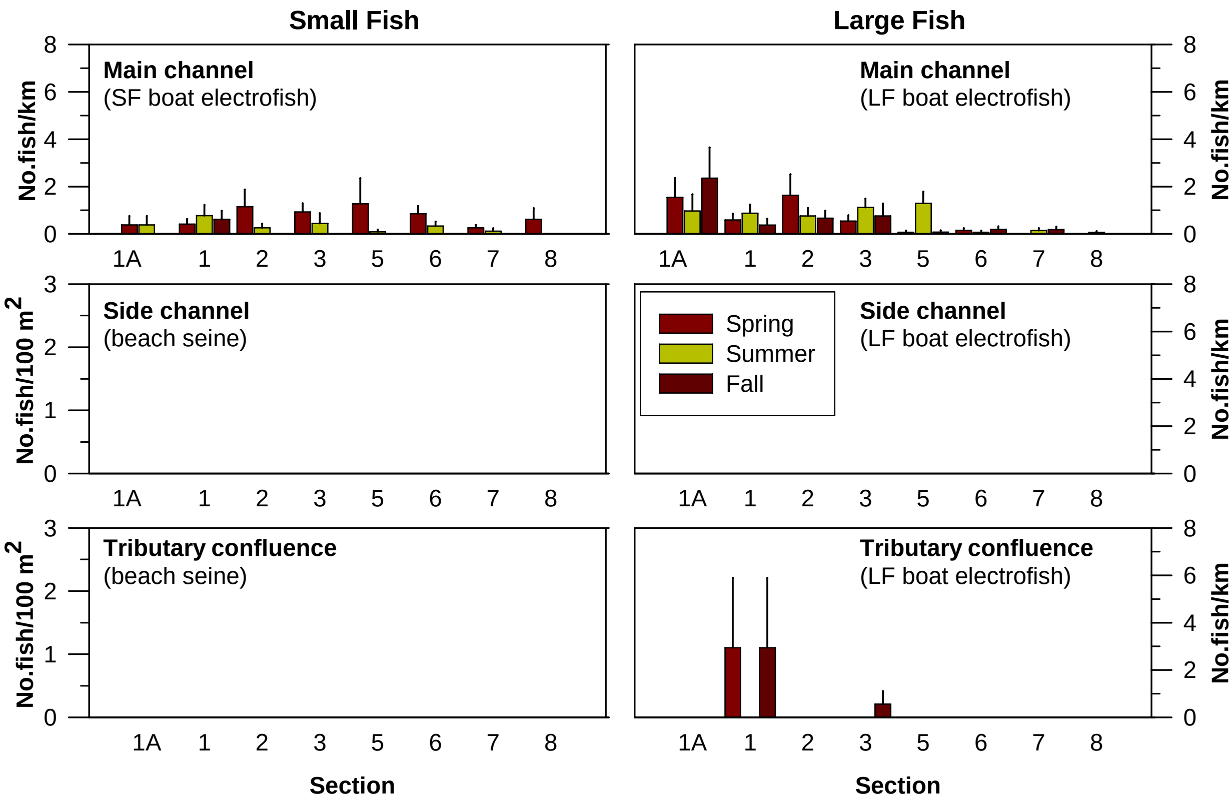


Figure 5.2.8 Average catch rates (± SE) of rainbow trout in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Burbot

In total, 51 burbot were enumerated during the study and catch rates were low (Figure 5.2.9). Small burbot were rarely encountered. Large burbot were recorded in Sections 3, 5, 6, 7, and 8. Large burbot catch rates ranged from 0.1 fish/km to 2.2 fish/km, but were highest in spring in Sections 7 and 8. This species was recorded in main channel and tributary confluence areas. Tributary confluences where burbot were encountered included the Halfway, Pine, Beatton, Kiskatinaw, and Pouce Coupe Rivers.

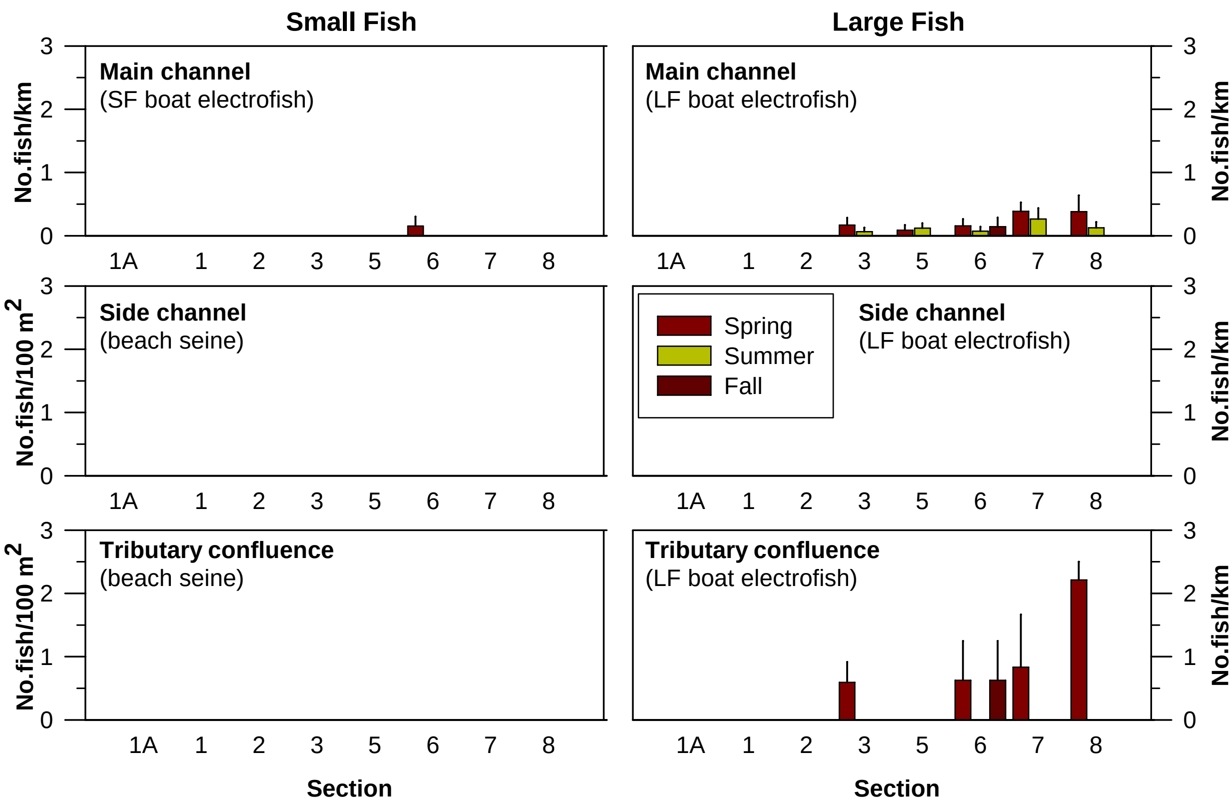


Figure 5.2.9 Average catch rates (± SE) of burbot in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Goldeye

In total, 82 goldeye were enumerated during the study. Goldeye were recorded only in sections downstream of the proposed Site C dam location (Sections 5 to 8), but catch rates were highest in Sections 7 and 8 (Figure 5.2.10). Large goldeye dominated the catch. A single small goldeye was recorded during the study. Large goldeye occurred in all three habitat areas, but catch rates in main channel and side channel areas were low.

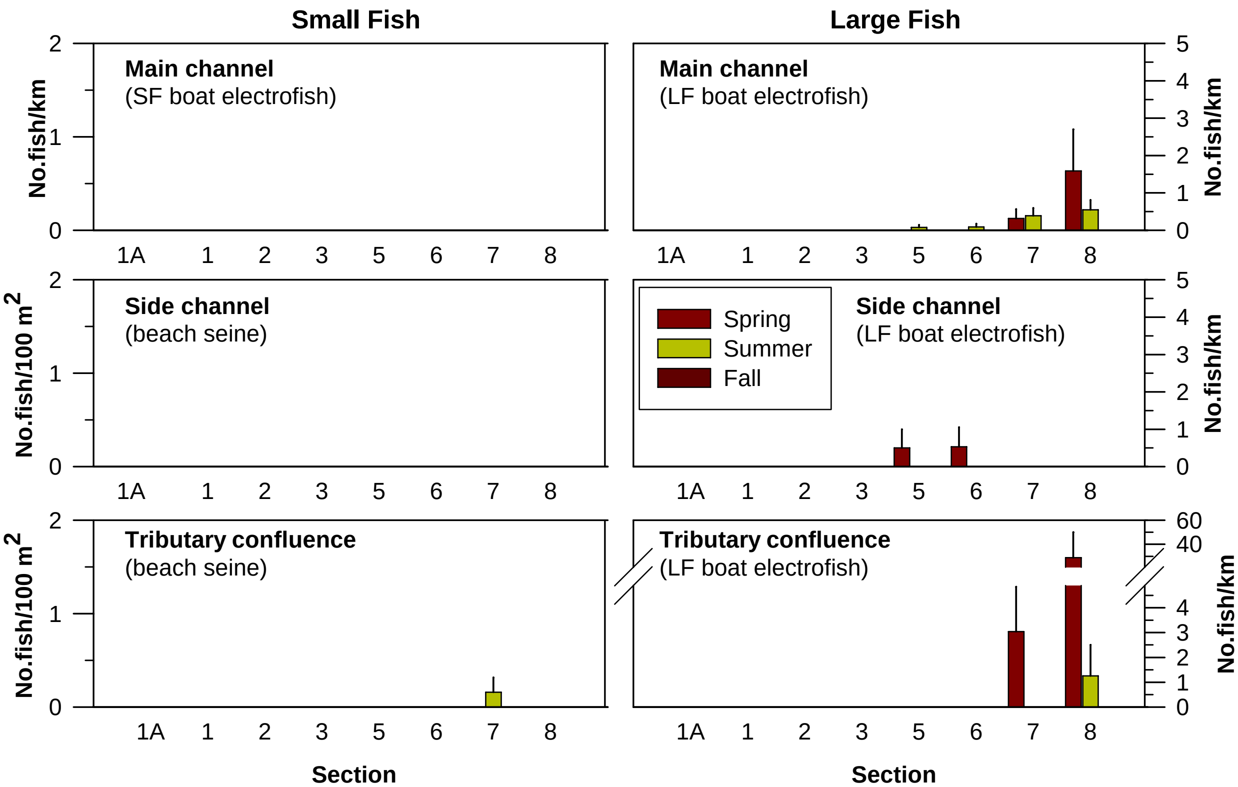


Figure 5.2.10 Average catch rates (± SE) of goldeye in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Large goldeye catch rates were highest in spring, low in summer, and no fish were recorded in the study area during fall. Highest catch rates were recorded at tributary confluences in spring. A catch rate of 28.9 fish/km was recorded at the confluence of the Beatton River. Large goldeye were also recorded at the confluences of the Kiskatinaw River, Pouce Coupe River, and Clear River.

Northern pike

In total, 338 northern pike were recorded in the study area. Small and large northern pike were recorded in Sections 2 to 8, but catch rates were highest in Sections 5, 6, and 7 (Figure 5.2.11). Small and large fish were recorded in all three habitats, but catch rates of both groups were higher in side channel and tributary confluence areas than in main channel areas.

Average catch rates of large and small northern pike in main channel areas were ≤ 1.2 fish/km. Average catch rates in side channel and tributary confluence areas were ≥ 0.6 fish/km (large fish) and were ≥ 0.1 fish/100 m^2 (small fish). Catch rates were higher in summer compared to catch rates recorded in spring and fall.

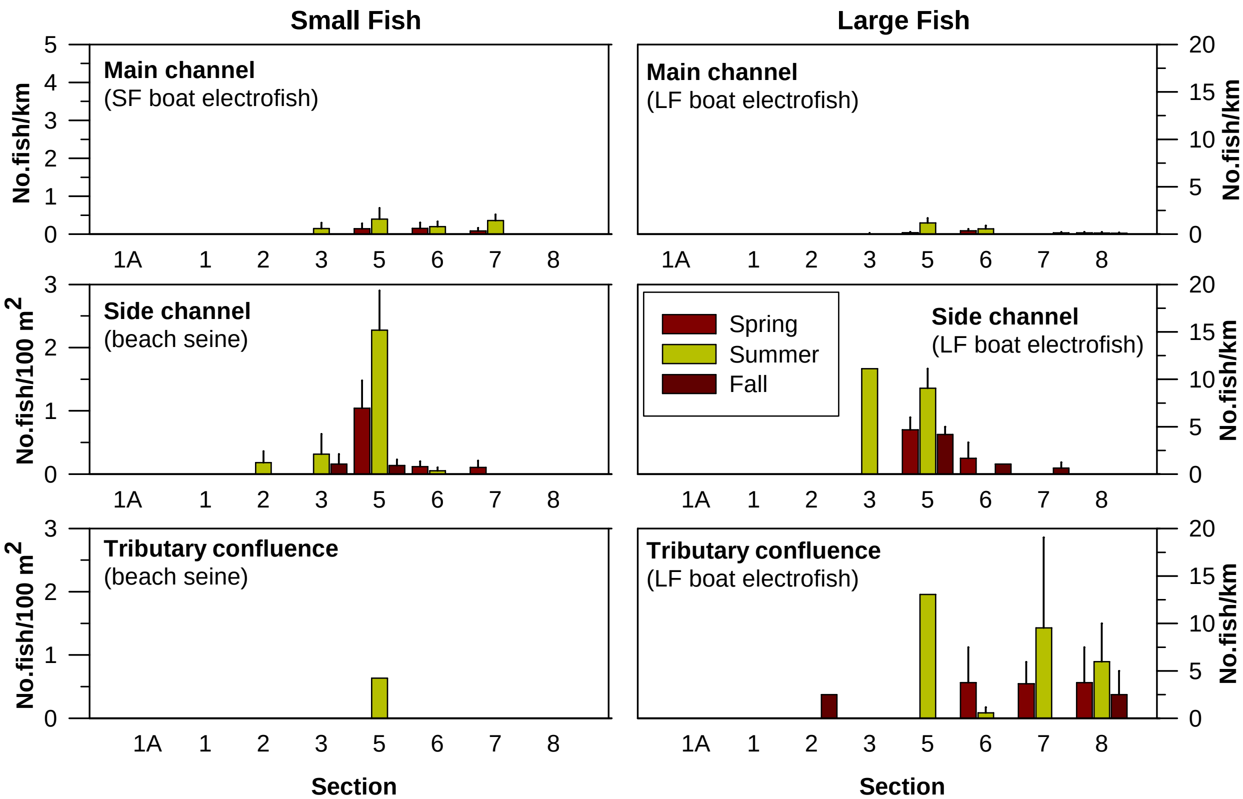


Figure 5.2.11 Average catch rates (± SE) of northern pike in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Walleye

In total, 332 walleye were enumerated during the study. Walleye were only encountered in the downstream portion of the study area in Sections 5, 6, 7, and 8 (Figure 5.2.12). Small fish were scarce. Large walleye occurred in all three habitat areas, but catch rates in main channel and side channels areas were low (< 3.1 fish/km) compared to catch rates in tributary confluence areas (up to 55.6 fish/km). Fish were recorded at confluences of the Moberly River, Beatton River, Kiskatinaw River, Pouce Coupe River, and Clear River. A total of 87 fish were recorded at the confluence of the Beatton River (Section 7) during a single sample session. There were no strong seasonal variations in walleye catch rates.

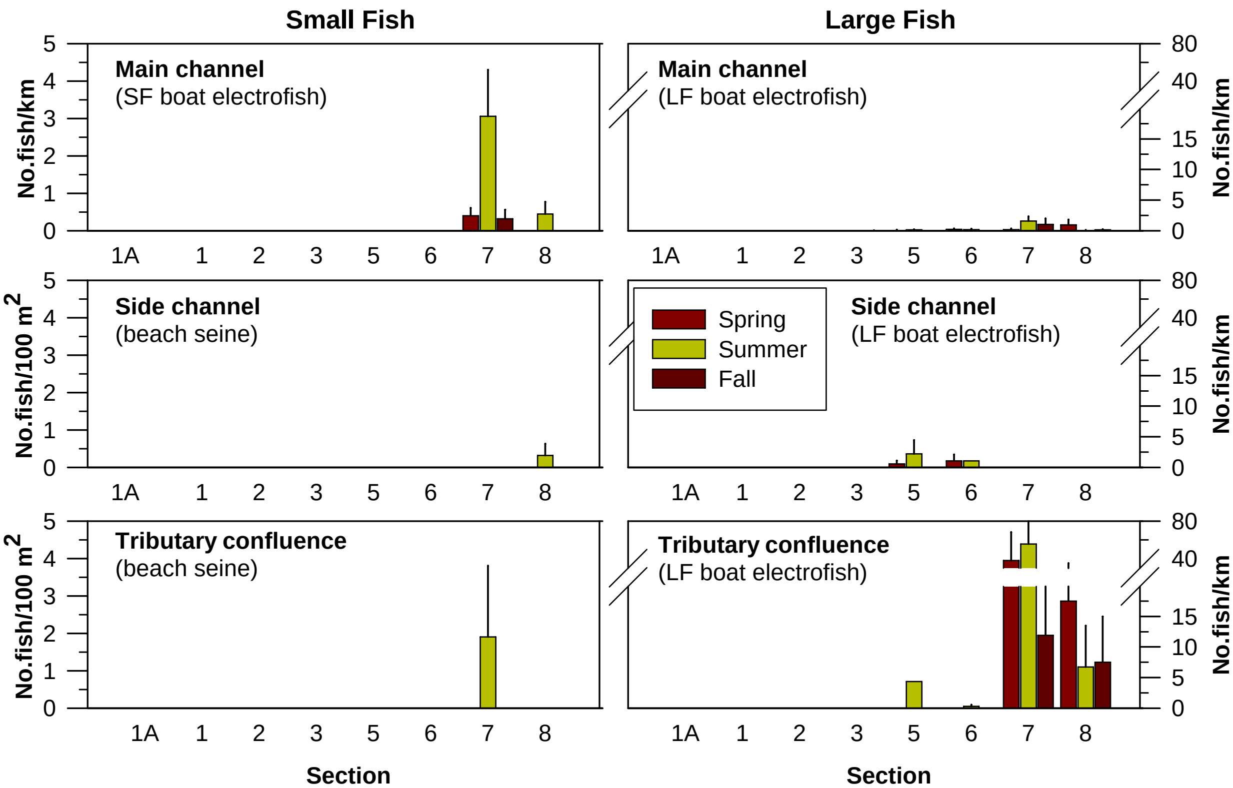


Figure 5.2.12 Average catch rates (± SE) of walleye in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Yellow perch

In total, 635 yellow perch were enumerated during the study. The distribution of yellow perch was spatially and seasonally restricted (Figure 5.2.13). All fish recorded during the study were small fish (≤ 200 mm fork length). Although yellow perch were recorded in Sections 5, 6, 7, and 8, high catch rates occurred only in Section 5 and Section 8. In Section 5, yellow perch were exclusively recorded in side channels during spring and summer. In these areas, catch rates were as high as 15.8 fish/100 m^2. In Section 8, yellow perch catches were recorded in spring and summer in all three habitat types, but catch rates were highest in the main channel in spring (7.5 fish/km).

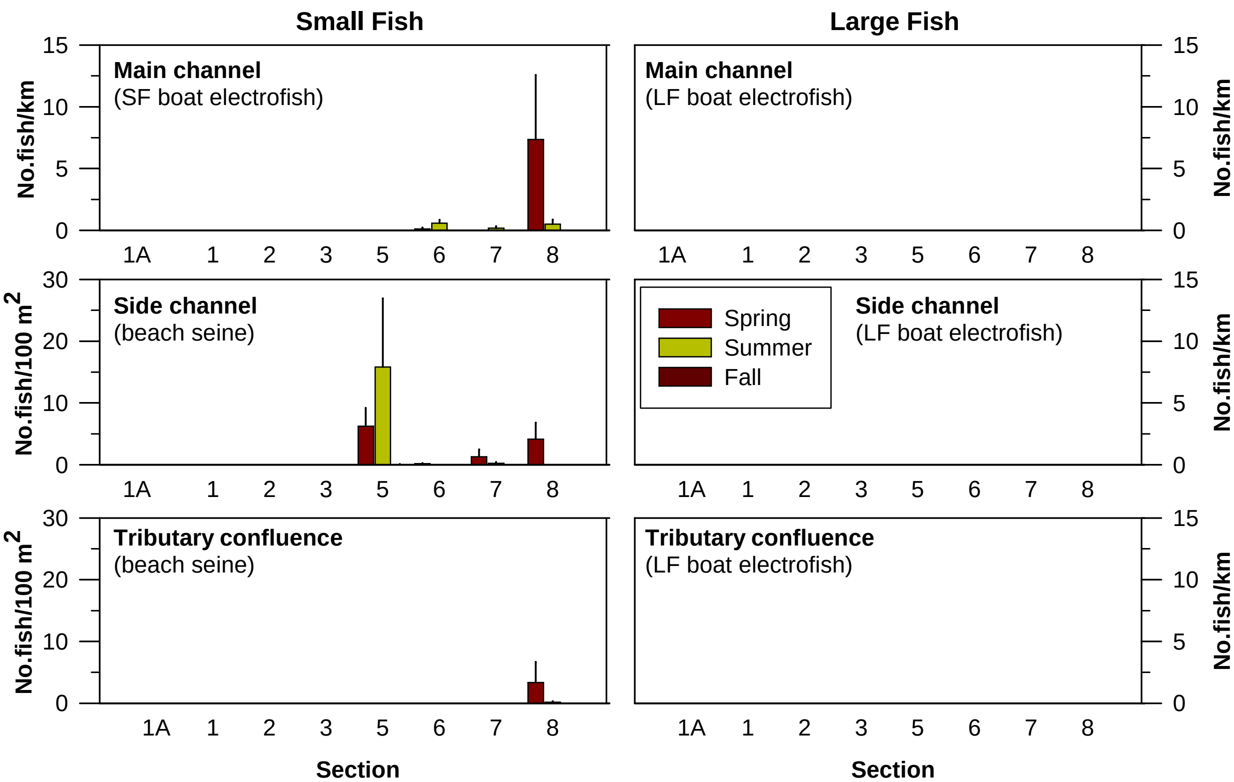


Figure 5.2.13 Average catch rates (± SE) of yellow perch in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Longnose sucker

In total, 4,165 longnose suckers were enumerated during the study and this species was found in all eight sections and in all three habitats (Figure 5.2.14). In main channel areas, longnose suckers catch rates increased from upstream to downstream. Catch rates of large fish were low in Section 1A to Section 2 (≤ 0.5 fish/km), but increased to a high of approximately 15 fish/km in Sections 6, 7, and 8. A similar pattern was recorded for small longnose suckers.

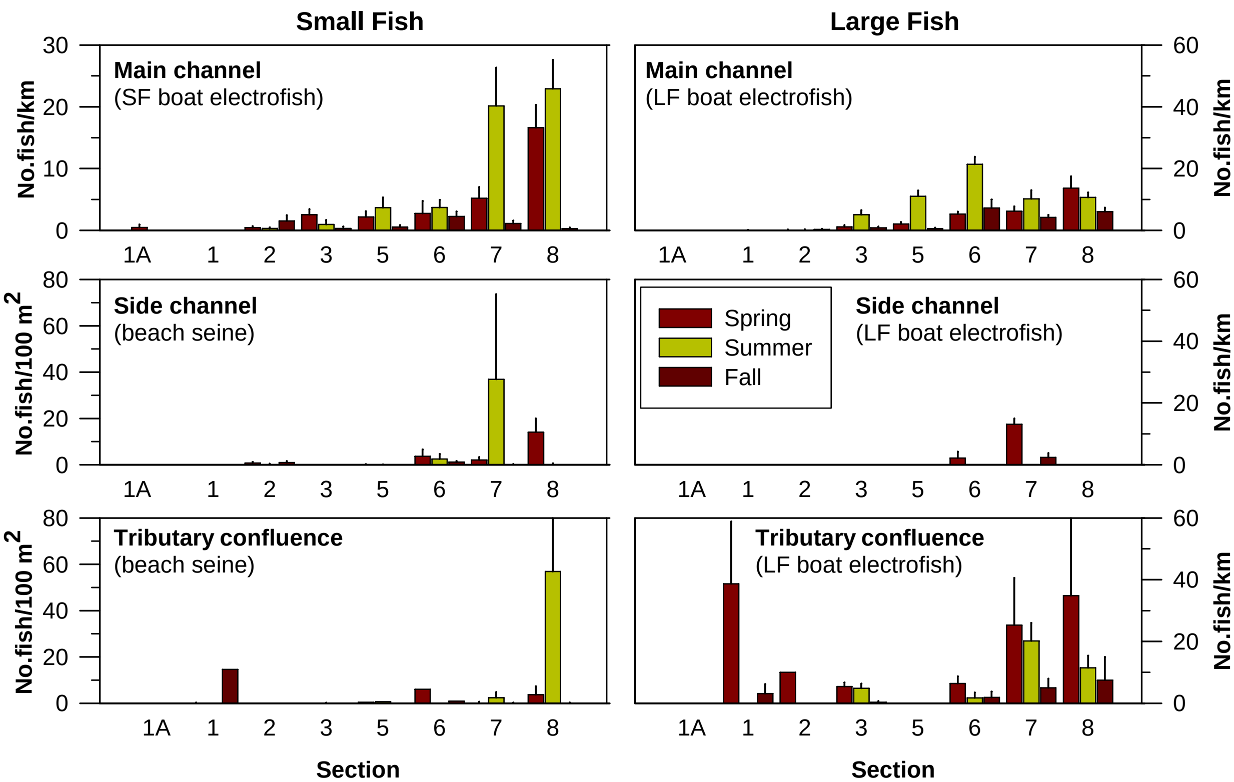


Figure 5.2.14 Average catch rates (± SE) of longnose suckers in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

High catch rates of large longnose suckers were recorded at tributary confluence habitats (38.6 fish/km), but fish were generally scarce in side channel habitats. Small longnose suckers were found in side channel and tributary confluence habitats, but catch rates were generally low.

There were seasonal variations in longnose suckers catch rates in main channel habitat. Catch rates were intermediate in spring, highest in summer, and lowest in fall. It should be noted that Age 0 suckers were not differentiated to species in spring and summer, and therefore, were not included in this analysis.

<u>Largescale sucker</u>

In total, 1,085 largescale suckers were enumerated during the study and fish were located in most sections and in all three habitats (Figure 5.2.15). Largescale suckers were absent only from Section 1A. In main channel areas, catch rates of small and large fish were generally ≤ 5.0 fish/km.

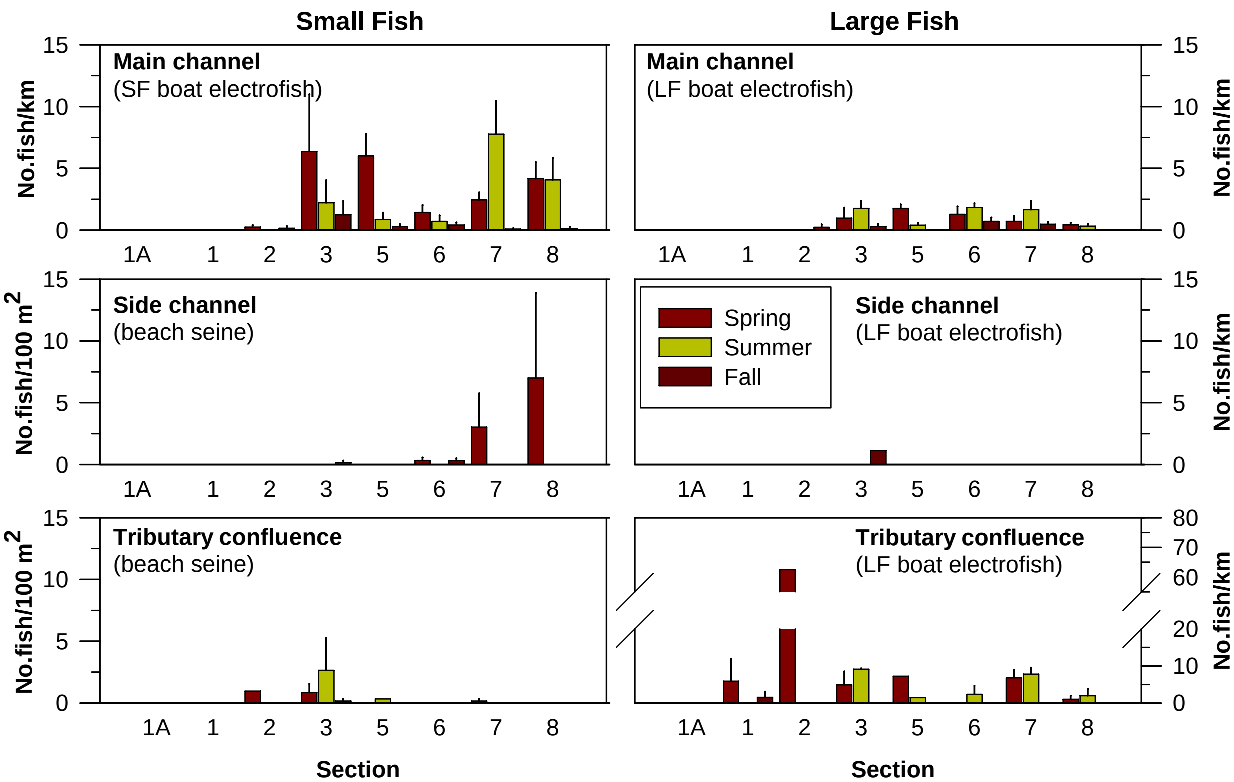


Figure 5.2.15 Average catch rates (± SE) of largescale suckers in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Large fish catch rates were higher in tributary confluence areas compared to main channel areas. The highest catch rate was recorded at the Farrell Creek confluence (Section 2) in spring (62.5 fish/km). Large fish were scarce in side channel habitat. Small fish were mostly encountered in main channel areas where catch rates reached up to 7.8 fish/km in Section 7.

White sucker

In total, 271 white suckers were enumerated during the study and catch rates were low (Figure 5.2.16). White suckers were primarily recorded in Sections 3 to 7 and fish were present in all three habitats. Catch rates of large white suckers were low in main channel areas (approximately 0.5 fish/km), intermediate at tributary confluences (approximately 2.0 fish/km), and highest in side channel areas (approximately 5.0 fish/km). Small fish catch rates were very low in all three habitat types.

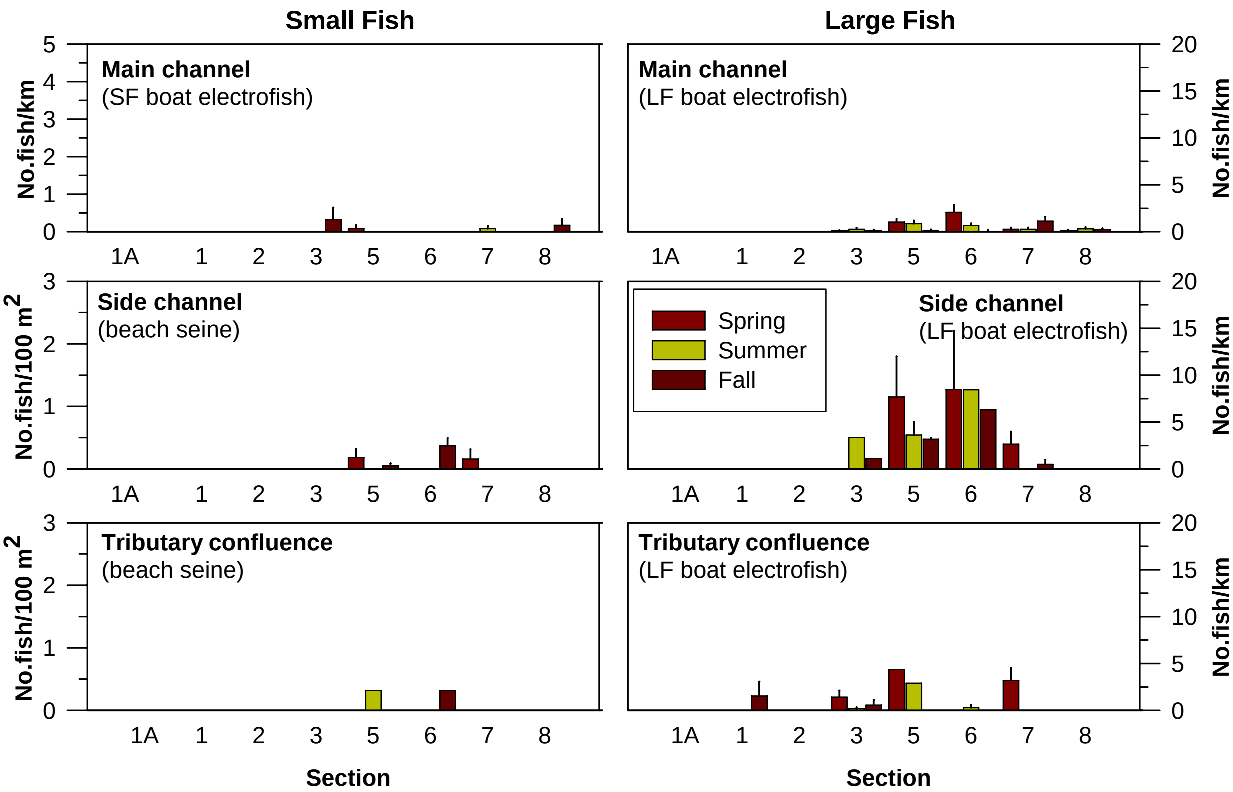


Figure 5.2.16 Average catch rates (± SE) of white suckers in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Northern pikeminnow

In total, 620 northern pikeminnow were enumerated during the study. Northern pikeminnow were recorded in most sections except Sections 1A and 1; this species was also recorded in all three habitat areas (Figure 5.2.17). There was no strong spatial pattern in the northern pikeminnow catch rates. Large fish catch rates typically were highest in tributary confluence areas (up to 10.0 fish/km), but rarely exceeded 0.5 fish/km in main channel and side channel areas. Small fish catch rates were also higher at tributary confluence areas (beach seine catch up to 10.0 fish/100 m^2).

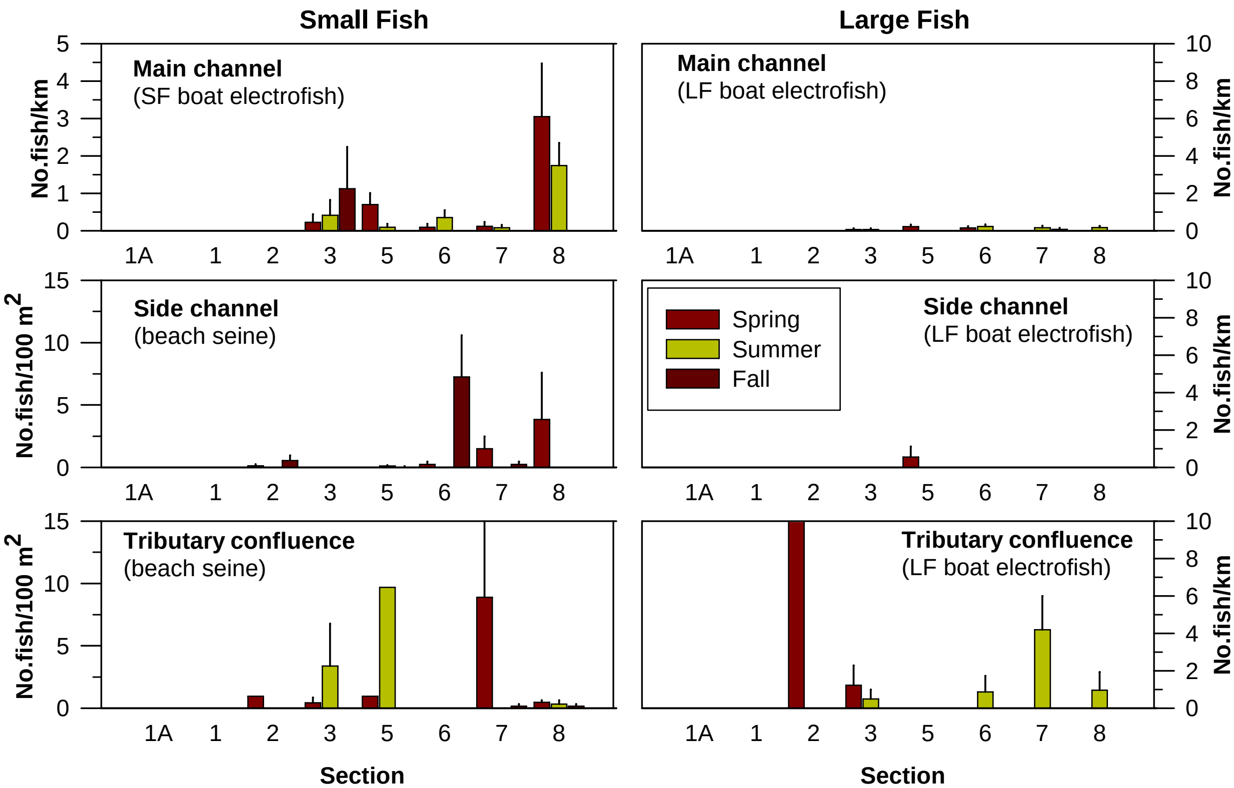


Figure 5.2.17 Average catch rates (± SE) of northern pikeminnow in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (small fish ≤ 200 mm fork length and large fish > 200 mm fork length; SF – small fish method, LF – large fish method) (from Mainstream 2011f).

Redside shiner

Redside shiners were the most numerous minnow species encountered during the study. Catch rates of redside shiner often exceeded 20 fish/100 m^2 in the beach seine samples from all three habitat types; however, highest catch rates were recorded at side channel and main channel sites (Figure 5.2.18). Catch rates of this species were highest in sections located in Zone 2, but redside shiner was numerous as far upstream as Section 2 in Zone 1.

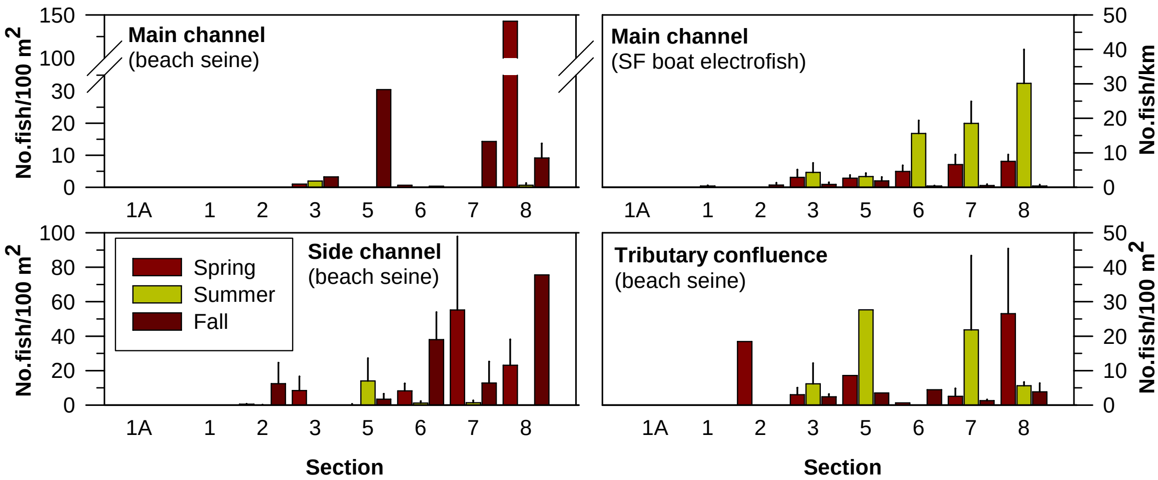


Figure 5.2.18 Average catch rates (± SE) of redside shiner in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (from Mainstream 2011f).

Spottail shiner

Catch rates of spottail shiners were also high. Catch rates of spottail shiner often exceeded 10 fish/100 m^2 in the beach seine samples. Spottail shiners were most numerous in side channel areas (Figure 5.2.19). Spottail shiner catch rates were high in main channel areas of Section 6 and tributary confluence areas in Section 7.

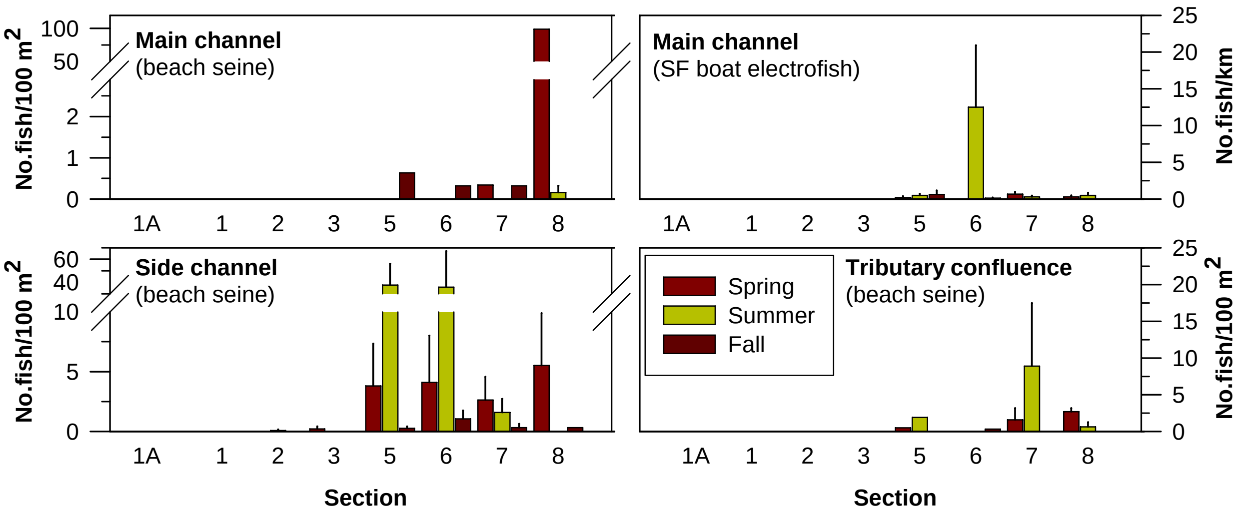


Figure 5.2.19 Average catch rates (± SE) of spottail shiner in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (from Mainstream 2011f).

Slimy sculpin

Slimy sculpins were the most numerous sculpin species encountered during the study. Catch rates were consistently highest in main channel habitats and often exceeded 5 fish/km in the small fish boat electrofisher catch (Figure 5.2.20). Catch rates were highest in Sections 1 to 5.

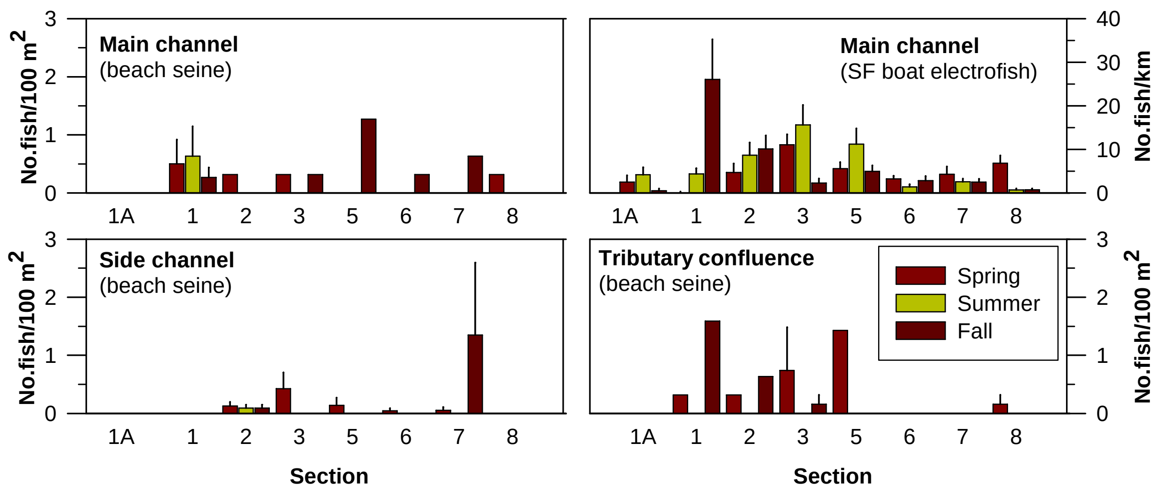


Figure 5.2.20 Average catch rates (± SE) of slimy sculpin in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (from Mainstream 2011f).

Prickly sculpin

Prickly sculpin also were numerous in the study area. Catch rates were highest in main channel habitats; they averaged 1.2 fish/km in the small fish boat electrofisher catch (Figure 5.2.21). Catch rates of prickly sculpins in main channel habitats declined from upstream to downstream. Catch rates were highest in Section 1A (11.8 fish/km in summer) and lowest in Section 8 (< 0.4 fish/km).

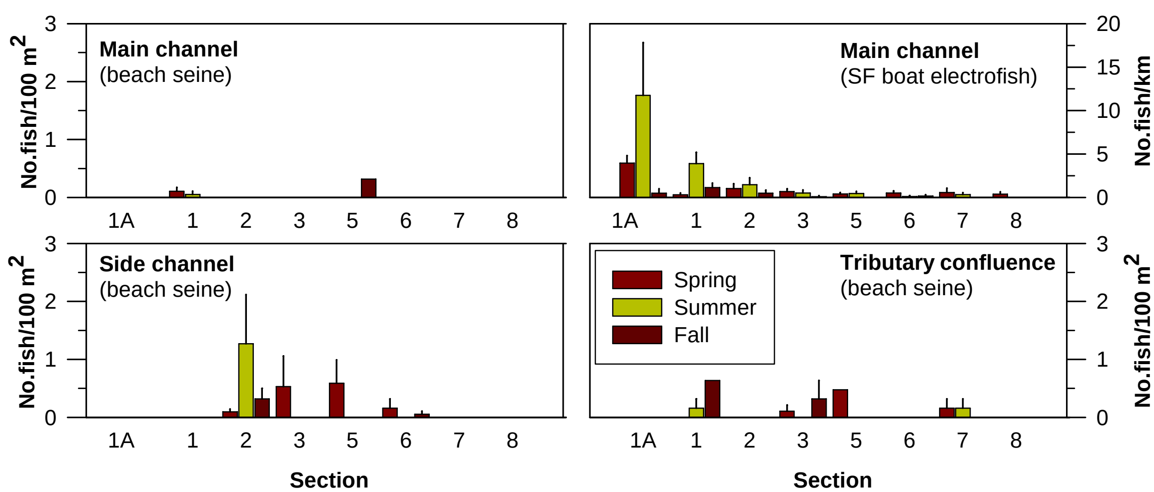


Figure 5.2.21 Average catch rates (± SE) of prickly sculpin in study sections during spring, summer, and fall, 2010 Peace River Fish Inventory (from Mainstream 2011f).

5.2.4.2 Estimates of Abundance

The Peace River Fish Index Project under the administration of BC Hydro Water License Requirements has been monitoring the abundance of three target fish species in the Peace River from 2002 to present – Arctic grayling, bull trout, and mountain whitefish. The program encompasses a 92 km portion of the Peace River from just downstream of the Peace Canyon Dam to downstream of the Moberly River confluence. Sampling occurs in three sections (1, 3, and 5) from late August to late September. Section lengths are 8.2 km (Section 1), 9.4 km (Section 3), and 11.4 km (Section 5).

The sample period was chosen for the following reasons (P&E and Gazey 2003). First, fish catch rates are highest when flows are high and stable. Given the operational regime of the Bennett Dam, September to October has the highest probability to provide the best opportunity for high and stable flows. Second, high water clarity, which improves sampling effectiveness, most often occurs starting in August when tributary inputs are low. Third, late August to September is the period when adult Arctic grayling that use tributary systems for spawning, and to a lesser extent bull trout, are expected to have returned to the mainstem river and mountain whitefish exhibit sedentary behaviour prior to the fall spawning period. Fourth, day length and air temperatures during this period maximize sampling effectiveness by field crews.

Discrete sites are repeatedly sampled (i.e., six sessions) using a boat electrofisher. Each site represented one of two distinct habitat categories -- nearshore habitat with physical cover (SFC) or nearshore habitat without physical cover (SFN). These habitat categories were selected for sampling during initial studies because they represented the two dominant habitat categories in the study area and could be effectively sampled using boat electrofisher (P&E and Gazey 2003). Sampling occurs during daylight hours and is restricted to nearshore areas (i.e., river margins from 0.5 to 2.0 m depth). Boat electrofisher effectiveness on the Peace River is severely reduced beyond a depth of 2.0 m. Larger-sized fish were targeted (> 150 mm fork length). As part of the population estimate component of the study, individuals of target fish species ≥ 250 mm fork length in good condition were marked using Passive Integrated Transponder tags, or "PIT tags". During each year a mark-recapture program was conducted using these data.

<u>Mountain whitefish</u>

The large number of mountain whitefish recaptures allowed for quantitative model selection using POPAN-5 (UFIT module) software for mark-recapture data (Arnason *et al.* 1998). Typically, several thousand fish are marked and several hundred are recaptured (Mainstream and Gazey 2012).

Mountain whitefish abundance in the sampled sections ranged from 6,500 fish to 27,000 fish. The results indicate that there are spatial and temporal differences in mountain whitefish abundance. In general taggable mountain whitefish (≥ 250 mm fork length) are most abundant in Section 1 near Peace Canyon Dam, intermediate in abundance in Section 3 near Halfway River, and least abundant in Section 5 (downstream of the Moberly River (Table 5.2.5). In general mountain whitefish abundance was lowest at the beginning of the index program (2002 and 2003) and highest at the end of the program (2010 and 2011) (Figure 5.2.22).

Table 5.2.5 Population estimates by section for mountain whitefish, 2011 Peace River Fish Index Project (from Mainstream and Gazey 2012).

Section	**Bayesian Mean**	**MLE**	**95% Highest Probability Density**		**Standard Deviation**	**CV (%)**
			Low Hig	**h**		
One	26,671	26,460	23,540	29,940	1,632	6.1
Three	18,710	18,620	17,080	20,400	840	4.5
Five	15,542	15,400	13,620	17,540	998	6.4
Total	60,923		56,828	65,018	2,089	3.4

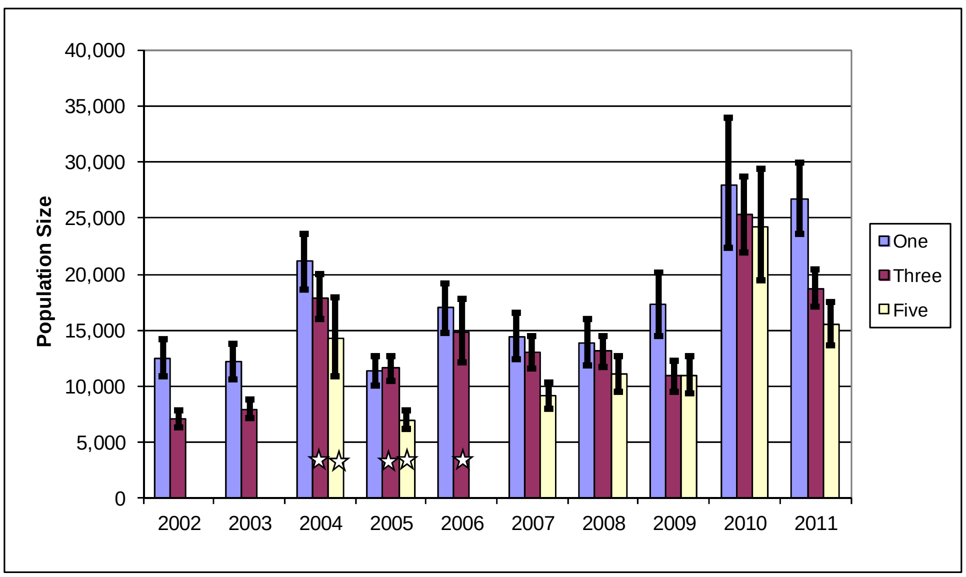


Figure 5.2.22 Mountain whitefish population estimates from 2002 to 2011, Peace River Fish Index Project (vertical lines represent 95% confidence intervals; star indicates suspect population estimate due to violation of assumptions) (from Mainstream and Gazey 2012).

These data represent mountain whitefish abundance in discrete sections. The abundance of mountain whitefish in the entire technical study area can be estimated by applying an estimate of mountain whitefish catchability, which Mainstream and Gazey (2011) deemed to be stable over most years and sections (Figure 5.2.23). The relationship between mountain whitefish population estimate and mountain whitefish boat electrofisher catch rate (i.e., catchability) is 0.00235 ± 0.0004 (95% confidence intervals).

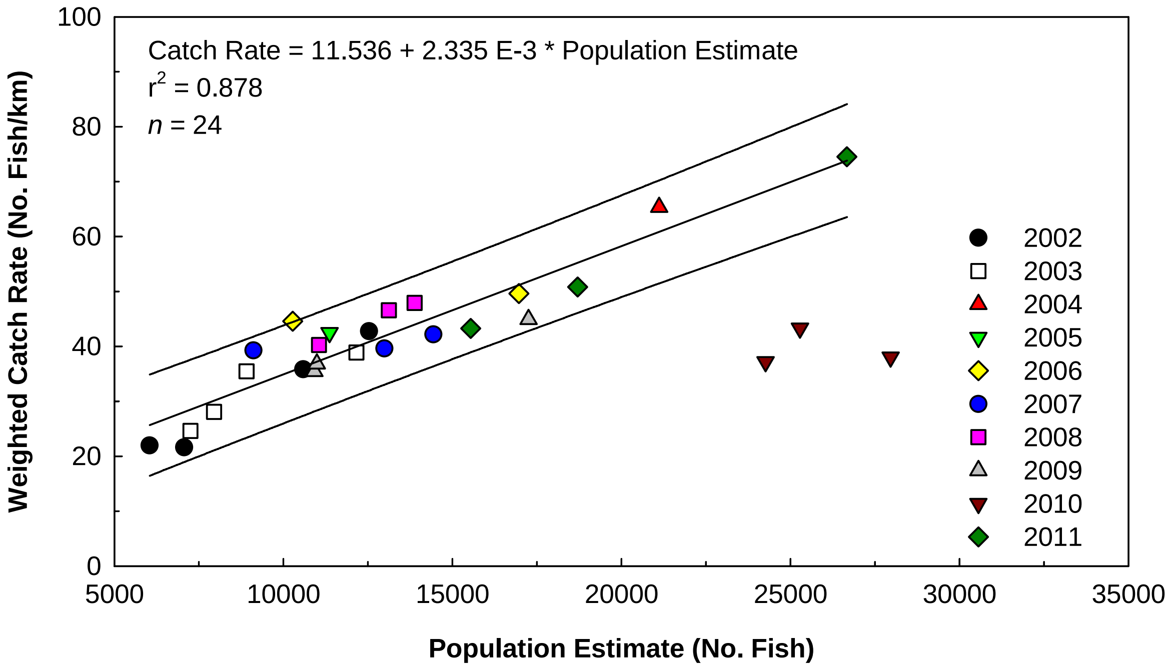


Figure 5.2.23 Relationship between population estimate and catch rate weighted for habitat of mountain whitefish during the Peace River Fish Index Project, 2002 to 2011 (data from 2010 excluded from regression; dashed lines represent 95% prediction intervals (from Mainstream and Gazey 2012).

The catchability estimate from Mainstream and Gazey (2012) and large fish boat electrofisher catch rates from Mainstream 2012a) can be used to calculate the abundance of mountain whitefish (> 200 mm fork length) in the Peace River within the technical study area (Table 5.2.6).

The calculations indicate that there are approximately 275,508 mountain whitefish in the Peace River between the Peace Canyon Dam and the Site C dam location and 86,241 mountain whitefish in the Peace River from the Site C dam location to the Many Islands area, which was the downstream boundary of Section 9. The estimates should be considered minimum values because less than 100% of each section was actually sampled and it represents that portion of the population ≥ 200 mm fork length. In addition, catchability likely was lower than assumed in locations downstream of the Beatton River because water clarity was reduced at the time of sampling (Mainstream 2012a). Based on mountain whitefish numbers and the average weight of processed fish mountain whitefish a rough estimate of mountain whitefish biomass can be calculated. Mountain whitefish biomass is approximately 70,436 kg upstream of the Site C dam location and 29,135 kg downstream of the Site C dam location.

Table 5.2.6 Mountain whitefish abundance and biomass in the Peace River upstream and downstream of the Site C dam location in 2011 (generated from collected by Mainstream 2012a and Mainstream and Gazey 2012).

Zone[a]	Section	Catch Rate (No. fish/ km)[b]	Estimated No. Fish in Section[c]	Population Estimate[d]	Sampled Section Length (km)	Portion of River not Sampled Dwst of Section	No. Fish in Area[e]	Average Weight of Fish (g)	Biomass (kg) of Fish in Area[e]
Upstream	1A	5.87	2,498		2.3	2.2	4,887	231.7	1,133
	1	67.02	28,519	26,671	7.5	12.7	76,812	253.0	194,36
	2	61.76	26,281		5.7	20.3	1198,78	247.1	29,624
	3	45.96	19,557	18,710	9.1	25.3	73,931	273.8	20,243
	Sub-total						*275,508*		*70,436*
Downstream	5	45.88	19,523	15,542	11.4	6.1	29,970	336.0	10,069
	6	36.94	15,719		11.4	8.4	27,302	336.0	9,172
	7	15.75	6,702		13.4	20.1	16,755	340.8	5,710
	8	6.70	2,851		13.7	30.0	9,094	333.6	3,034
	9	7.33	3,119		13.3	0.0	3,119	368.7	1,150
	Sub-total						*86,241*		*29,135*
Total							**361,748**		**99,571**

[a] Description provided in Section 5.2 of this report.
[b] Based on average catch recorded by large fish boat electrofisher in fall in main channel habitats.
[c] Catchability Coefficient = 0.2335 x 10^{-3}, from Mainstream and Gazey (2012).
[d] From Mainstream and Gazey (2012).
[e] Area includes sampled and unsampled portions of the Peace River.

Bull trout

Based on the target species life history characteristics and sampling conditions, the Peace River Fish Index Project is designed to occur from late August to late September (P&E 2002). The annual results of the index program have established that the majority of bull trout collected are subadult fish because adults are in spawning tributaries at the time of sampling, and, the portion of the sample represented by adults varies annually depending on the timing of the post-spawning migration (Mainstream and Gazey 2004 to 2011). As such, population estimates generated by the Peace River Index Project represent subadult abundance rather than adult abundance.

During most sample years, an insufficient number of bull trout are marked and recaptured to permit calculation of precise population estimates (Mainstream and Gazey 2011). Typically, less than one hundred fish are marked and less than one dozen of marked fish are recaptured.

A summary of the 2011 population estimates for the Bayes sequential model are given in Table 5.2.7. The number of bull trout in Section 3 was 331 fish. Because of sparse recoveries in Sections 1 and 5 the estimates were unreliable. Construction of minimum population probability curves inferred a

0.95 probability that the population size was at least 117 and 175 bull trout in Sections 1 and 5, respectively. A bar plot of the population estimates for the 2002 to 2011 studies with sections common to 2011 is provided in Figure 5.2.24.

Table 5.2.7 Population estimates by section for bull trout, 2011 Peace River Fish Index Project (from Mainstream and Gazey 2012).

Section	**Bayesian Mean**	**MLE**	**95% Highest Probability Density**		**Standard Deviation**	**CV (%)**
			Low Hig	**h**		
One	734	176	49	2,504	761	103.7
Three	331	284	177	524	96	29.1
Five	504	266	106	1,226	390	77.3
Total	1,569	969	533	3,178	861	54.8

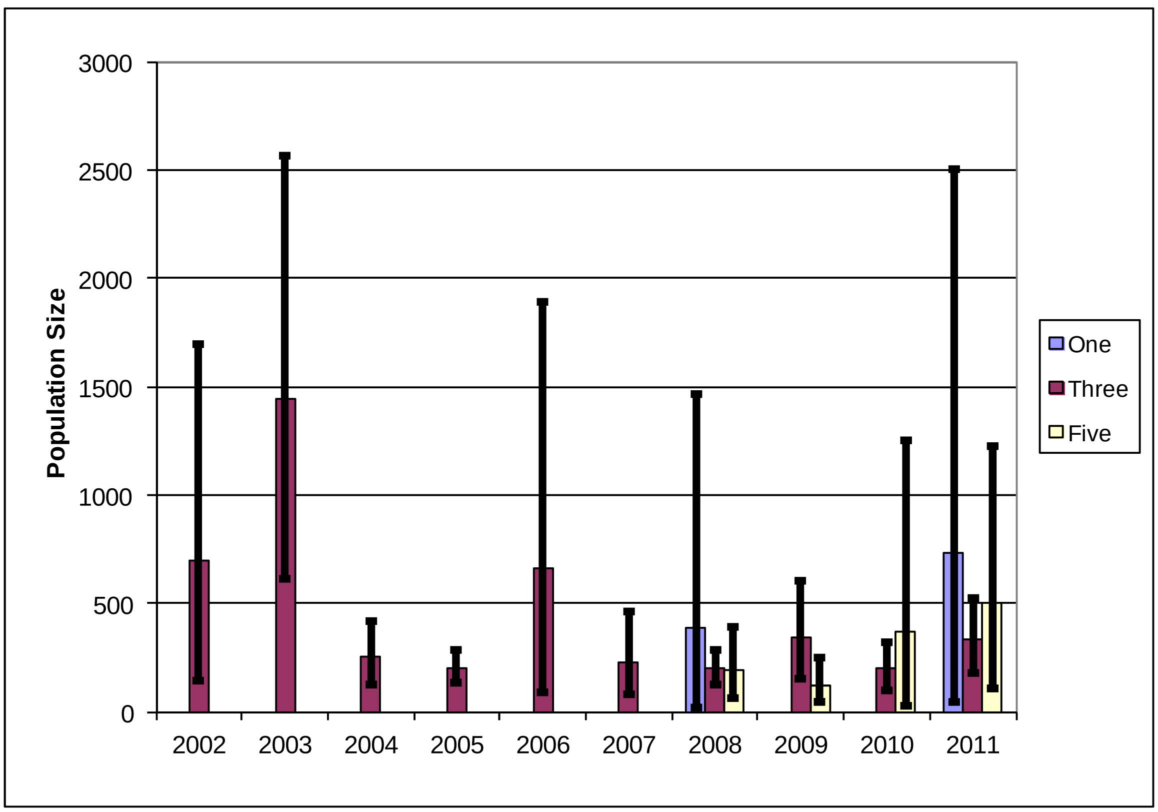


Figure 5.2.24 Bull trout population estimates by section from 2002 to 2011, Peace River Fish Index Project (vertical lines represent 95% confidence intervals) (from Mainstream and Gazey 2012).

Figure 5.2.24 indicates that bull trout population estimates with a reasonable amount of precision (coefficient of variation ≤ 25%) were achievable only for Section 3 during some years. For years with reasonably precise estimates, the population of subadult bull trout in Section 3 is approximately 275 fish.

Extrapolation of the bull trout population estimate data from Section 3 to the entire Peace River technical study area is not deemed appropriate because spatial differences in bull trout catch rates provides strong evidence differing abundance (see Section 5.2.4.1 of this report). Work completed by Mainstream and Gazey (2009) documented a significant correlation between mountain whitefish catch rate and bull trout catch rate using data collected from 2002 to 2008. The correlation was statistically significant in Section 5 (Pearson correlation 0.960, p = 0.020) and Section 3 (Pearson correlation 0.898, p = 0.049), but not in Section 1 (Pearson correlation -0.102, p = 0.414). The authors hypothesized that the absence of young mountain whitefish in Section 1 was a possible reason for the lack of a correlation.

If bull trout catch rates are highly correlated with mountain whitefish catch rates, then inferences can be made about spatial trends in bull trout numbers in the technical study area using the mountain whitefish numbers presented in Table 5.2.6. A plot of bull trout and mountain whitefish catch rates recorded in 2011 in Peace River sections sampled in fall by Mainstream (2012a) demonstrates a strong linear positive relationship (Figure 5.2.25). The one outlier is Section 1. The correlation is statistically significant (Pearson correlation 0.732, p = 0.013 [Section 1 included]; Pearson correlation 0.964, p = 0.013 [Section 1 excluded]). The results corroborate the findings of Mainstream and Gazey (2009).

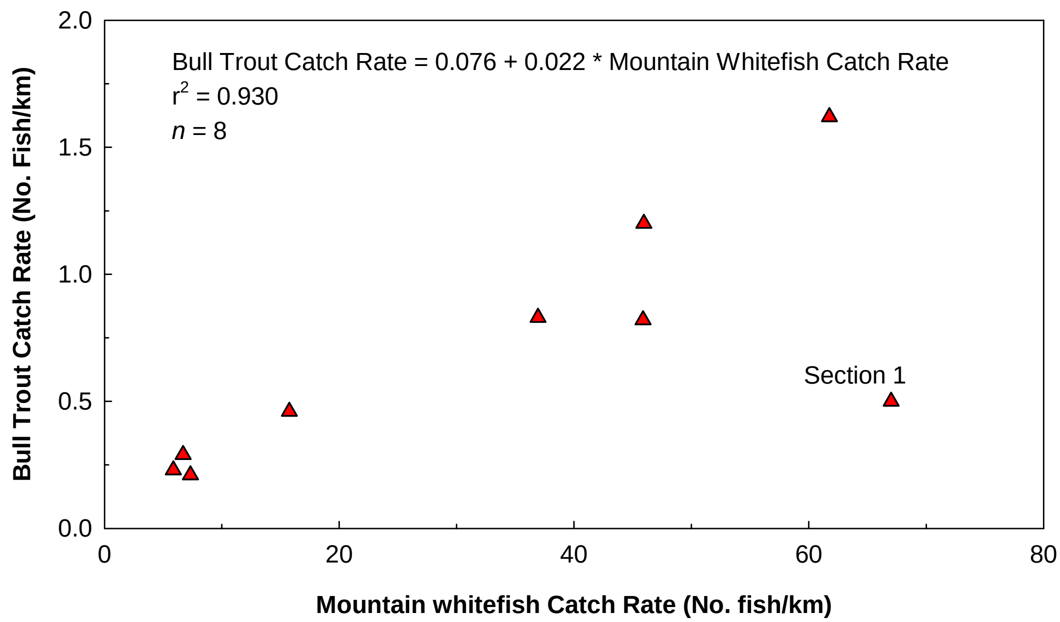


Figure 5.2.25 Relationship between mountain whitefish catch rate and bull trout catch rate in the large fish boat electrofisher catch from main channel habitats in fall 2010 (data from Mainstream 2011f; Section 1 omitted from analysis).

This relationship may reflect changes in bull trout catchability based on the availability of mountain whitefish prey in areas sampled the large fish boat electrofisher. Or, it represents an actual index of bull trout abundance in a sampled area. If one assumes that the latter explanation is correct and bull trout catchability is stable, then mountain whitefish numbers presented in Table 5.2.6 can be used to calculate bull trout numbers in the Peace River technical study area by applying the relationship between bull trout and mountain whitefish catch rates.

Application of the equation presented to mountain whitefish numbers presented in Table 5.2.6 indicates that there are potentially 2,787 bull trout in sampled sections of the Peace River study area and 8,079 bull trout in the entire Peace River technical study area (Table 5.2.8). Of these fish 6,152 bull trout are present upstream of the Site C dam location, or 76% of the Peace River population.

Table 5.2.8 Bull trout abundance in the Peace River upstream and downstream of the Site C dam location in 2011 (generated from data presented in Mainstream 2012a and Mainstream and Gazey 2012).

Zone[a]	**Section**	**Number Mountain whitefish in Section[b]**	**Number Mountain whitefish in River Area[b,d]**	**Number Bull trout in River Section[c]**	**Number Bull trout in River Area[c,d]**
Upstream	1A	2,498	4,887	56	109
	1	28,519	76,812	637	1,715
	2	26,281	119,878	587	2,677
	3	19,557	73,931	437	1,651
	Sub-total	*76,855*	*275,508*	*1,716*	*6,152*
Downstream	5	19,523	29,970	436	669
	6	15,719	27,302	351	610
	7	6,702	16,755	150	374
	8	2,851	9,094	64	203
	9	3,119	3,119	70	70
	Sub-total	*47,915*	*86,241*	*1,070*	*1,926*
Total 2,				**787**	**8,079**

[a] Description provided in Section 5.2 of this report.
[b] From Table 5.2.6.
[c] Calculated using linear function presented in Figure 5.2.25.
[d] Area includes sampled and unsampled portions of the Peace River.

Arctic grayling

Low numbers of Arctic grayling have recorded during all years of the Peace River Fish Index Project. During most sample years, an insufficient number of fish are marked and recaptured to permit calculation of precise population estimates (Mainstream and Gazey 2011). Typically, less than several dozen taggable fish are marked and less than one dozen of marked fish are recaptured. In addition, taggable Arctic grayling are rarely encountered in Section 1 (Mainstream 2010a, 2011f, 2012a; Mainstream and Gazey 2012).

A summary of the 2011 population estimates for the Bayes sequential model are given in Table 5.2.9 for Sections 3 and 5 (Mainstream and Gazey 2012). A bar plot of the historical population estimates of sections common to 2011 are provided in Figure 5.2.26.

Table 5.2.9 Population estimate in Sections 3 and 5 for Arctic grayling, 2011 Peace River Fish Index Project (from Mainstream and Gazey 2012).

Section	**Bayesian Mean**	**MLE**	**95% Highest Probability Density**		**Standard Deviation**	**CV (%)**
			Low Hig	**h**		
Three	230	172	91	428	94	40.9
Five	66	58	41	97	15	23.1
Total	296	240	151	492	95	32.2

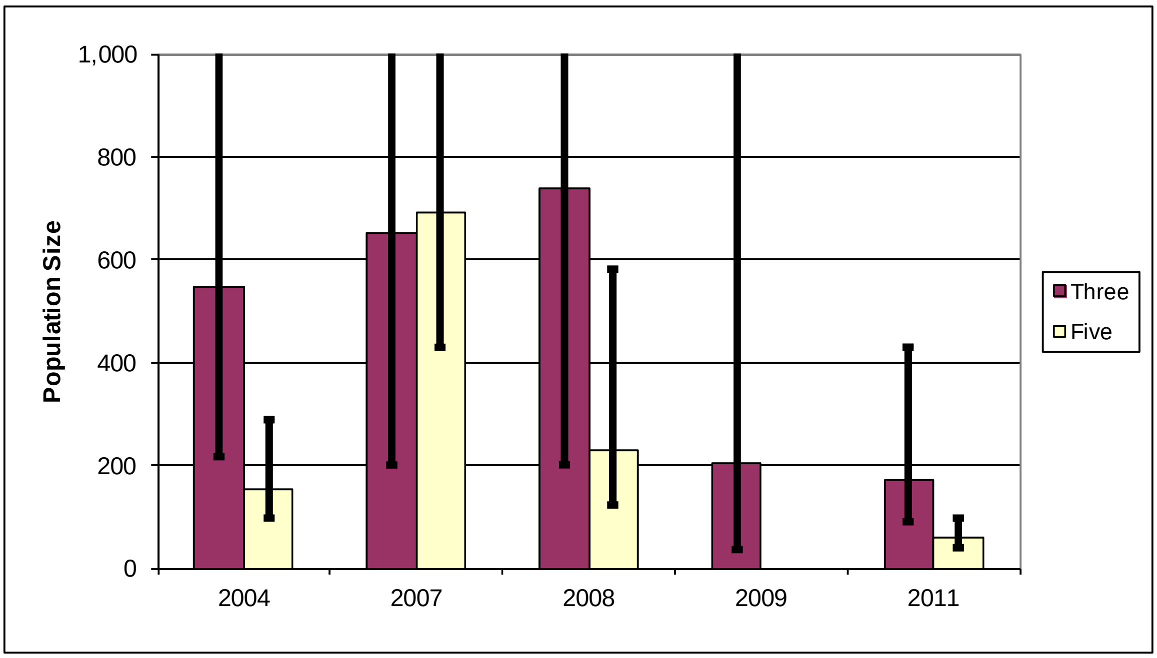


Figure 5.2.26 Arctic grayling population estimates by section for 2004, 2007, 2008, 2009, and 2011, Peace River Fish Index Project (vertical lines represent 95% confidence intervals) (from Mainstream and Gazey 2012).

The Arctic grayling section population estimates ranged from 66 fish to 750 fish; however in most years the precision of the estimate is very low. The most precise estimate was 66 fish in Section 5 in 2011 (coefficient of variation = 23.1%).

Arctic grayling catch rates recorded by fish inventories on the Peace River (Mainstream 2010a, 2011f, 2012a) are consistent with catch rates of the Peace River Fish Index Project; therefore, adult Arctic grayling are not abundant in the Peace River portion of the technical study area.

5.3 TRIBUTARIES

5.3.1 General Tributary Surveys

AMEC and LGL (2008a) and Mainstream (2009c) completed fish inventories of Peace River tributaries affected by the Site C Clean Energy Project. The study results were similar. The following is a summary of the Mainstream (2009c) information.

The study area included eight tributaries of the Peace River located upstream of the Site C dam location (Table 5.3.1). The study area on each tributary included Upper and Lower tributary sections delineated by AMEC and LGL (2008a), which are located upstream and downstream of the Site C reservoir inundation level.

Table 5.3.1 Study tributaries and sampled sections, 2008 tributaries juvenile fish summer survey (from Mainstream 2009c).

Tributary Section		Section Location (km)	Inundation Location[a] (Km)
Maurice Creek	Lower Upper	Km 0.0 to 0.83 Km 0.83 to 1.86	0.83
Lynx Creek	Lower Upper	Km 0.0 to 1.19 Km 1.19 to 2.04	1.19
Farrell Creek	Lower Upper	Km 0.0 to 3.39 Km 3.39 to 4.28	3.39
Halfway River	Lower Upper	Km 0.0 to 13.45 Km 13.45 to 42.83	13.45
Cache Creek	Lower Upper	Km 0.0 to 7.02 Km 7.02 to 11.09	7.02
Red Creek[b]	Lower Upper	Km 0.0 to 1.99 Km 1.99 to 2.59	1.99
Wilder Creek	Lower	Km 0.0 to 2.51	2.51
Moberly River	Lower Upper	Km 0.0 to 9.11 Km 9.11 to 21.43	9.11

[a] Distance from confluence with the Peace River; assumes reservoir elevation of 461.8 m.

[b] Tributary to Cache Creek located 4.68 km upstream from confluence with the Peace River.

5.3.1.1 Species Composition

In total, 20 fish species were recorded in the study tributaries (Table 5.3.2). There was representation by sportfish (6 species), suckers (3 species), minnows/trout-perch (8 species), and sculpins (3 species). There was a range in the number of species recorded in each tributary, which was generally correlated with stream size. Two species were recorded from Red Creek which is a tributary to Cache Creek (smallest tributary), while 18 species were recorded in the Halfway River (largest tributary). Maurice Creek, Lynx Creek, Farrell Creek, and Cache Creek were of similar size and most (all except Maurice Creek) contained between 11 and 12 fish species. Seven species were encountered in Maurice Creek, which reflected the absence of several minnow species. Wilder Creek was not sampled during the summer survey because the Lower Section was dry; however, six species were recorded in this tributary in May during spring sampling (Mainstream 2009a).

Table 5.3.2 Fish species distribution and relative abundance in study tributaries, 2008 tributaries juvenile fish summer survey (from Mainstream 2009c).

Group	Species	Maurice Creek	Lynx Creek	Farrell Creek	Cache Creek	Red Creek	Moberly River	Halfway River
Sportfish	Arctic grayling						x	x
	Bull trout							x
	Burbot						X	x
	Mountain whitefish	x	x	x	X		x	X
	Northern pike							x
	Rainbow trout	**X**[a]	X	X				x
Suckers	Longnose sucker	X	X	X	X	X	**X**	X
	Largescale sucker		x	x	x		x	x
	White sucker				x			
Minnows/ Trout-perch	Flathead chub		x	x				x
	Lake chub		**X X**		**X**	**X**	x	x
	Longnose dace	X	x	x	x		X	x
	Northern pikeminnow		x	x	x		x	x
	Northern redbelly dace						x	
	Peamouth			x	x		x	x
	Redside shiner		x	x	x		x	**X**
	Trout-perch							x
Sculpins	Prickly sculpin	x	X	X	X		x	x
	Slimy sculpin	X	x	x			X	X
	Spoonhead sculpin	x			x		x	x
Number of Species		**7**	**11 12**	**11**		**2**	**14**	**18**

[a] X denotes most numerous species in the group; **X** denotes most numerous species in the tributary.

5.3.1.2 Distribution and Abundance

Species distribution and abundance varied among streams. Of the sportfish group, Arctic grayling was recorded only in the Moberly River and the Halfway River. Rainbow trout were recorded in four tributaries, but was numerically important only in Maurice Creek, Lynx Creek, and Farrell Creek. It was the dominant species in Maurice Creek. Mountain whitefish were widely distributed (recorded in 6 tributaries), but this species was abundant only in the Halfway River. It should be noted that the scarcity of mountain whitefish in the Moberly River ($n = 15$) may have been an artifact of the fish capture technique (backpack electrofisher), which may not have been effective in this moderate sized stream.

Other investigations have recorded large numbers of YOY mountain whitefish dispersing from this tributary in fall (Mainstream 2009b).

Other sportfish species including bull trout, burbot, and northern pike were recorded only in the two large tributaries (Moberly River and/or the Halfway River) and of these neither bull trout nor northern pike were abundant. Tributaries to the upper Halfway River system are important spawning and early rearing areas for bull trout (Baccante 2007); however, the present study area was well downstream of these systems. Burbot were rare in the Halfway River (n = 2), but were the dominant sportfish in the Moberly River. This species was not overly abundant at any particular location, but was widely distributed throughout the surveyed area, which suggested that the Moberly River may provide important rearing habitat for burbot.

Longnose sucker was the dominant species in the sucker group. This fish was widespread and numerically abundant in all study tributaries. Largescale sucker was recorded in five study tributaries. This species was abundant in Farrell Creek, Cache Creek, and the Halfway River. White sucker was recorded only in Cache Creek and it was not abundant.

Four of the species in the minnows/trout-perch group were widespread and abundant. These were lake chub, longnose dace, northern pikeminnow, and redside shiner. Lake chub was the numerically dominant species in four tributaries (Lynx Creek, Farrell Creek, Cache Creek, Red Creek), while redside shiner was the dominant fish species in the Halfway River. Longnose dace was the dominant minnow species in Maurice Creek and the Moberly River, and was very abundant in the Halfway River, three tributaries that contained large amounts of cobble bed material.

Other minnow species such as flathead chub, northern redbelly dace, peamouth, and the trout-perch were not as widely distributed or as abundant as other species in this group. Northern redbelly dace were recorded only in the Moberly River, while trout-perch were recorded only in the Halfway River.

Sculpins were recorded in most study tributaries except Red Creek, but were considered abundant only in Maurice Creek, Moberly River, and Halfway River. Slimy sculpin was the dominant species in these three tributaries, while prickly sculpin dominated in Lynx Creek, Farrell Creek, and Cache Creek. Spoonhead sculpin was present in four tributaries, but it was scarce in all systems except the Moberly River.

Mainstream (2009c) found that the species assemblages were generally similar among Upper and Lower sections of the study tributaries. However, there were spatial differences in the abundance of a particular species within each tributary. In Maurice Creek, rainbow trout were three times as numerous in the Upper Section compared to the Lower Section. In Lynx Creek, the four numerically dominant species (rainbow trout, longnose sucker, lake chub, and longnose dace) exhibited higher catch rates in the Upper Section than in the Lower Section. In Farrell Creek, the opposite trend occurred. Species that preferred riffle/run habitats with cleaner rock materials (e.g., rainbow trout, mountain whitefish, longnose sucker, longnose dace, slimy sculpin, and prickly sculpin) were more abundant in the Lower Section compared to the Upper Section. No strong spatial differences in fish abundance were recorded in Cache Creek, Red Creek, or Moberly River.

Mainstream (2009c) found that coldwater sportfish were not evenly distributed in the Halfway River. Species such as bull trout, rainbow trout, and Arctic grayling were recorded only in the Upper Section. In general, catch rates of most species were higher in the Upper Section compared to the Lower Section; however, differences in sampling effectiveness caused by changes in water clarity, may explain the results.

Mainstream (2009c) made comparisons to other studies. Several investigations have inventoried fish communities in the study tributaries. Surveys completed by Pattenden *et al.* (1990, 1991), ARL (1991a, 1991b), RL&L (2001), P&E (2002), AMEC and LGL (2008a), and Mainstream (2009a) all documented fish use of tributaries in summer. Despite the extended sample period (1989 to 2006) the findings of those investigations were very consistent with the results of Mainstream (2009c) in terms of species composition, distribution, and relative abundance.

An investigation by Mainstream (2009a) in summer 2006 examined fish distribution and abundance in the Upper and Lower sections of the Halfway River. One important finding of that study was the spatial difference in the abundance of mountain whitefish. High densities of Age 0 mountain whitefish were recorded in the Lower Section suggesting that that portion of the Halfway River was an important rearing area. The results of the present study did not identify spatial differences in mountain whitefish abundance.

5.3.1.3 Summary

Mainstream (2009c) described juvenile fish use and habitat characteristics of eight tributaries to the Peace River during summer and reviewed results of previous investigations. Mainstream (2009c) monitored environmental conditions (general water quality, water temperature, and discharge), measured physical characteristics of habitats, and described the small fish community (composition, distribution, and abundance). The study also compared tributary sections located upstream and downstream of the Site C reservoir inundation level. The summary discussion by Mainstream (2009c) is presented below.

Environmental characteristics of the study tributaries influenced the availability and quality of juvenile fish habitats, and likely was the primary factor that explained the fish community that was recorded in each stream. High summer water temperatures in the small tributaries, Farrell Creek, Cache Creek, Red Creek, and Wilder Creek probably limited use by coldwater fish species such as rainbow trout, bull trout, Arctic grayling, and mountain whitefish. High summer water temperatures were not as severe in Maurice Creek, Lynx Creek, Moberly River, and Halfway River. Discharge in all study tributaries was high in spring, but declined to base flow conditions by summer. The relationship between bankfull width and wetted width suggested highly variable flows. Low flows in all small streams during the study reduced the availability and quantity of juvenile fish habitat. This was particularly evident in Cache Creek and Red Creek (standing water) and Wilder Creek (no surface water). There also was evidence of high sediment loads in all tributaries, which can be detrimental to young fish of all species recorded during the survey.

The physical characteristics of juvenile fish habitats in the study tributaries were influenced primarily by low flow conditions at the time of the survey and relative stream size. For example low flows limited the surface area of the wetted channel (i.e., fish habitat) and small tributaries were more strongly affected than large tributaries. The physical characteristics of fish habitats were generally similar among study tributaries and among sections within tributaries. Habitats were dominated by riffle/pool-run complexes and bed materials were dominated by pebbles/gravels and cobbles. The quality of rock substrates was generally reduced by embeddedness and compaction caused by sedimentation. These characteristics indicated that the tributaries are suitable for juvenile fish use, but the quality of those habitats was not optimal. As stated earlier, environmental conditions such as water temperature, discharge, and sediment load also had a strong influence on juvenile fish use.

Twenty fish species were recorded during the study, which represented four groups that included sportfish, suckers, minnows/trout-perch, and sculpins. In general, the relative importance of a particular species, in terms of numbers recorded, varied among tributaries, but the species assemblage did not vary substantially among sections within a tributary. Notable findings of the study were as follows:

1. Suckers and minnows were the numerically dominant groups in most tributaries.
2. Sculpins were widely distributed in the study tributaries, but substantial numbers were recorded only in Maurice Creek, Moberly River, and Halfway River.
3. Juvenile bull trout did not use the inventoried sections of the study tributaries; other investigations have identified the upper Halfway River system as important bull trout rearing habitat.
4. Maurice Creek, and to a lesser extent Lynx Creek and Farrell Creek, provided habitat for juvenile rainbow trout. The remaining small tributaries did not.
5. Young Arctic grayling were recorded only in the Moberly River and the Halfway River. This was evidence that both systems provided rearing habitat for this species; the small tributaries do not provide Arctic grayling rearing habitat.
6. Substantial numbers of young burbot were recorded in the Moberly River suggesting that the system was important for juvenile burbot. This was a new finding not documented by previous studies.
7. Few young mountain whitefish were recorded in the small tributaries indicating limited use as juvenile habitat; however, the Moberly River and the Halfway River were important rearing areas for this species.

5.3.2 Large Tributary Surveys

The work by Mainstream in 2008 (Mainstream 2009c) was followed by a series of more extensive summer fish surveys of the Moberly River and Halfway River (Mainstream 2010b, 2011a, 2012b). The purpose of these studies was to collect baseline information to describe fish communities of the mainstem Moberly River and mainstem Halfway River from the headwater areas to the confluence of the Peace River, with the primary focus being young sportfish. The objectives related to the fish community were as follows:

1. Sample the small fish community during summer in sections distributed from the headwater area to the Peace River confluence. Small fish are defined as ≤ 200 mm length.
2. Quantify the physical characteristics of sampled habitats.
3. Collect and record the incidental catch of large fish to document the presence of resident fish populations. Large fish are defined as > 200 mm length.

5.3.2.1 Moberly River

The following presents the results by Mainstream (2010b). Mainstream (2010b) was selected because sampling conditions on the Moberly River were ideal and a variety of sampling methods were employed.

Note that zone designations by Mainstream (2010b) correspond to the Reach designations in Section 4.2.2 as follows:

Zone 1 = Reach 3
Zone 2 = Reach 2
Zone 3 = Reach 1B
Zone 4 = Reach 1A (inundation area)

Species Composition

In total, 4506 fish were recorded during the small fish survey on the Moberly River (Table 5.3.3). The sample consisted of 16 species, which included 6 sportfish, 3 suckers, 5 minnows, and 2 sculpin species.

Table 5.3.3 Number and percent composition of fish species recorded in the Moberly River, Halfway River and Moberly River summer fish survey 2009 (from Mainstream 2010b).

Group Species		Number	Percent
Sportfish	Arctic grayling	106	2.4
	Bull trout	1	< 0.1
	Burbot	119	2.6
	Lake whitefish	1	< 0.1
	Mountain whitefish	1,145	25.4
	Northern pike	64	1.4
	Subtotal	*1,436*	*31.9*
Suckers	Largescale sucker	114	2.5
	Longnose sucker	975	21.6
	White sucker	153	3.4
	Subtotal	*1,242*	*27.6*
Minnows/Trout-perch	Lake chub	139	3.1
	Longnose dace	547	12.1
	Northern pikeminnow	36	0.8
	Redside shiner	784	17.4
	Trout-perch	66	1.5
	Subtotal	*1,572*	*34.9*
Sculpins	Prickly sculpin	5	0.1
	Slimy sculpin	251	5.6
	Subtotal	*256*	*5.7*
Total 4,		**506**	**100.0**

Sportfish accounted for 31.9% of the total sample. Mountain whitefish numerically dominated with 25.4% of the total sample. The remaining sportfish, which included burbot 2.6%, Arctic grayling 2.4%, and northern pike 1.4%, were well represented. Only one bull trout and one lake whitefish were captured during the program.

Suckers accounted for 27.6% of the total sample. Longnose sucker was the most abundant species in this group (21.6%), followed by white sucker (3.4%), and largescale sucker (2.5%). Minnows were the dominant group (34.9%) in the total sample. The minnow group was dominated by redside shiner (17.4%) and longnose dace (12.1%). The remaining minnow species each accounted for ≤ 3.1% of the total sample. These included lake chub, northern pikeminnow, and trout-perch. The sculpin group accounted for 5.7% of the total sample. Of the two species recorded, slimy sculpin numerically dominated (5.6%), while prickly sculpin was scarce (0.1%).

<u>Species Diversity and Distribution</u>

Of the 16 fish species recorded on the Moberly River, no more than 13 species were located in any one zone or section (Table 5.3.4). The uppermost (Section 1) and lowermost sections (Sections 8, 9, and 10) had slightly fewer species than the middle sections of the study area (11 versus 13 species, respectively).

Table 5.3.4 Fish species distribution present in each section of the Moberly River, Halfway River and Moberly River summer fish survey 2009 (from Mainstream 2010b).

Group Species		**Zone and Section**									
		1 2						**3**			**4**
		1	**2**	**3 4**		**5 6**		**7**	**8 9**		**10**
Sportfish	Arctic grayling	x	x	x	x	x	x	x	x	x	x
	Bull trout										x
	Burbot	x	x	x	x	x	x	x	x	x	x
	Lake whitefish		x								
	Mountain whitefish	x	x	x	x	x	x	x	x	x	x
	Northern pike	x	x	x	x	x	x	x		x	
Suckers	Largescale sucker						x	x	x	x	x
	Longnose sucker	x	x	x	x	x	x	x	x	x	x
	White sucker	x	x	x	x	x	x	x			
Minnows/ Trout-perch	Lake chub			x	x	x	x	x	x	x	x
	Longnose dace	x	x	x	x	x	x	x	x	x	x
	Northern pikeminnow					x	x	x	x	x	x
	Redside shiner	x	x	x	x	x	x	x	x	x	x
	Trout-perch	x	x	x	x	x	x	x	x		
Sculpins	Prickly sculpin	x	x	x							
	Slimy sculpin	x	x	x	x	x	x	x	x	x	x
No. of Species per	Section	***11***	***12***	***12***	***11***	***13***	***13***	***13***	***11***	***11***	***11***
	Zone	***12***		***13***				***13***			***11***

Ten species were widely distributed and were recorded in most sections. These included Arctic grayling, burbot, mountain whitefish, northern pike, longnose sucker, lake chub, longnose dace, redside shiner, trout-perch, and slimy sculpin. A small number of species (3) were primarily restricted to the upper portion of the study area. Lake whitefish were recorded only in Section 2, white sucker occurred in Sections 1 through 7, and prickly sculpin were recorded in Sections 1 to 3. The remaining three species occurred only in the lower portion of the study area. Bull trout were recorded only in Section 10, largescale sucker occurred in Sections 6 to 10, while northern pikeminnow were in Sections 5 to 10.

Catch Rates

The survey targeted small fish ≤ 200 mm length. Catch rates generated using the three fish capture methods varied according to fish group. Species in the sportfish and sucker groups were most frequently encountered and catch rates were highest using boat electrofisher and backpack electrofisher

(Figure 5.3.1). Species in these groups were rarely captured using beach seines. The only exceptions were northern pike, longnose sucker, and unidentified young-of-the-year suckers.

In general, species in the minnow and sculpin groups were recorded using all three fish capture methods; however, fish were most frequently encountered and exhibited highest catch rates using backpack electrofisher, followed by boat electrofisher, and beach seine methods (Figure 5.3.2).

Sportfish

Arctic grayling mean catch rates per section in the boat electrofisher catch varied from 0.33 fish/km to 3.54 fish/km. Arctic grayling catch rates were low in the upper portion of the study area (Sections 1 and 2) and in the lowermost portion of the study area (Section 10). Highest catch rates occurred in Sections 6 to 8. Backpack electrofisher catch rates were highly variable, as evidenced by the large range (i.e., 0 fish/100 m to 1 fish/100 m).

Burbot catch rates ranged from 0.17 fish/km to 5.11 fish/km in the boat electrofisher catch and 0.20 fish/100 m to 2.14 fish/100 m in the backpack electrofisher catch. In the boat electrofisher catch, burbot catch rates were highest in upstream Sections 1 to 6, but were very low in downstream Sections 7 to 10. Although variable, backpack electrofisher burbot catch rates were similar among sections.

Mountain whitefish were consistently encountered only with the boat electrofisher. Mean catch rates were high in all sections (range = 7.78 fish/km to 22.21 fish/km). Mountain whitefish catch rates varied spatially. Catch rates were approximately 10 fish/km in upper Sections 1 to 4. They increased to above 15 fish/km in Sections 5 to 8, and then progressively declined to 6.66 fish/km by Section 10.

Northern pike catch rates were low. Mean catch rates at sites that contained fish ranged from 0.15 fish/km to 2.00 fish/km using boat electrofisher and 0.15 fish/100 m to 1.08 fish/100 m using the backpack electrofisher. Northern pike were largely restricted to upper Sections 1 to 6.

Suckers

Largescale suckers catch rates were low in the study area and this species was only encountered downstream of Section 5. Mean catch rates at sites that contained fish ranged from 0.17 fish/km to 1.85 fish/km using boat electrofisher and 0.15 fish/100 m to 1.49 fish/100 m using the backpack electrofisher. Largescale sucker catch rates exhibited a spatial pattern.

Catch rates of longnose suckers were second only to mountain whitefish and this species was recorded in all sections. Mean catch rates at sites that contained fish ranged from 1.11 fish/km to 18.23 fish/km in the boat electrofisher catch and 1.72 fish/100 m to 4.57 fish/100 in the backpack electrofisher catch. The spatial pattern of longnose sucker boat electrofisher catch rates was similar to that of mountain whitefish. Boat electrofisher catch rates were ≤ 3.84 fish/km in upper Sections 2 to 4. They increased to above 14 fish/km in most sections between Sections 5 to 8 (all except Section 6), and then declined to 8.77 fish/km by Section 10.

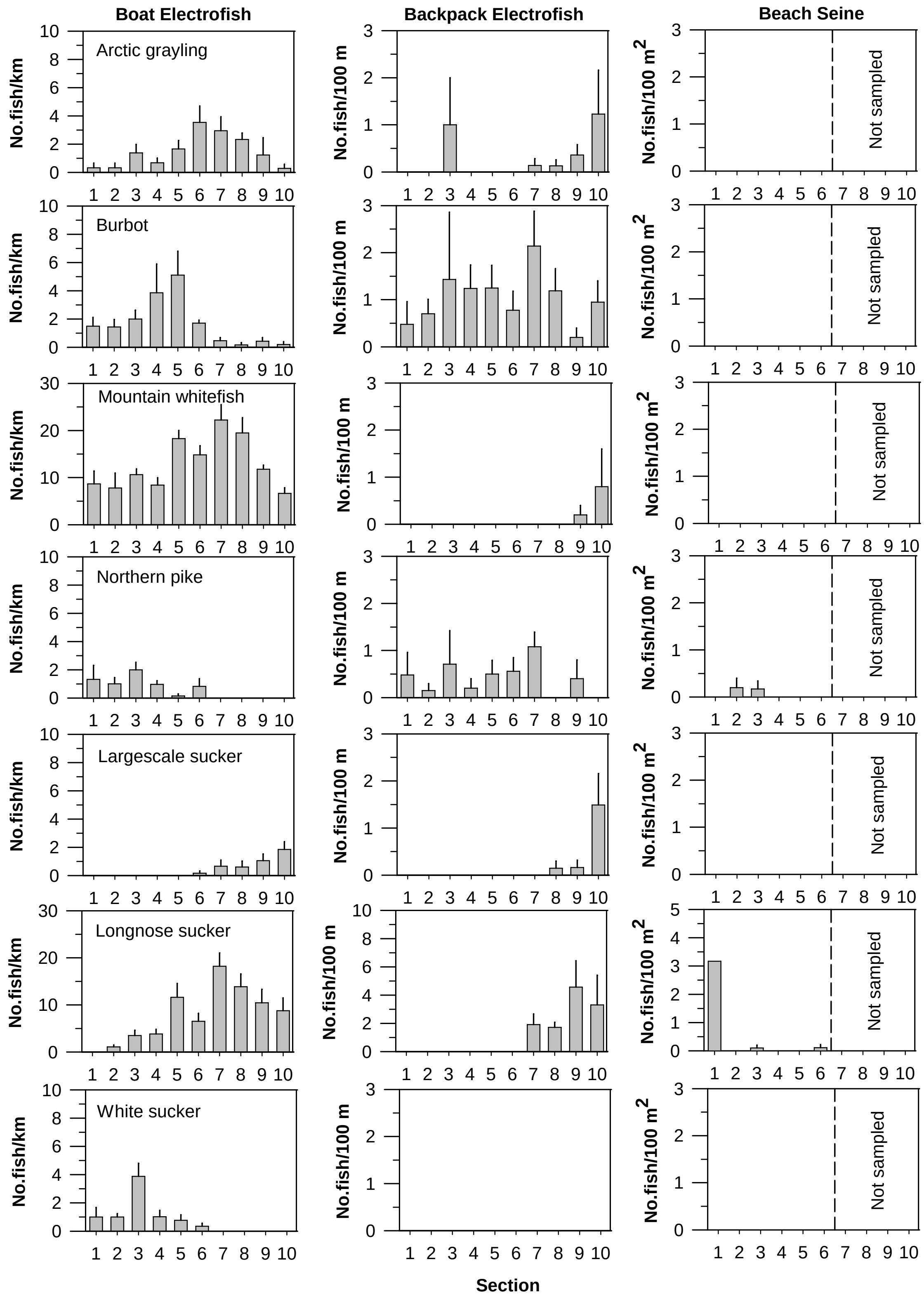


Figure 5.3.1 Catch rates (mean ± SE) of young (≤ 200 mm length) large-fish species in sampled sections on the Moberly River, Halfway River and Moberly River summer fish survey 2009 (from Mainstream 2010b).

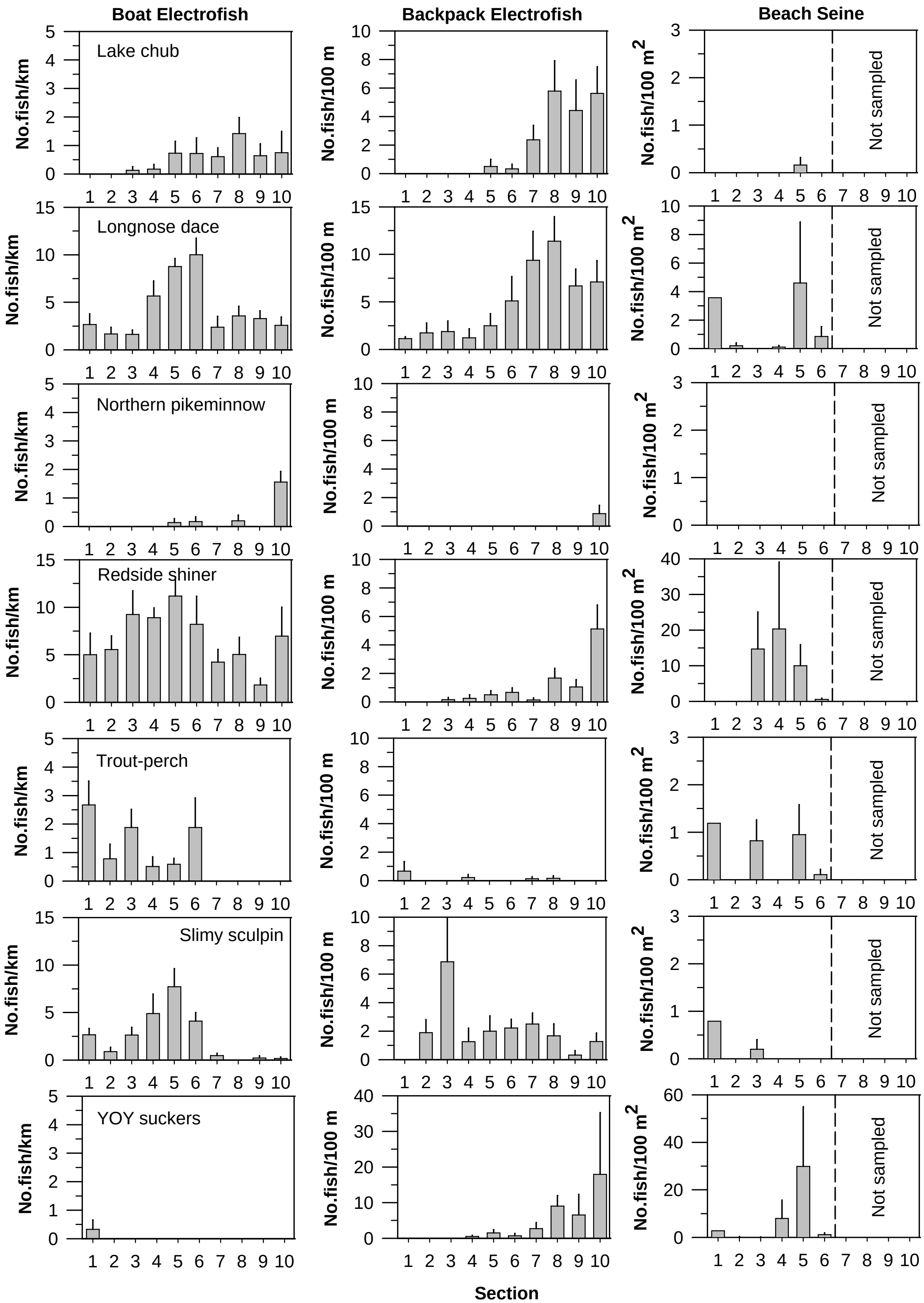


Figure 5.3.2 Catch rates (mean ± SE) of small-fish species in sampled sections on the Moberly River, Halfway River and Moberly River summer fish survey 2009 (from Mainstream 2010b).

Catch rates of white suckers were low. Mean boat electrofisher catch rates at sites that contained fish ranged from 0.35 fish/km to 3.88 fish/km. White suckers were restricted to upper Sections 1 to 6. There was a weak trend of declining catch rate from upstream to downstream.

Minnows and Sculpins

In the minnow group catch rates of redside shiner and longnose dace were high and these two species were widespread in the study area. In the sculpin group slimy sculpin exhibited the highest catch rates and were widespread. The spatial pattern of catch rates varied by species. Redside shiner, longnose dace, and slimy sculpin boat electrofisher catch rates tended to be highest in Sections 3 to 6. Lake chub and northern pikeminnow catch rates were higher in the downstream Sections 5 to 10. In contrast, trout-perch catch rates tended to be highest from Sections 1 to 6.

5.3.2.2 Halfway River

The following presents the results by Mainstream (2011a). Mainstream (2011a) was selected because sampling conditions on the Halfway River were good and a variety of sampling methods were employed. Note that reach designations by Mainstream (2011a) correspond to reach designations in Section 4.2.2.

<u>Species Composition</u>

In total, 8,481 fish were recorded during the small fish survey on the Halfway River (Table 5.3.6). The sample consisted of 20 species, which included 8 sportfish, 2 suckers, 7 minnows, and 3 sculpin species. Sportfish accounted for 22.9% of the total sample. The sportfish group was dominated by mountain whitefish, which accounted for 19.5% of the total sample. Arctic grayling (1.2%), bull trout (1.2%), and rainbow trout (0.9%), also were represented. The remaining sportfish, including 1 kokanee, 6 burbot, 3 northern pike, and 1 walleye were scarce.

Suckers were the dominant group and accounted for 37.1% of the total. Longnose sucker numerically dominated with 28.7% of the total. Largescale suckers accounted for 8.3% of the total sample.

Minnows were the second most numerically dominant group (35.8%) in the total sample. Longnose dace (17.9%), redside shiner (10.5%), lake chub (4.9%), and northern pikeminnow (2.4%) were numerically dominant. The remaining minnow species, flathead chub, northern redbelly dace, and trout-perch, each accounted for < 0.1% of the total sample. The sculpin group accounted for 4.2% of the total sample. Slimy sculpin numerically dominated the group (4.1%), while prickly sculpin (n = 6) and spoonhead sculpin (n = 2) were scarce.

Table 5.3.6 Number and percent composition of fish species recorded in the Halfway River, 2010 Moberly River and Halfway River Fish Inventory 2010 (from Mainstream 2011a).

Group Species		**Number**	**Percent**
Sportfish	Arctic grayling	105	1.2
	Bull trout	102	1.2
	Burbot	6	0.1
	Kokanee	1	< 0.1
	Mountain whitefish	1,653	19.5
	Northern pike	3	< 0.1
	Rainbow trout	75	0.9
	Walleye	1	< 0.1
	Subtotal	*1,946*	*22.9*
Sucker	Largescale sucker	707	8.3
	Longnose sucker	2,436	28.7
	Subtotal	*3,143*	*37.1*
Minnows/Trout-perch	Flathead chub	2	< 0.1
	Lake chub	419	4.9
	Longnose dace	1,514	17.9
	Northern pikeminnow	201	2.4
	Northern redbelly dace	4	< 0.1
	Redside shiner	891	10.5
	Trout-perch	3	< 0.1
	Subtotal	*3,034*	*35.8*
Sculpin	Prickly sculpin	6	0.1
	Slimy sculpin	350	4.1
	Spoonhead sculpin	2	< 0.1
	Subtotal	*358*	*4.2*
Total 8		**,481**	**100**

Species Diversity and Distribution

Of the 20 fish species recorded on the Halfway River, no more than 17 species were located in any one reach or section (Table 5.3.7). The lowermost Reaches 1 and 2 had more species (16 and 17, respectively) than the uppermost Reaches 3 and 4, (12 species in each). Species diversity was highest in lowermost Sections 8, 9, and 10 (13 to 16 species).

Ten species were widely distributed and were recorded in most sections. These included Arctic grayling, bull trout, mountain whitefish, rainbow trout, largescale sucker, longnose sucker, lake chub, longnose dace, redside shiner, and slimy sculpin. Five species were primarily restricted to the lower portion of the study area, including kokanee, northern pike, walleye, northern pikeminnow, and prickly sculpin. The five remaining species burbot, flathead chub, northern redbelly dace, trout-perch, and spoonhead sculpin were scarce and occurred in no more than three sections.

Table 5.3.7 Fish species distribution in each section of the Halfway River, 2010 Moberly River and Halfway River Fish Inventory 2010 (from Mainstream 2011a).

Group Species		**Reach and Section**									
		4 3							**2**		**1**
		1	**2**	**3 4**	**5 6**			**7 8**	**9**		**10**
Sportfish	Arctic grayling	x	x	x	x	x	x	x	x	x	x
	Bull trout	x	x	x	x	x	x	x	x	x	x
	Burbot		x							x	x
	Kokanee									x	
	Mountain whitefish	x	x	x	x	x	x	x	x	x	x
	Northern pike								x	x	x
	Rainbow trout	x	x	x	x	x	x			x	x
	Walleye										x
Sucker	Largescale sucker		x	x	x	x	x	x	x	x	x
	Longnose sucker	x	x	x	x	x	x	x	x	x	x
Minnows/Trout-perch	Flathead chub				x						x
	Lake chub	x	x	x	x	x	x	x	x	x	x
	Longnose dace	x	x	x	x	x	x	x	x	x	x
	Northern pikeminnow								x	x	x
	Northern redbelly dace	x									
	Redside shiner	x		x	x	x	x	x	x	x	x
	Trout-perch								x		
Sculpin	Prickly sculpin									x	x
	Slimy sculpin	x	x	x	x	x	x	x	x	x	x
	Spoonhead sculpin							x	x		
Number of Species per	**Section**	**10**	**10**	**10**	**11**	**10**	**10**	**10**	**13**	**15**	**16**
	Reach 12			**12**					**17**		**16**

Catch Rates

The Halfway River survey targeted small fish ≤ 200 mm length. This section focuses on catch rates of selected species for this size range; all catch rate data are presented in Appendix E of Mainstream (2011a). Catch rates generated using the three fish capture methods varied according to fish group. Species in the sportfish group were most frequently encountered and catch rates were highest using boat electrofisher and backpack electrofisher (Figure 5.3.3). Sucker species tended to be equally abundant using all three methods.

Species in the minnow and sculpin groups also were recorded using all three fish capture methods; however, most were frequently encountered and exhibited highest catch rates using backpack electrofisher and beach seine (Figure 5.3.4).

Sportfish

Arctic grayling were consistently encountered with the boat electrofisher and mean catch rates per section in the boat electrofisher catch where fish were present ranged from 0.2 fish/km to 5.2 fish/km. Arctic grayling catch rates were highest in the upstream Section 1 and lowest in the downstream sections (9 and 10). Catch rates were similar in Sections 3 to 6 and 8; they were also high in Section 7, located just upstream of the Cameron River confluence. Backpack electrofisher catch rates were low and Arctic grayling were only caught using this method in Sections 1 and 5.

Bull trout catch rates were low and this species was recorded primarily with the boat electrofisher. Where this species was recorded, mean catch rates ranged from 0.2 fish/km to 0.8 fish/km. Bull trout exhibited a downward trend in catch rates from upstream to downstream; and similar to Arctic grayling, bull trout catch rates were highest in Section 1. Bull trout were only caught using the backpack electrofisher method in Section 1.

Mountain whitefish mean catch rates were highest of all the sportfish and were encountered primarily with the boat electrofisher and backpack electrofisher. Mean catch rates ranged from 17.4 fish/km to 47.0 fish/km using the boat electrofisher and 0.0 fish/100 m to 2.1 fish/100 m using the backpack electrofisher. Mountain whitefish were the only sportfish encountered with the beach seine, but catch rates were low (i.e., less than 0.5 fish/100 m^2). Mountain whitefish catch rates varied spatially; catch rates were highest in Section 1, intermediate in Sections 2 to 7 and 9, and lowest in Sections 8 and 10.

Rainbow trout were primarily recorded in the boat electrofisher catch. Mean catch rates in sections that contained this species ranged from 0.2 fish/km to 1.2 fish/km. Rainbow trout catch rates exhibited a truncated distribution; catch rates were highest in Sections 1 to 5, but catch rates were very low in the lowermost Sections 6 to 10.

Burbot, kokanee, northern pike, and walleye were only recorded in the boat electrofisher catch. Catch rates for these species were < 0.1 fish/km.

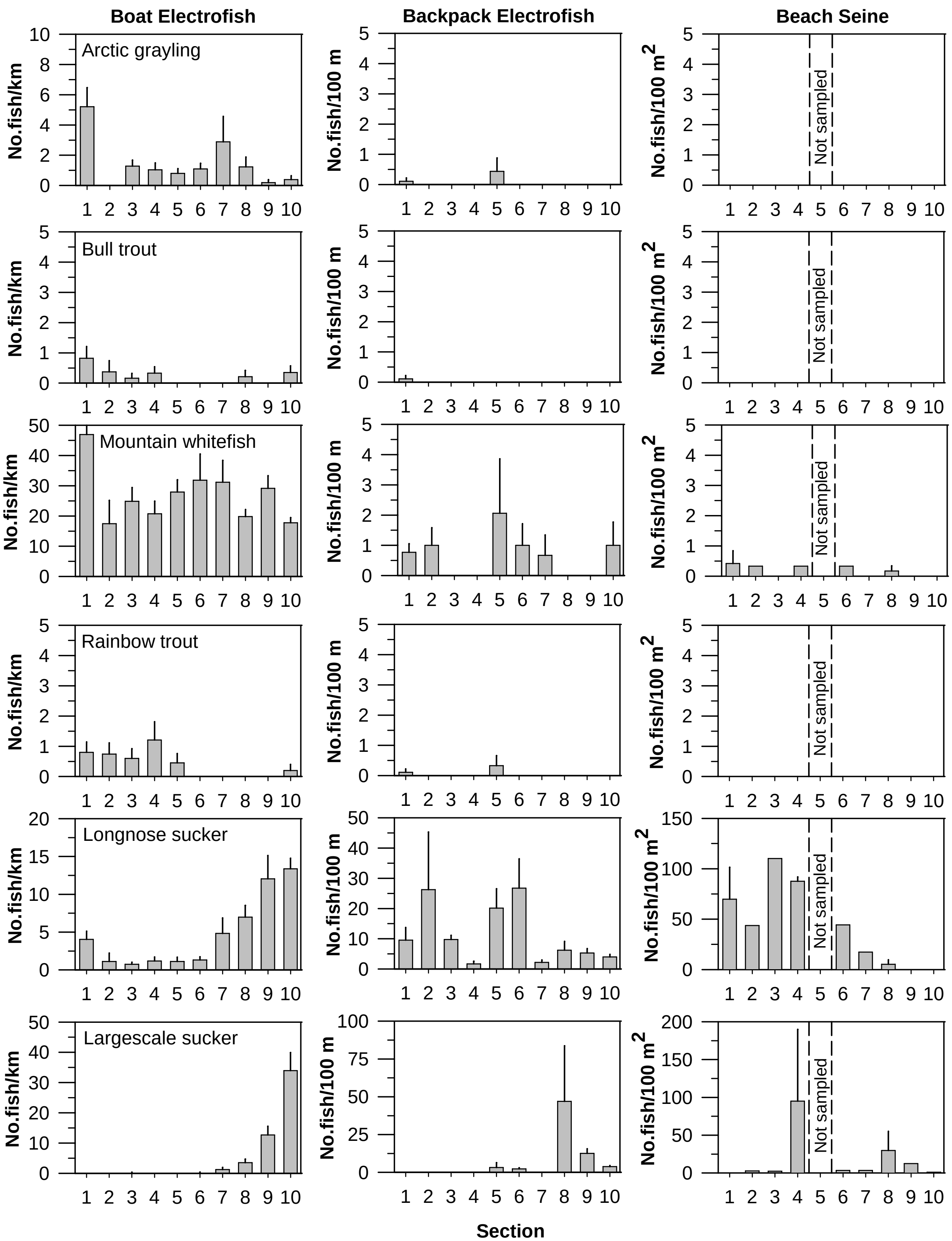


Figure 5.3.3 Catch rates (mean number of fish ± SE) of selected sportfish and sucker species in sampled sections on the Halfway River, 2010 Moberly River and Halfway River Fish Inventory (from Mainstream 2011a).

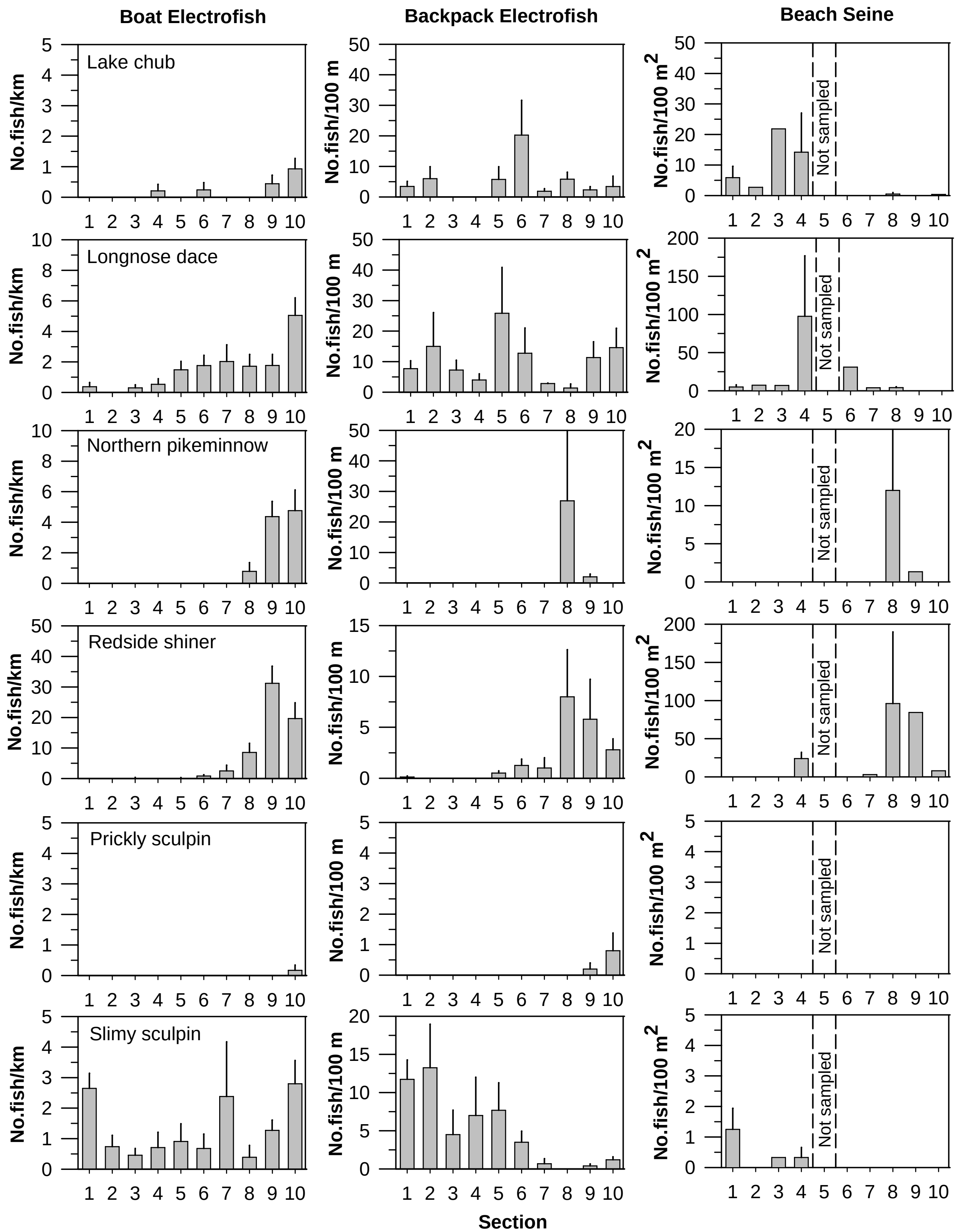


Figure 5.3.4 Catch rates (mean number of fish ± SE) of selected minnow and sculpin species in sampled sections on the Halfway River, 2010 Moberly River and Halfway River Fish Inventory (from Mainstream 2011a).

Suckers

Longnose sucker catch rates were high and this species was recorded in all sections. Mean catch rates ranged from 0.7 fish/km to 13.4 fish/km in the boat electrofisher catch and 1.7 fish/100 m to 26.8 fish/100 m in the backpack electrofisher catch. Longnose sucker also were encountered using beach seine, although the catch was highly variable (range from 0.0 fish/100 m^2 to 110.2 fish/100 m^2). There was no consistent spatial pattern in longnose sucker catch rates between methods. Highest boat electrofisher catch rates occurred in Sections 9 and 10, while highest backpack electrofisher catch rates occurred in Sections 2, 5, and 6 and highest beach seine catch rates occurred in Sections 1, 3, and 4.

Largescale sucker were largely restricted to downstream sections of the study area. They were recorded as far upstream as Section 2, but catch rates were generally highest from Section 8 downstream to Section 10. Boat electrofisher catch rates increased from Section 7 to 10, whereas, backpack electrofisher catch rates decreased from Section 8 to 10. In these sections, mean boat electrofisher catch rates ranged from 0.2 fish/km to 34.0 fish/km and mean backpack electrofisher catch rates ranged from 2.3 fish/100 m to 47.0 fish/100 m. Largescale sucker were also in the beach seine catch -- the highest recorded mean value was 94.9 fish/100 m^2 in Section 4.

Minnows and Sculpins

Lake chub and longnose dace exhibited the highest catch rates in the minnow group, while in the sculpin group slimy sculpin exhibited the highest catch rates and were widespread. The pattern of species catch rate varied by method and/or by species. For all methods, there was no strong pattern for lake chub. Boat electrofisher catch rates for longnose dace increased from upstream to downstream, while backpack electrofisher catch rates varied between sections. Northern pikeminnow and redside shiner were largely restricted to downstream sections of the study area and for all capture methods; catch rates were highest in Sections 8 and 9. Slimy sculpin catch rates did not exhibit a consistent trend in the boat electrofisher catch, but the backpack electrofisher catch rates tended to decline from upstream to downstream.

5.3.2.3 Summary

Based on fish community investigations on the Moberly River and Halfway River, Mainstream (2012b) presented the following conclusions:

Moberly River

The Moberly River supports a diverse fish community that includes sportfish, suckers, minnows, and sculpins. Young sportfish recorded during the study included Arctic grayling, burbot, mountain whitefish, and northern pike. Notable findings were as follows:

1. Longnose sucker and longnose dace were the numerically dominant species in the catch.
2. Other abundant nonsportfish included redside shiner, lake chub, and slimy sculpin.
3. Young (i.e., Age 0 and 1) burbot were the most numerous sportfish.
4. The upper reaches supported the highest numbers of Age 0 burbot, which suggested that this portion of the study area was important for rearing by this species.
5. The study area is not used by bull trout or rainbow trout for spawning and early rearing.
6. Adult fish of several sportfish and sucker species were recorded suggesting that the study area supports resident large-fish populations.

Halfway River

The Halfway River supports a diverse fish community that includes sportfish, suckers, minnows, and sculpins. Young sportfish recorded during the study included Arctic grayling, bull trout, mountain whitefish, and rainbow trout. Notable findings were as follows:

1. Longnose suckers were the most numerous fish in the study area followed by redside shiner.
2. Age 0 bull trout, rainbow trout, and Arctic grayling were scarce or absent indicating that the mainstem Halfway River is not a major spawning and early rearing area for these species; Halfway River tributaries likely provide these habitats.
3. Age 0 mountain whitefish were widespread and abundant.
4. Sucker and minnow species were numerically important downstream of the Cameron River confluence.
5. Adult fish of several sportfish and sucker species were recorded suggesting that the study area supports resident large-fish (> 200 mm) populations.

6.0 HABITAT UTILIZATION

Habitat utilization includes two components -- habitats that are important to the long-term sustainability of a fish population (e.g., spawning/egg incubation, rearing, feeding and wintering) and movement strategies used by fish populations to access those habitats. The fish and fish habitat information summarized in Section 4.0 and Section 5.0 provides the basis for understanding fish habitat utilization of the Peace River and its tributaries in the technical study area. This section summarizes more focused studies designed to help improve our understanding of fish habitat utilization. This includes work that described:

- movement by adult fish to important habitats
- downstream dispersal by small fish
- tributary use by Peace River populations
- recruitment sources of Peace River fish populations

6.1. FISH MOVEMENT

6.1.1 Radio Telemetry

6.1.1.1 Initial Studies

Movements of selected fish species in 1990 were described by Pattenden *et al.* (1991) based, in part, on information from fish implanted with radio transmitters in fall 1989 and spring 1990. The following summarizes the results of that study.

Ninety five fish representing adults of five species were implanted (7 Arctic grayling, 8 bull trout, 9 northern pike, 18 rainbow trout, 53 walleye). Locations of radio-tagged fish were collected by aerial surveys completed two or three times a month from June to December. Useable results were collected for all species except Arctic grayling.

Bull trout

Seven of eight radio-tagged bull trout provided useable information by the authors. Six fish moved into the Halfway River prior to the fall spawning period from release locations upstream (as far as the Peace Canyon Dam tailrace) or downstream (as far as the Moberly River confluence) of the Halfway River confluence. Movements into the Halfway River occurred as early as May. All fish completed extensive upstream migrations in the Halfway River and a number entered the Graham River system, presumably to spawn. One fish was tracked back to the Peace River after the spawning period.

Northern pike

All nine radio-tagged northern pike remained in the Peace River during the survey period and most fish did not move great distances (i.e., < 10 km). Fish were typically located in protected side channels. Six radio-tagged fish congregated in one large side channel complex located upstream of the Halfway River during the spring spawning period. Following the spawning period one of these fish moved to a side channel located 20 km downstream of the Halfway River before moving upstream to the Lynx Creek area near its original release location.

Rainbow trout

During winter most radio-tagged rainbow trout were sedentary. However, prior to and during spring a number of fish moved upstream from their release locations. Fish released as far downstream as the Halfway River migrated upstream to Lynx Creek, Maurice Creek, and the Peace Canyon Dam tailrace. Fish were recorded entering Lynx Creek and Maurice Creek, presumably to spawn. A number of fish were described as seeking suitable spawning habitats due to complex movements between several tributary mouths and eventual movements to the Peace Canyon Tailrace. Fish moved downstream following the spring spawning period to an area downstream of the Halfway River. The authors suggested that this section of river may be used for adult feeding and wintering.

Walleye

The authors indicated that most of the twenty walleye implanted with radio tags in fall 1989 exhibited abnormal unidirectional downstream movements and were removed from the data set. Twenty four fish radio-tagged in 1990 exhibited distinct upstream movements from their release sites near the mouth of the Beatton River. Fish tended to concentrate at tributary confluences of the Pine River and Moberly River. One individual moved upstream to the mouth of Lynx Creek, while six walleye moved upstream to the mouth of the Halfway River. Walleye also were recorded several kilometers upstream in the Pine River, Moberly River, Kiskatinaw River, and Beatton River. By the end of the survey in December 1990, most radio-tagged walleye had moved downstream of the Pine River confluence. Several fish had moved downstream into Alberta.

6.1.1.2 Current Studies

AMEC and LGL (2008b, d) completed fish movement studies in 2006 and 2007 using radio-tagged fish of five fish species. The following quotes the results presented in the executive summary of that report.

Between 2005 and 2007, 342 large-bodied fish were tagged in the Peace River drainage below Peace

Canyon Dam. A total of 116 mountain whitefish, 57 Arctic grayling, 47 rainbow trout, 58 walleye and 64 bull trout were tagged, by AMEC and LGL, Golder and Associates and B.C. Ministry of Environment, in these years. The majority of the tagged fish were captured, tagged and released into the Peace River mainstem. However in 2006, all of the bull trout and some Arctic grayling (14%) and rainbow trout (32%) were tagged in the Pine River system.

The movements of the radio-tagged fish were monitored from early spring through fall in 2006 and 2007 with a network of fixed-station receivers and mobile tracks. In 2007, a total of ten fixed-stations were strategically located throughout the Peace River drainage. Five fixed-stations were located in the Peace River mainstem between the Peace Canyon Dam and the Beatton River. Another five receivers were placed upstream in the following tributaries: the Halfway River at the Graham River, the Pine River at the Murray and Sukunka Rivers, and the Moberly River approximately 10 km upstream from the Peace River, just above the potential zone of inundation.

In addition to monitoring the movements of the radio-tagged populations with the fixed station receivers, 12 aerial flights were conducted between March and November to determine the location of radio-tagged fish. The flight path typically included: the Peace River mainstem from Peace Canyon Dam to Peace River, Alberta; the Halfway River to the Graham River; the Beatton River to the Doig River; Moberly River to Moberly Lake; and, the Pine River system to the upper Burnt River. Aerial survey tracks were conducted biweekly in the spring and fall and monthly in the summer. The key findings of the 2007 radio telemetry program, by species, are as follows:

Rainbow trout

Radio-tagged rainbow trout in the Peace River showed limited movement throughout the two-year tracking period. Rainbow trout were distributed mainly between the Peace Canyon Dam and Cache Creek, upstream of Site C, with only 1 fish (3%) moving past the proposed Site C dam location. The median distance moved by rainbow trout was 9 km and 7 km in 2006 and 2007, respectively. The greatest movement was observed during their spawning season (April-May). One rainbow trout detected in Maurice Creek is the only observed instance of a Peace River rainbow trout using any tributary upstream of the proposed Site C dam location in 2007.

The rainbow trout tagged in the Pine River drainage never moved downstream into the Peace River in 2007. These fish remained in the mainstem of the Pine and Sukunka Rivers for the duration of the year, with the exception of 6 rainbow trout that moved into the Burnt River during the summer months.

Mountain whitefish

Throughout the 2006 and 2007 tracking periods, mountain whitefish remained widely distributed in the Peace River mainstem from the Peace Canyon Dam to Dunvegan, Alberta. In 2007, eight of the tagged mountain whitefish (8%) moved past the proposed Site C dam location. In the present study, the median distance moved by mountain whitefish was 20.3 km and 6.3 km in 2006 and 2007 respectively, with the movement in 2006 being almost exclusively in the downstream direction at a rate of 69 m per day. Their significantly greater displacement in 2006 is most probably related to the short recovery period after tagging (~1 month) before tracking was begun and should not be taken as representative of the movement of the untagged population.

The most mountain whitefish ever detected in the tributaries occurred in October when 11 fish (12% of those detected) were observed in the Halfway and Pine Rivers. Throughout fall, a few fish were detected in the lower and upper reaches of the Halfway River and in the lower Pine River, with a slight increase in their numbers in these areas between August and October, the period when they are likely to be spawning.

Arctic grayling

Arctic grayling moved an average of 9 km with the greatest movement observed during spring. In 2007, 10 of the radio-tagged Arctic grayling (24%) moved past the proposed Site C dam location. The 2007 tracking results show clear evidence of several Arctic grayling moving well upstream of the potential zone of inundation in the Moberly River in spring, and then retreating back into the Peace River mainstem in June. Arctic grayling were not detected in any of the smaller tributaries (Maurice, Lynx, Farrell, Cache Creeks) upstream of Site C. Two fish were detected within the vicinity of the Beatton River mouth and one fish was detected some 20 km upstream from the mouth in May 2007 suggesting that spawning might also occur in this river.

Based on 2007 tracking results, it is very likely that Arctic grayling in the upper Pine River watershed is a resident population that remains there year round. This population showed relatively little movement from March through to October, and all fish remained in the mainstem of the upper Pine and Sukunka Rivers. No tagged Arctic grayling moved from the Pine River drainage into the Peace River.

Walleye

Two years of tracking has provided strong evidence on the walleye movements in the Peace River study area. This population moves extensively within and between the Peace River mainstem and major tributaries, with a well-defined spawning migration up the Beatton River in May and back out in June. Most walleye that moved up the Beatton River in spring were fish that over-wintered (October-April) within the vicinity of the Beatton River mouth. In contrast, those that did not move up the Beatton River remained mostly downstream in the Peace River mainstem, widely distributed, with some as far as Peace River, Alberta. The median distance moved by walleye was significantly greater than that of all other species in both years, being 80 km in 2006 and 118 km in 2007. Their mean monthly distance moved was sporadic, but clearly highest in spring (April-May) and autumn (September).

After spawning, walleye that were observed in the Beatton River moved from the Beatton River upstream into the Peace River mainstem to as far as the Moberly River. Several fish moved into the Pine River. In 2007, 5 walleye (10%) moved upstream past the proposed Site C dam location. By late October, the walleye returned to the Beatton River or to the Peace River near the Beatton River mouth.

Bull trout

Bull trout showed considerable variation in movements among radio-tagged fish in 2007. Overall, the median distance moved over the duration of the tracking period in 2007 was 51 km. In general, the mean monthly distance moved by bull trout was low from March through June (~5 km) and increased in the following months to peak in September (~30 km). Two bull trout made extensive migrations of approximately 450 km. These fish moved from the Pine River system to the upper Halfway River drainage in late summer, remained in the Halfway River system until the end of the spawning period, and then returned to the Pine River in late fall. Another two bull trout moved out of the Pine River system and upstream into the Peace River past the proposed Site C dam location. One of these bull trout moved to just above the mouth of Cache Creek in May and was still detected in that location during the last aerial track (November 1). The other bull trout in the Peace River mainstem was detected near the mouth of Tea Creek during the last tracking survey and moved towards this location after being tagged in the Wolverine River in mid-September. In total, 4 (7%) of the bull trout tagged in the Pine River drainage moved upstream past the proposed Site C location.

From the results to date, it appears that there may be two populations of bull trout radio tagged in the Pine River drainage in 2006: one population rears and forages primarily in the Pine River system and spawns in the Burnt River and another population that forages in the Pine River, but spawns and rears (juvenile stages) in the upper Halfway River drainage.

AMEC and LGL (2010a)

The work by AMEC and LGL (2008b,d) was supplemented by additional radio telemetry work in 2009 by AMEC and LGL (2010a). The following quotes the results presented in the executive summary of that report.

Bull trout

- The majority of bull trout in the Pine River watershed appear to be resident fish that do not move extensively; migratory fish probably constitute a minor proportion (perhaps < 5%) of the overall population;
- The migratory form appears to consist of two life history types: one that spawns in the Halfway and forages/overwinters in the Pine mainstem (2%; 2/104 fish in 2007; none in 2008 and 2009), the other spawns in the Pine and forages/overwinters in the Peace mainstem (2%, 4% and 2% in 2007, 2008 and 2009 respectively);
- Very few bull trout were detected in the Peace River mainstem, and none were recorded between July and September;
- The distribution of bull trout in the Pine River watershed was relatively stable over time: 51-64% were in the Pine mainstem, 18-30% in the Burnt/Sukunka Rivers, and 18-24% in the Murray/Wolverine drainage;
- The median distance moved by bull trout became progressively shorter with each successive year: 51, 27 and 12 km in 2007, 2008 and 2009, respectively; fewer movements were recorded outside of the Pine watershed in 2008 (4 fish) and 2009 (2 fish) than in 2007 (5 fish);
- Of the fish that did not exit the Pine watershed, some made annual forays between the Burnt/Sukunka drainage and the Pine mainstem, spending late summer-autumn in the Burnt/Sukunka area and winter-summer period in the Pine mainstem.

Arctic grayling

- Movement distances among Arctic grayling generally were not extensive (median movement 7.4 km); none was detected outside of the Pine River watershed, consistent with the findings of the MOE 1996-1999 radio-tracking study;
- In all months, the majority of Arctic grayling detected were in the Pine mainstem below the Murray River, and invariably their movement was progressively downstream from release to site of last detection.

Rainbow trout

- Movement distances among rainbow trout were variable, consisting of minor, moderate and extensive movers (median distance 6.9 km); a few fish exited the Pine, but, with one exception (one fish moved ~10 km past the Moberly, then downstream to near the Beatton, and returned to the Pine), did not move far from the river's mouth;
- During all months, rainbow trout were proportionally distributed fairly evenly between the Burnt/Sukunka drainage and the lower Pine mainstem.

Walleye

- Of the few walleye detected in 2009 (due to battery end of life), their locations in the Peace mainstem and tributaries (Beatton and Pine Rivers) were consistent with those identified previously (2006-2008);

Summary

The overall results of three years of tracking of the Pine-tagged fish populations suggest:

- It is very unlikely that Arctic grayling will exit the Pine River and move past the Site C dam location;
- A few rainbow trout may exit the Pine, but in most instances will probably not move upstream past the Site C dam location;
- Movement past the Site C dam location may be limited to a few bull trout that move between the Pine and Halfway Rivers in either direction to complete their life cycle.

6.1.1.3 Bull Trout and Arctic Grayling Studies by MOE

AMEC and LGL (2010b) analyzed and mapped results of the MOE 1996-1999 study on movements of bull trout and Arctic grayling in the upper Peace River watershed. The following quotes the results presented in the executive summary of that report.

In total, 76 bull trout (primarily from the upper Halfway River) and 49 Arctic grayling (upper Halfway and Sukunka Rivers) were radio-tagged, of which 71 and 48 'active' tags, respectively, were tracked (primarily by aerial surveys) to determine fish movements within and among the tributaries and Peace River mainstem. The key findings are:

- 36% (25 of 69) of the bull trout released in the Halfway River watershed did not exit the river, whereas 64% (44 of 69) made at least one foray into the Peace River mainstem.
- The majority (63-77%) of bull trout detected were in the Halfway River watershed from July-September. In all other months, the majority (56-75%) of individuals were detected in the Peace River mainstem.
- Other than the Halfway River, no bull trout were detected in any tributary of the Peace River mainstem.
- Only one of the Arctic grayling released in the Halfway River, and none of the Sukunka River fish, emigrated into the Peace River mainstem.
- Arctic grayling released in the Halfway River drainage moved significantly longer distances (median 127 km) than those released in the Sukunka River (median 79 km); the Halfway watershed consisted of minor (< 100 km), moderate (100-200 km) and extensive (> 200 km) movers.
- Bull trout displacement was primarily upstream in July-August (pre-spawning) and pronouncedly downstream in September (post-spawning); Arctic grayling displacement was clearly upstream from May-July (spawning/feeding), and downstream from August-November (pre over-wintering movement).
- 21% (15 of 71) of the bull trout moved past the potential Site C dam location.

6.1.1.4 Downstream Peace River Studies

Movement studies were completed as part of pre and post-approval fish studies for the Dunvegan Hydroelectric Project located 128 km downstream of the B.C./AB boundary. Movement information collected in 2002/03 (Mainstream 2004), 2004/05 (Mainstream 2006a), and 2008/09 (Mainstream 2009d) was used to support the design and monitoring of the fish passage mitigation facilities of the Project. Collected information was to be used to quantify seasonal movement patterns, evaluate mitigation effectiveness, and guide adaptive management of the fish passage facilities.

The studies focused on adults of four species -- goldeye, walleye, longnose sucker, and burbot. Fish were implanted with high frequency radio tags and their movements monitored from the air at standardized intervals within a defined survey area. The study area encompassed the Peace River from Vermillion Chutes upstream to the Peace Canyon Dam in British Columbia and the lower sections of several tributaries. For each investigation, fish were captured in spring of the initial study year and then monitored for approximately 16 months, which was the expected life span of the radio transmitter. This approach allowed fish to fully recover from the surgical implant operation before a full year of movement information was collected. A summary of movement studies findings are presented below.

Goldeye

Radio-tagged goldeye moved long distances and the total range of movement encompassed approximately 700 km of river from Vermillion Chutes to the Pine River confluence in British Columbia. Although the majority of goldeye were highly migratory, not all fish moved past the Dunvegan site during annual migrations. A portion of the sample population remained downstream. Peak upstream migrations were most likely to occur between May and July. Downstream were most likely to occur between August and October when fish returned to wintering habitats.

Radio-tagged goldeye frequented confluence areas of several tributaries, generally were not recorded moving upstream into the tributary. Exceptions include upstream migrations by goldeye into the Smoky River near the Town of Peace River, Alberta, as well as the Clear River and Beatton River near the B.C./Alberta boundary. The presence of goldeye in the tributaries during the spawning period suggested that tributaries may be used for spawning by goldeye.

Walleye

Most radio-tagged walleye moved moderate distances during the studies, while some fish completed longer movements. The total range of the sample population was approximately 500 kilometers from downstream of the Notikewin River confluence to the Pine River confluence in British Columbia. Walleye exhibited seasonal movement patterns. Fish moved upstream during spring and early summer, and then downstream in fall.

During the spring spawning period the majority of radio-tagged walleye remained dispersed and there was no strong unidirectional movement to a specific area or tributary. However, radio-tagged walleye were frequently located at tributary confluences or in tributaries proper during the study.

Longnose sucker

Most radio-tagged longnose suckers were sedentary with a few highly mobile individuals. The total range of the sample population encompassed 390 km from the Notikewin River to the Montagneuse River. Longnose suckers did not demonstrate clear movement patterns in terms of timing and direction. No spawning tributaries were identified, but fish regularly frequented tributary confluences.

Burbot

Radio-tagged burbot were highly sedentary and distance traveled rarely exceeded 20 km. The total range of the sample population was large (707 km) because a small number of fish dispersed a long distance downstream. Burbot did not exhibit a strong pattern of upstream or downstream movements during most of the year. The only exception was an increase in the frequency of downstream movements during the month of December followed by an increase in the frequency of upstream movements in January, February, and March. This pattern likely represented pre and post-spawning movements to tributaries located downstream of the Dunvegan Project.

The most recent fish movement work in the Dunvegan area included a burbot study in 2009 (Mainstream 2010e). The purpose of the burbot study was to collect information in order to better understand the ecology of the Peace River burbot population in the vicinity of the Dunvegan Project. The study included a review of existing information and a field component that involved a fish and habitat component and fish movement component that focused on juvenile fish. The results of the fish movement component are summarized below.

Small radio-tagged burbot undertook limited movements during the period of June to October, 2009. Fish movement typically ranged no more than 15 km. There were no strong tendencies for upstream or downstream movements and the distance traveled between surveys was typically less than 1 km. The sedentary lifestyle of the small-sized burbot used in this study was similar to movement patterns of larger-sized burbot of previous studies at Dunvegan. Small-sized burbot moved farther than large-sized burbot suggesting that smaller fish may have a higher tendency to disperse or were being displaced from preferred habitats by larger fish.

A survey in January documented large movements by some radio-tagged burbot to areas located downstream of Dunvegan. This movement pattern was recorded for larger-sized burbot by previous Dunvegan studies. It may reflect spawning migrations (i.e., some of the study burbot were adults and not juveniles) or downstream displacement of fish.

Habitat use by most radio-tagged burbot was restricted to the mainstem Peace River. A single burbot moved to and entered the Smoky River by late August, and then remained in the Smoky River for the remainder of the study. In the Peace River, smaller sized burbot were located in habitats adjacent to the channel margins. The majority of burbot were found in backwater habitats in areas containing an abundance of large rock. Run habitats with rock substrates were also used by burbot. Backwaters are a minor component in the Dunvegan area with an estimated 1.4% of the headpond surface area. Run habitats containing rock are even rarer at 0.7%. Use of backwaters and rocky runs by the majority of burbot indicates selection of these unique habitat types.

6.1.2 Recapture of Marked Fish

A standard procedure of baseline inventories was to mark selected fish (i.e., individuals of target fish species ≥ 250 mm fork length in good condition) with T-bar anchor Floy tag or Passive Integrated Transponder tags, or “PIT tags”. Marked fish that were subsequently recaptured were used to generate population estimates and evaluate growth rates (Mainstream and Gazey 2011) or to document fish movements to important habitats.

Mainstream (2009c and 2010b) captured several marked mountain whitefish during fall fish studies of the Moberly River and Halfway River. In 2008, a total of 67 mountain whitefish sampled from the Moberly River using fish traps and Halfway River using electrofishers during the fall program were recaptured (Mainstream 2009c). Recaptured fish originated from a large area of the Peace River

(Figure 6.1.1). Marking locations extended from just upstream from the Pine River confluence to just downstream of the Peace Canyon Dam. Of the 24 marked fish that entered the Halfway River, 13 fish originated from the Peace River between the Halfway River and Cache Creek. Of the remaining fish, seven originated well upstream from the Hudson's Hope area, two were from the Peace River downstream of Cache Creek, and two were released downstream of the Moberly River. In total, 43 marked fish were recaptured in the Moberly River. A large number of these fish originated from the Peace River just downstream of the Moberly River (35 fish). Of the remaining fish, two came from the Peace River as far upstream as the Farrell Creek area, five originated from the Halfway River area, and one fish had been released just upstream of the Moberly River.

There was a large difference in the mean distance traveled to the Moberly River and Halfway River by marked fish (Table 6.1.1). Mean distance traveled was 22.1 km for the Halfway River fish and 9.3 km for the Moberly River fish. The maximum distance traveled was similar (50.7 km and 56.2 km, respectively). Marked mountain whitefish traveled downstream and upstream to enter the tributaries. Recapture results from both the Halfway River and Moberly River indicated that the majority of fish moved upstream (71% and 81%, respectively).

Table 6.1.1 Distance and direction traveled by marked adult mountain whitefish that were recaptured in the Moberly River and Halfway River during the fall program, 2008 tributaries spring and fall use study 2008 (from Mainstream 2009b).

River Samp	**le**	**Distance Traveled (km)**		**Direction Traveled (Number of Fish)**	
		Mean Ra	**nge**	**Downstream**	**Upstream**
Halfway River	24	22.1	7.1 – 50.7	7	17
Moberly River	43	9.3	1.0 – 56.2	8	35

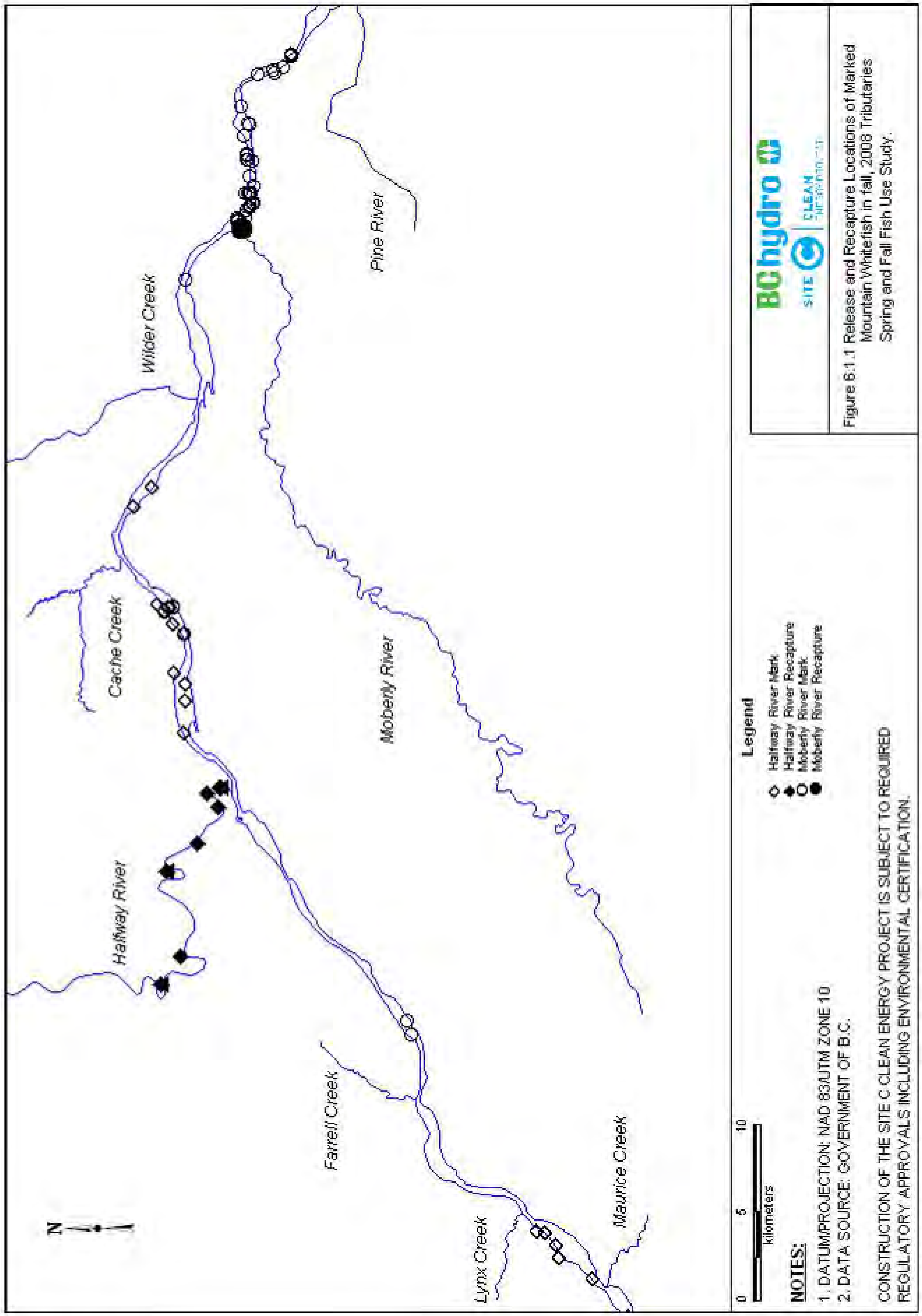


Figure 6.1.1 Release and Recapture Locations of Marked Mountain Whitefish in fall, 2008 Tributaries Spring and Fall Fish Use Study.

In 2009, a total of 104 marked mountain whitefish were collected from the Moberly River fish traps (Mainstream 2010c). Of these fish, 44 had been marked and released in 2009, while 60 fish had been marked and released between 2001 and 2008 (Table 6.1.2).

Table 6.1.2 Distance and direction traveled in the Peace River by marked mountain whitefish that were recaptured in the Moberly River, Halfway and Moberly Rivers mountain whitefish migration and spawning study 2009 (from Mainstream 2010c).

Marking Period	**Direction of Movement in Peace River**	**Number of Recaptures**	**Distance traveled (Km)**	
			Average Ra	**nge**
2009	Downstream	13	38.8	25.0 – 79.8
	Upstream	31	5.8	1.0 – 25.2
Pre-2009	Downstream	10	31.7	5.5 – 75.8
	Upstream	50	4.9	1.0 – 11.4

Recaptured fish originated from a large area of the Peace River (Figure 6.1.2). The majority of fish marked in 2009 had moved upstream from their release locations to enter the Moberly River. Average distances traveled by these groups were similar – 5.8 km for fish marked in 2009 and 4.9 km for fish marked pre-2009. When compared to upstream migrants, fewer fish moved downstream to enter the Moberly River, but average distance traveled was greater – 38.8 km for fish marked in 2009 and 31.7 km for fish marked pre-2009. Individual fish moved substantial distances to reach the Moberly River. Within the 2009 marked cohort, maximum distance traveled was 79.8 km downstream and 25.2 km upstream. Fish that completed these movements had been at large for no more than 60 days.

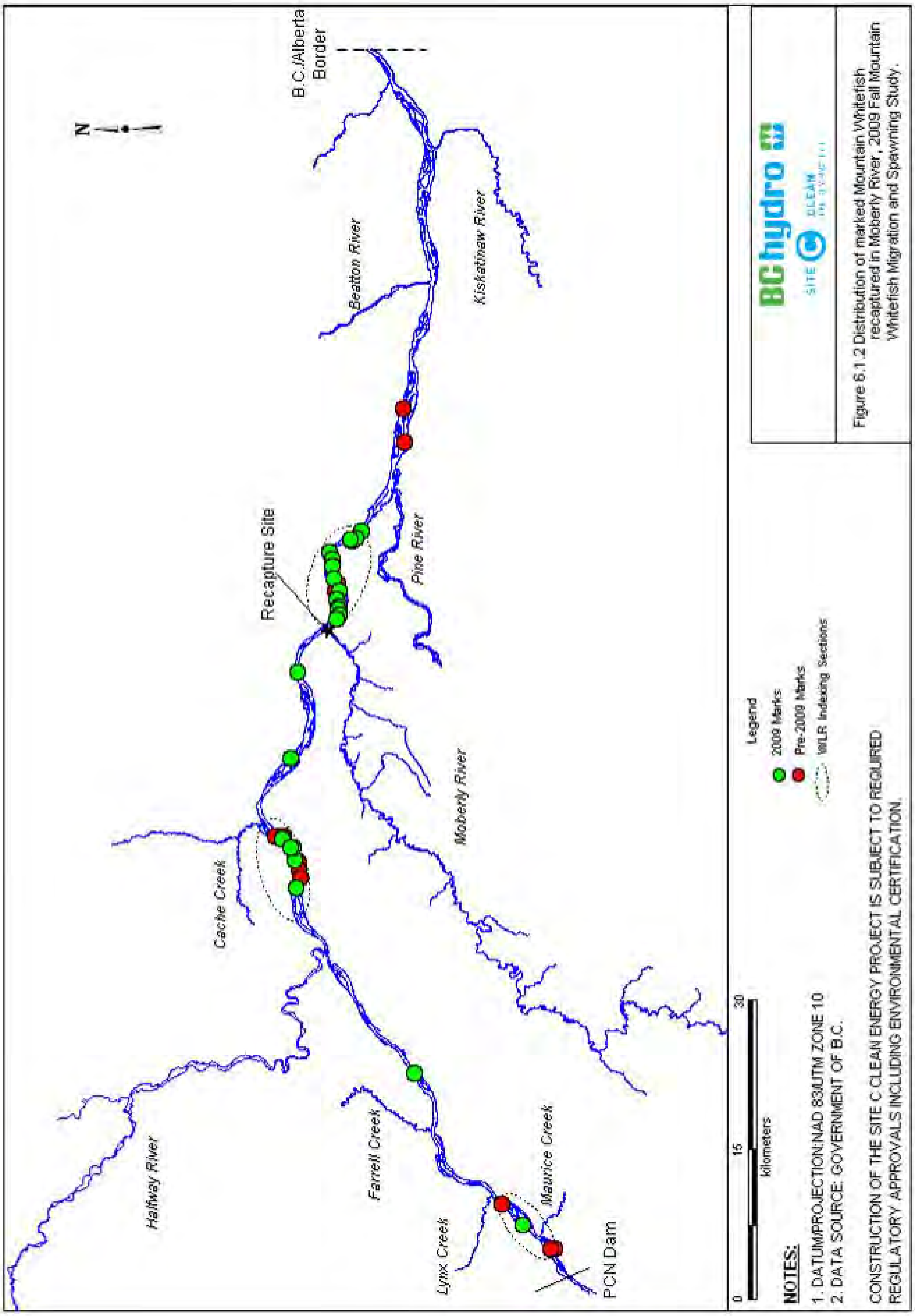


Figure 6.1.2 Distribution of marked Mountain Whitefish recaptured in Moberly River, 2009 Fall Mountain Whitefish Migration and Spawning Study.

It should be noted that the results from marked fish may not be completely representative of the distribution and movement of marked mountain whitefish. Marked fish were not released at random in the Peace River, but from five discrete locations (Mainstream and Gazey 2004, P&E and Gazey 2003). In addition, the data were composed of fish that were marked and released between 2002 and 2008. Therefore they may represent redistribution of fish rather annual movements into tributaries.

In total, 19 of the marked mountain whitefish were released in 2008 from late August to late September. The 3 fish that entered the Halfway River originated from three locations – Hudson's Hope, Halfway River, and Moberly River areas. The 16 fish that entered the Moberly River originated from the Moberly River area (14 fish) and the Halfway River area (2 fish). As such, the results from the 2008 fish are similar to the results using the entire data set.

Based on the recapture information, a portion of adult fish that entered the Moberly River and Halfway River during the fall program originated from a large area of the Peace River. Some individuals moved substantial distances and the majority originated downstream of the tributaries.

6.2 SMALL FISH DISPERSAL

6.2.1 Rotary Screw Trap

Mainstream (2010d, 2011c) utilized the Rotary Screw Trap (RST) method on the Peace River at the Site C dam location and on the Moberly River in 2010 and on the Peace River at the Site C dam location and on the Moberly River and Halfway River in 2011. The purpose of the studies was to enumerate fish that move downstream at selected locations within the technical study area to make inferences about recruitment sources to the Peace River fish community and movements of fish past the proposed Site C dam location.

The objectives of the studies, in part, were as follows:

1. Document the seasonal abundance, based on catch rates, of fish that move downstream from the Halfway River and the Moberly River into the Peace River during the open water period (Halfway River sampled only in 2011).
2. Document the seasonal abundance, based on catch rates, of fish that move downstream in the Peace River in the vicinity of the proposed Site C dam site during the open water period.
3. Describe the biological characteristics of fish collected during the study.

The study area included the lower sections of the Moberly River and the Halfway River (2011 only) and the Peace River in the immediate vicinity of the Site C dam location. One RST was placed in the Moberly River and two traps were placed in the Halfway River. In the Peace River, one RST was placed downstream of the Moberly River confluence on the south bank and one RST was placed upstream of the Moberly River confluence along an island near the north bank. The RSTs sampled continuously for approximately six months from May to October each year. Sampling did not occur when sampling conditions were suboptimal (i.e., periods of high woody debris loads).

Peace River

The Peace River RSTs captured several hundred fish representing twenty two species. The lower numbers of fish recorded in the Peace River RSTs compared to the Moberly River RST may reflect low fish capture effectiveness and/or the absence of downstream movements by most fish species expected to occur in the Peace River in the vicinity of the Site C dam location. The exception was the numerical importance of kokanee in the catch, which is a pelagic species that occurs in the Peace River. In general, results recorded for the Peace River RSTs were similar to the 2010 results. Differences included the capture of fewer fish and kokanee were largely absent from the catch.

Notable findings of the RST study on the Peace River in 2010 were as follows:

1. In the Peace River upstream of the Moberly River confluence, longnose sucker was the most abundant species followed by redside shiner, kokanee, mountain whitefish, and slimy sculpin.
2. In the Peace River downstream from the Moberly River confluence, redside shiner was the most abundant species followed by kokanee, longnose sucker, spottail shiner, and longnose dace.
3. The RST program recorded the first occurrence of yellow perch upstream of the Moberly River confluence.
4. Higher fish numbers at Site P01 located downstream of the Moberly River confluence compared to Site P02 located upstream of the Moberly River confluence provided indirect evidence of fish dispersal from the Moberly River into the Peace River.

Moberly River

In 2010, the Moberly River RST collected several thousand fish representing twenty two species and multiple fish life stages. Results were indicative of the fish community in the Moberly River that were recorded by Mainstream (2009c, 2010b, 2011a, 2012b). Information collected by the Moberly River RST characterized seasonal movement patterns of several species, which added to our knowledge of the Moberly River fish community ecology. The Moberly River RST was not fully operational in 2011.

Notable findings of the RST study on the Moberly River in 2010 were as follows:

1. Finescale dace and spottail shiner were two species collected by the RST that were not previously recorded from the Moberly River.
2. The five dominant species in decreasing numerical importance were redside shiner, longnose sucker, mountain whitefish, longnose dace, and Arctic grayling.
3. The fish catch appeared to be related to seasonal environmental conditions that included discharge, water clarity, and water temperature.
4. Several fish species demonstrated seasonal movement patterns based on life stage.
5. The presence of juvenile and adult mountain whitefish in the early spring catch indicates possible overwintering of these life stages in the Moberly River.
6. The presence of post-spawning Arctic grayling provides evidence that fish of this life stage move downstream to the Peace River immediately after spawning in the Moberly River.

Halfway River

In 2011, the Halfway River RSTs collected several thousand fish representing twenty species and multiple fish life stages. The results were indicative of the fish community in the Halfway River that were recorded by Mainstream (2009c, 2010b, 2011a, 2012b).

Notable findings of the RST study on the Halfway River in 2011 were as follows:

1. The five dominant species in decreasing numerical importance were longnose dace, redside shiner, longnose sucker, largescale sucker, and northern pikeminnow. Over one hundred each of mountain whitefish and bull trout were encountered, but few Arctic grayling were recorded.
2. The fish catch appeared to be related to seasonal environmental conditions that included discharge, water clarity, and water temperature.

6.3 TRIBUTARY USE

A number of fish fence and trap studies were completed on Peace River tributaries. AMEC and LGL (2008b) used block nets and hoop traps in several tributaries during spring 2006 to document fish use. In 2008, the spring work was duplicated by Mainstream (2009b) and expanded to include fall use of tributaries by fish. The fall program undertaken by Mainstream (2009b) on the Moberly River and Halfway River was repeated in 2009 by Mainstream (2010c).

The objective of the 2008 study by Mainstream (2009b) was to describe fish use of selected tributaries in spring and fall with the primary focus being spawning large-fish species. The study area encompassed seven tributaries located upstream of the proposed Site C dam site. This included five small tributaries, Maurice Creek, Lynx Creek, Farrell Creek, Cache Creek, and Wilder Creek, and two large tributaries, Halfway River and Moberly River. The study period included a spring session (17 May to 5 June 2008) and a fall session (1 October to 26 October 2008). The results of Mainstream (2009b) are presented below.

In spring, upstream fish traps were placed in most tributaries, with the exception of Wilder Creek. Fish use was also assessed by backpack electrofisher (small tributaries) and boat electrofisher (Halfway River). Sampling the Moberly River in spring was severely restricted using either method due to high water flows. In fall, upstream and downstream fish traps were placed on the Halfway River and the Moberly River, while backpack electrofishers were used on the small tributaries. Due to its large size, the Halfway River was sampled using a boat electrofisher. Kick net surveys for mountain whitefish eggs were completed on the Halfway River and the Moberly River to ascertain the distribution of spawning sites.

6.3.1 Spring

The spring program described fish use of Peace River tributaries in spring with the primary focus being spawning large-fish species. Fish use of seven tributaries was monitored using a combination of fish traps and/or electrofishers during a three week period from 17 May to 5 June 2008.

Twenty fish species were recorded during the spring program and eleven of these species were considered spring spawners. The capture of many of these fish in fish traps placed on the tributaries near the confluence with the Peace River provided strong evidence that these fish originated from Peace River populations. A diverse fish assemblage was recorded from each tributary. The catch of spring spawning species included adult fish that were ready to spawn, but nonadult fish typically accounted for the largest portion of the catch. The same pattern was evident for species that were not spring spawners.

The fish species assemblages and numbers of fish differed between study tributaries based on size and location. Small tributaries, from upstream to downstream included Maurice Creek, Lynx Creek, Farrell Creek, Cache Creek, and Wilder Creek. The Halfway River and Moberly River were considered large tributaries.

Small Tributaries

The species assemblage and relative numbers of fish in each tributary recorded during the present study were consistent with results of previous investigations completed by AMEC and LGL (2008a) and ARL (1991a). General trends were as follows. Maurice Creek supported more sportfish and sculpins compared to other small tributaries, while Lynx Creek, Farrell Creek, and Cache Creek were dominated by minnows and suckers. Wilder Creek, which was the smallest tributary, contained few fish but the species assemblage was most similar to Cache Creek.

Arctic grayling were not recorded in small tributaries during the spring program, which supports findings by the previous investigations. The absence of Arctic grayling is not unexpected given the small size of the tributaries and the lack of suitable rearing and spawning habitats (AMEC and LGL 2008a; Mainstream 2009c).

Based on the spring trap data rainbow trout likely spawn in Maurice Creek and Lynx Creek, and to a lesser extent in Farrell Creek. Adult fish in spawning condition were recorded in all three streams, but recorded numbers were low during the present study and during previous investigations. Adult rainbow trout were not recorded in Cache Creek and Wilder Creek. Given the habitat conditions of these streams (AMEC and LGL 2008a; Mainstream 2009c) it is highly unlikely that they are used by spawning rainbow trout.

Adult longnose suckers were widespread and were the most abundant large-fish species in all the small tributaries. The most important systems identified by the present study and previous investigations were Maurice Creek, Farrell Creek, and Cache Creek. Although not as abundant as longnose sucker, largescale sucker and northern pikeminnow were the other two large-fish species that spawned in the small tributaries. Farrell Creek and Cache Creek appeared to be the most important systems for both species.

Several spring spawning minnow species were widespread and abundant in the small tributaries. The numerically dominant species included lake chub, longnose dace, and redside shiner. Cache Creek, Farrell Creek, and to a lesser extent Lynx Creek were the important tributaries. In contrast to the other systems, Maurice Creek contained lower numbers of minnows – only longnose dace were abundant.

Results from the small tributaries during the present study and previous investigations indicated that sculpins exhibited a restricted distribution. Maurice Creek was the only system that supported substantial numbers of prickly sculpin, slimy sculpin, as well as low numbers of spoonhead sculpin. The reasons for the restricted distribution likely were due to poor habitat in the other small tributaries (e.g., high siltation and high water temperatures, Mainstream 2009c). It should be noted that sculpins were not in spawning condition at the time of the spring investigation.

Large Tributaries

Attempts were made to sample the Halfway River and Moberly River during the spring program. Due to high discharge during the spring program, sampling effectiveness was limited on the Halfway River (poor fish trap success) and sampling on the Moberly River was severely limited (one day). As such, data from the present study were not adequate to develop conclusions regarding fish use in spring. Therefore, the following discussion is based largely on information collected by previous investigations.

The Moberly River is potentially used by several spring-spawning fish that include sportfish, suckers, minnows, and sculpins. Based on the capture of small numbers of adult Arctic grayling in spring, both AMEC and LGL (2008a) and ARL (1991a) suggested that the tributary was used for spawning. Other evidence supporting this suggestion includes results from a movement study by AMEC and LGL 2010a. Two radio-tagged Arctic grayling that originated from the Peace River moved into the Moberly and migrated several kilometres upstream during early spring, presumably to spawn. There is also indirect evidence that suggests use of the Moberly River for spawning. Sampling of the Moberly did not identify other spring spawning sportfish species. Specifically, adult rainbow trout have not been recorded in the Moberly River.

The Moberly River is an important tributary for other spring spawning species. Substantial numbers of adult longnose sucker, largescale sucker, and northern pikeminnow have been recorded (ARL 1991a; AMEC and LGL 2008b). Species such as longnose dace and redside shiner (minnows), as well as slimy sculpin have also been recorded in the Moberly River during spring.

The Halfway River likely is an important spawning tributary for several large-fish species. Sampling by the present study and previous investigations identified adult longnose suckers, largescale suckers, and white suckers, as well as adult northern pikeminnow. In contrast, the spring spawning sportfish Arctic grayling and rainbow trout have not been recorded in large numbers in the lower Halfway River in spring. A single adult Arctic grayling was recorded during the present study, but this species was not recorded by AMEC and LGL (2008b) during their spring fish trapping investigation. In addition, no radio-tagged Arctic grayling or rainbow trout were known to enter the system (AMEC and LGL 2010a).

Several spring spawning minnow species (lake chub, longnose dace, and redside shiner) and sculpin species (prickly sculpin, slimy sculpin, and spoonhead sculpin) were recorded in the Halfway River in spring. This provides evidence that the system may be used for spawning by small-fish species.

The Halfway River was used by adult nonspawning bull trout in spring. Large adult bull trout were identified several kilometers upstream from the confluence with the Peace River in concentrations well above those recorded within the Peace River (Mainstream and Gazey 2008). The reasons for these spring concentrations are not known, but it is likely the fish had entered the Halfway River to feed.

6.3.2 Fall

The fall program conducted by Mainstream (2009b) examined fish use of the Moberly River and the Halfway River between 1 and 26 October 2008, with the primary focus being the fall spawning large-fish species, mountain whitefish. A secondary objective was to monitor downstream movements of fish in these two systems. Methods used included fish traps, electrofishers, and egg surveys.

Downstream dispersal by large numbers of redside shiners and young-of-the-year mountain whitefish were recorded in downstream fish traps on the Halfway River and the Moberly River. This information suggested that these fish may leave the Moberly River and Halfway River to overwinter in the Peace River.

Electrofisher surveys of the small tributaries confirmed that adult mountain whitefish did not spawn in Maurice Creek, Lynx Creek, Farrell Creek, Cache Creek, and Wilder Creek; therefore, this discussion will focus on the results for the two large tributaries.

The field results indicated that fish trap effectiveness for upstream migrants was severely limited if the entire river channel was not blocked As such, evaluation of mountain whitefish use was restricted to boat electrofisher data from the Halfway River and fish trap data from the latter portion of the fall program on the Moberly River.

<u>Halfway River</u>

Adult mountain whitefish in spawning condition were recorded in the Halfway River. Catch rates, distribution of fish, numbers of fish in spawning condition, and recaptures of tagged fish provided evidence of potential spawning activity in this tributary. Catch rates increased over time indicating an influx of fish from the Peace River. The size distribution of mountain whitefish in the Halfway River was similar to those recorded in the Peace River, which also indicated that fish originated from the Peace River. Finally, mountain whitefish that had been originally marked and released in the Peace River by other studies (Mainstream and Gazey 2008) were recaptured in the Halfway River.

Mountain whitefish catch rates from the Halfway River were generally higher than catch rates recorded on the Peace River during the present study and other investigations (Mainstream and Gazey 2008), which suggested that large numbers of adult mountain whitefish were present in the system. Adult mountain whitefish in spawning condition were recorded throughout the surveyed area to the upper extent of sampling, which was 23 km from the Peace River. This included sections of the Halfway River upstream and downstream of the Site C reservoir inundation level.

Boat electrofisher sampling in the lower 4 km of the Halfway River in October 1989 also recorded large numbers of adult mountain whitefish (Pattenden *et al.* 1991). Of the 395 captured fish 340 fish (86% of the sample) were in spawning condition.

The mountain whitefish egg survey data contradicted the boat electrofisher results. Very few surveyed sites contained mountain whitefish eggs and all eggs were located in the lower section of the river. These results indicated that either the survey was not able to locate mountain whitefish eggs or that fish in spawning condition moved upstream outside the sampled area before they initiated spawning.

<u>Moberly River</u>

The fish trap results provided strong evidence that Peace River mountain whitefish populations spawn in the Moberly River. Similar to the Halfway River, catch rates, numbers of fish in spawning condition, and recaptures of tagged fish provided evidence indicating use of the tributary for spawning.

In total, 186 and 661 adult mountain whitefish were captured in the upstream and downstream trap, respectively. The majority of fish in the upstream trap were in spawning condition indicating entry into the Moberly River to spawn. In contrast, the majority of fish in the downstream trap indicated that fish had completed spawning and were returning to the Peace River. The size distribution of adult mountain whitefish in the fish trap catch was similar to those recorded in the Peace River, which also indicated that fish originated from the Peace River. Finally, 43 mountain whitefish that had been originally marked and released in the Peace River by other studies were recaptured in the Moberly River.

The mountain whitefish egg survey data supported the findings of the fish trap study. Mountain whitefish eggs were recorded at numerous sites distributed upstream and downstream of the Site C reservoir inundation level. Mountain whitefish eggs were also recorded in the Upper Section, which was 58 km upstream from the Peace River. Some caution should be used when interpreting the egg survey data in that there was no way to differentiate eggs that may have been deposited by resident fish versus Peace River fish. Regardless, the combined evidence from the fish traps, tagged fish, and egg surveys indicated that Peace River mountain whitefish populations spawn in the Moberly River.

6.3.3 Bull Trout Surveys

Adult bull trout of the Peace River population make annual movements to critical spawning habitat, located in the upper Halfway River watershed (Diversified and Mainstream 2009). Bull trout in this population appear to be phenotypically unique in that they are among the largest bull trout in the region.

Peace bull trout use critical spawning habitats located in large tributaries of the upper Halfway River watershed, including the upper Halfway mainstem, Cypress Creek, the Chowade River, Needham Creek, Turnoff Creek, and Fiddes Creek (Diversified 2011b). Surveys between 1994 and 1999 documented bull trout spawner numbers, redd densities (Baxter 1994a, 1994b, 1995, 1997a, 1997b; RL&L 1995), and migration patterns (Burrows *et al.* 2001, MELP 2000). The work documented the presence of two bull trout sub-populations in the watershed; a resident Halfway River population and the Peace River population.

Individuals of the Peace-Halfway bull trout population migrate up to 280 km from over-wintering areas in the lower Halfway River and the Peace River mainstem as far downstream as the Clear River in Alberta (Baxter 1997a, 1997b, Burrows *et al.* 2001, MELP 2000). In the Chowade River, which supports the majority of Peace-Halfway spawning activity, Baxter (1995) found bull trout arrived at the spawning zone as early as August 10, with evidence of redd building reported as early as August 27. Peak spawning activity occurs between September 5 and 12 (Baxter 1995, 1997a). Redd superimposition is common, suggesting that redd site selection is highly site-specific and that the density of spawners in the upper Chowade is substantial. Spawning is typically complete by September 25, by which time bull trout have emigrated from the Chowade River to overwintering sites within the lower Halfway and Peace Rivers (Baxter 1995, 1997a, Burrows *et al.* 2001, MELP 2000).

Past estimates of bull trout spawners in the Chowade River have ranged from 185 ± 75 (Baxter 1995) to 304 (range 231 - 431; RL&L 1995); differences in fish numbers observed reflect differences in sampling methodology and intensity. Frequency of repeat spawners, as identified from recaptures of marked fish (fin clips and spaghetti tags) while snorkeling and angling, has been estimated to be 18% to 25% (Baxter 1995, 1997a). Analysis of radio telemetry data also supports evidence of alternate year spawning and spawning site fidelity (Burrows *et al.* 2001, MELP 2000). While densities of bull trout are lower in the upper Halfway River mainstem and tributaries, timing of migration and spawning appear similar (MELP 2000, Euchner 2007).

Long term monitoring of Peace-Halfway migratory bull trout spawning runs serves as an index of the health of the population and is important for the species' conservation and management. Snorkel surveys augmented by aerial redd counts in 2002 and 2005 tracked bull trout spawner abundance and redd distribution and density in the Chowade WHA, as well as portions of the river upstream and downstream of the WHA (Euchner 2002, 2006). Monitoring in 2005 found an apparent two-fold increase in bull trout run size and redd numbers in the Chowade over previous counts in 2002.

Monitoring of bull trout spawners and redds was repeated in 2008 (Diversified and Mainstream 2009) and 2010 (Diversified and Mainstream (2011b). The 2008 and 2010 studies documented a continued increase in bull trout redd numbers, an increase in redd density, and an expansion of bull trout spawner distribution in the watershed (Figure 6.3.1 and Figure 6.3.2). A total of 1,315 individual redds were enumerated during the 2010 survey, within both previously monitored reaches and the expanded survey areas. Within all stream segments surveyed in both 2008 and 2010, a total of 1,113 redds were recorded in 2010, as compared to 646 redds observed in 2008 (Diversified and Mainstream 2009). The remaining 202 redds comprising the 2010 total were observed in previously unsurveyed reaches of Fiddes and Turnoff Creeks. The overall increase from 2008 to 2010, within previously monitored sub-drainages included a decrease in redd numbers in Cypress Creek and an increase in the remaining 3 sub-drainages.

Based on this information Diversified and Mainstream (2011b) concluded that the bull trout spawner population was expanding. And, the expansion likely was the result of implementation of conservative angling regulations beginning in 1997.

6.4 RECRUITMENT

6.4.1 Distribution of Young Fish

Fish inventories in the technical study area documented the seasonal distribution of young fish in the Peace River, Moberly River, and Halfway River. This information provided indirect evidence of potential recruitment sources for several species.

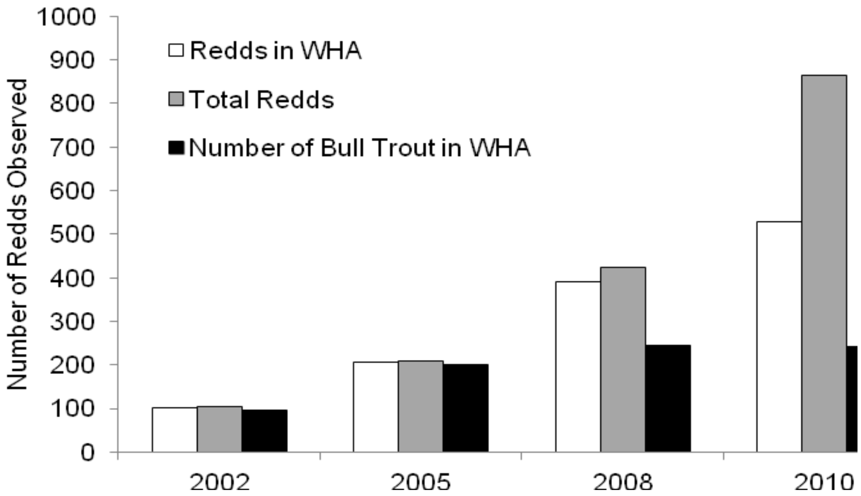


Figure 6.3.1 Comparison of counts of bull trout redds and adult spawners in the Chowade River between 2002 and 2010 (from Diversified and Mainstream 2009).

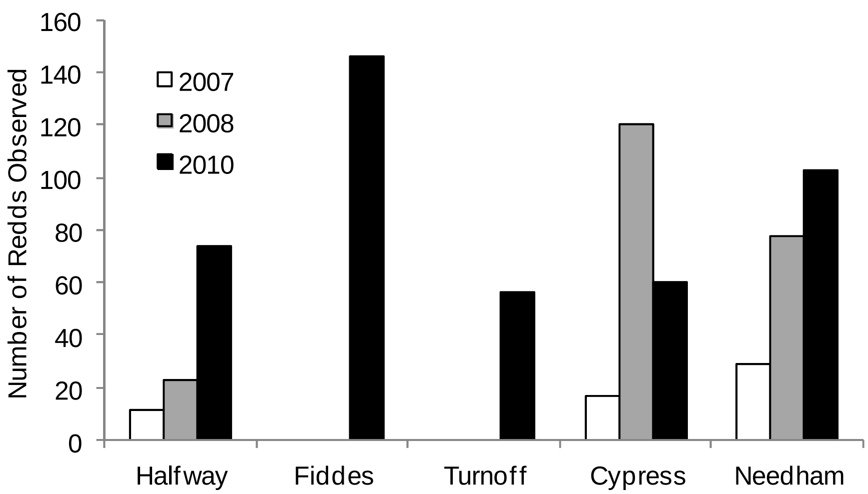


Figure 6.3.2 Comparison of the number of bull trout redds observed in the upper Halfway River mainstem, Fiddes Creek, Turnoff Creek, Cypress Creek, and Needham Creek in 2007, 2008, and 2010 (from Diversified and Mainstream 2009).

6.4.1.1 Peace River

The following is information presented in Mainstream 2011f. Section 5.3.2 of this document describes the study sections illustrated by the distribution maps.

Arctic grayling

There were spatial, seasonal, and habitat differences in the distribution of Age 0 Arctic grayling in the Peace River (Figure 6.4.1). Overall, Age 0 Arctic grayling were most often recorded downstream of the proposed Site C dam (Zone 2) in Sections 5, 6, and 7. Age 0 Arctic grayling were infrequently encountered in upstream sections (Sections 1, 2, and 3) and in the downstream Section 8. Main channels were the primary habitat. Age 0 Arctic grayling were infrequently encountered in spring, the percentage of sites containing fish increased from summer to fall.

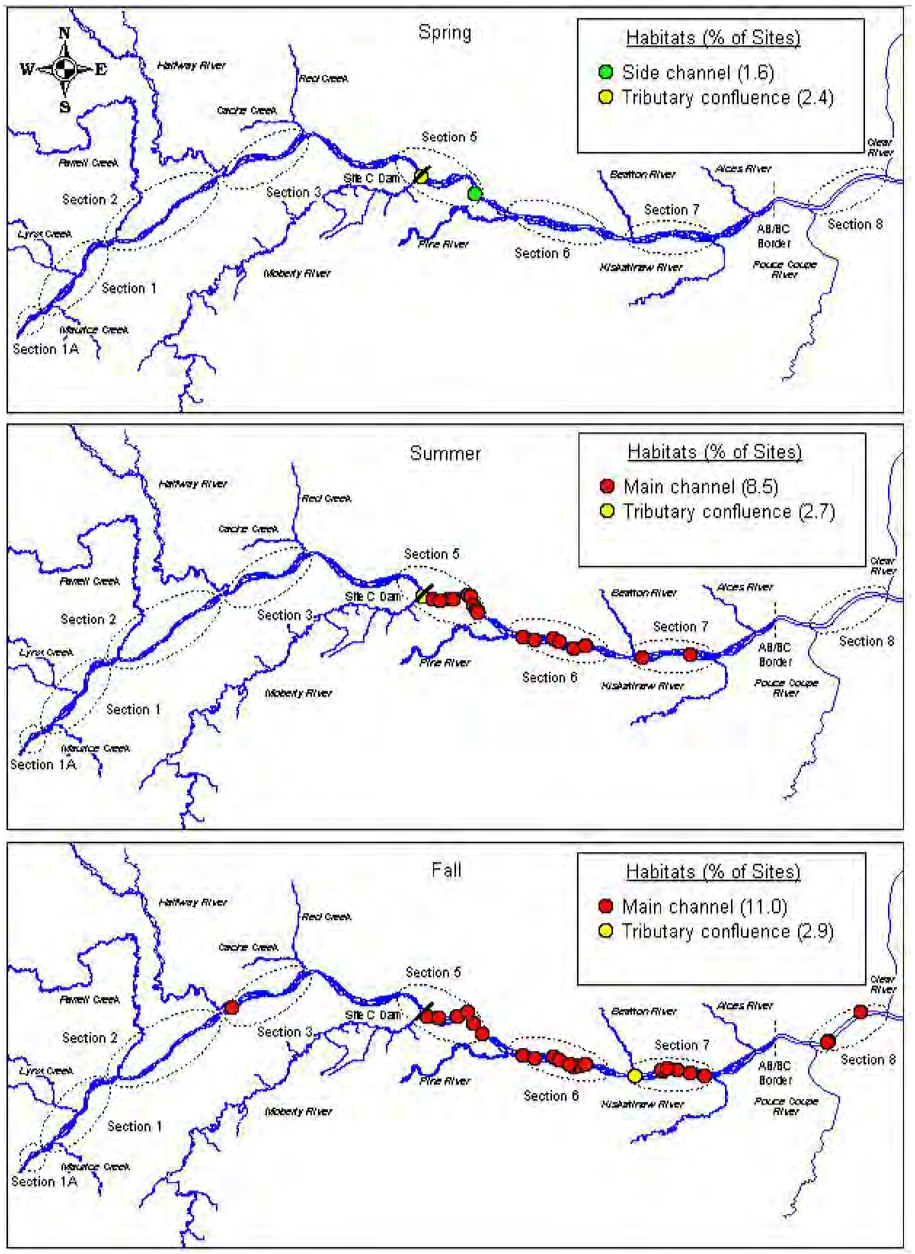


Figure 6.4.1 Distribution of Age 0 Arctic grayling (% of sites with Age 0 Arctic grayling recorded), 2010 Peace River Fish Inventory (from Mainstream 2011f).

Bull trout

No Age 0 bull trout were captured in the study area. Young bull trout were recorded primarily in the upper portion of the study area (Sections 1, 2, and 3) (Figure 6.4.2). All young bull trout in Zone 1 were recorded in main channel habitats. Based on the assumption that young bull trout do not migrate long distances upstream in the Peace River from the confluence of the Halfway River, the presence of young bull trout far upstream (i.e., approximately 17 – 44 km upstream) of the Halfway River, which is the primary spawning and rearing system for the Peace River population provides evidence of alternate sources of recruitment for this population (i.e., entrainment through Peace Canyon Dam). Three young bull trout were recorded downstream of the proposed Site C dam (Zone 2). All were in Section 6.

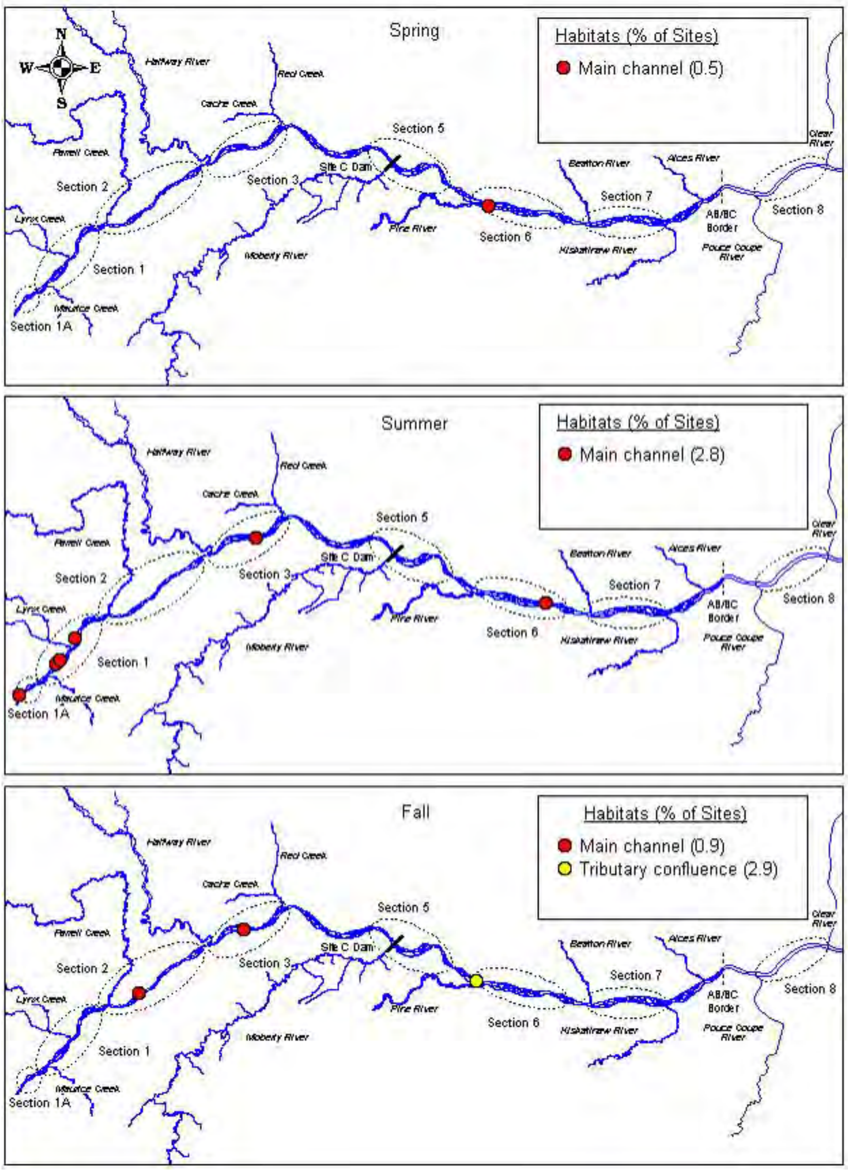


Figure 6.4.2 Distribution of young (Age 1) bull trout, 2010 Peace River Fish Inventory (from Mainstream 2011f).

Kokanee

In spring, numerous young kokanee were recorded throughout Zone 1 in Sections 1A, 1, 2, and 3 and in Section 5 of Zone 2 (Figure 6.4.3). In contrast, few fish (n = 4) were recorded in downstream sections (Sections 6, 7, and 8). Most young kokanee were recorded in main channel habitats. One individual was recorded at the confluence of Lynx Creek in Section 1 and one fish was recorded in a side channel in Section 7. The number of young kokanee encountered in summer was low and most were recorded in Zone 1. In fall, two young kokanee were recorded in Section 3 in main channel habitat.

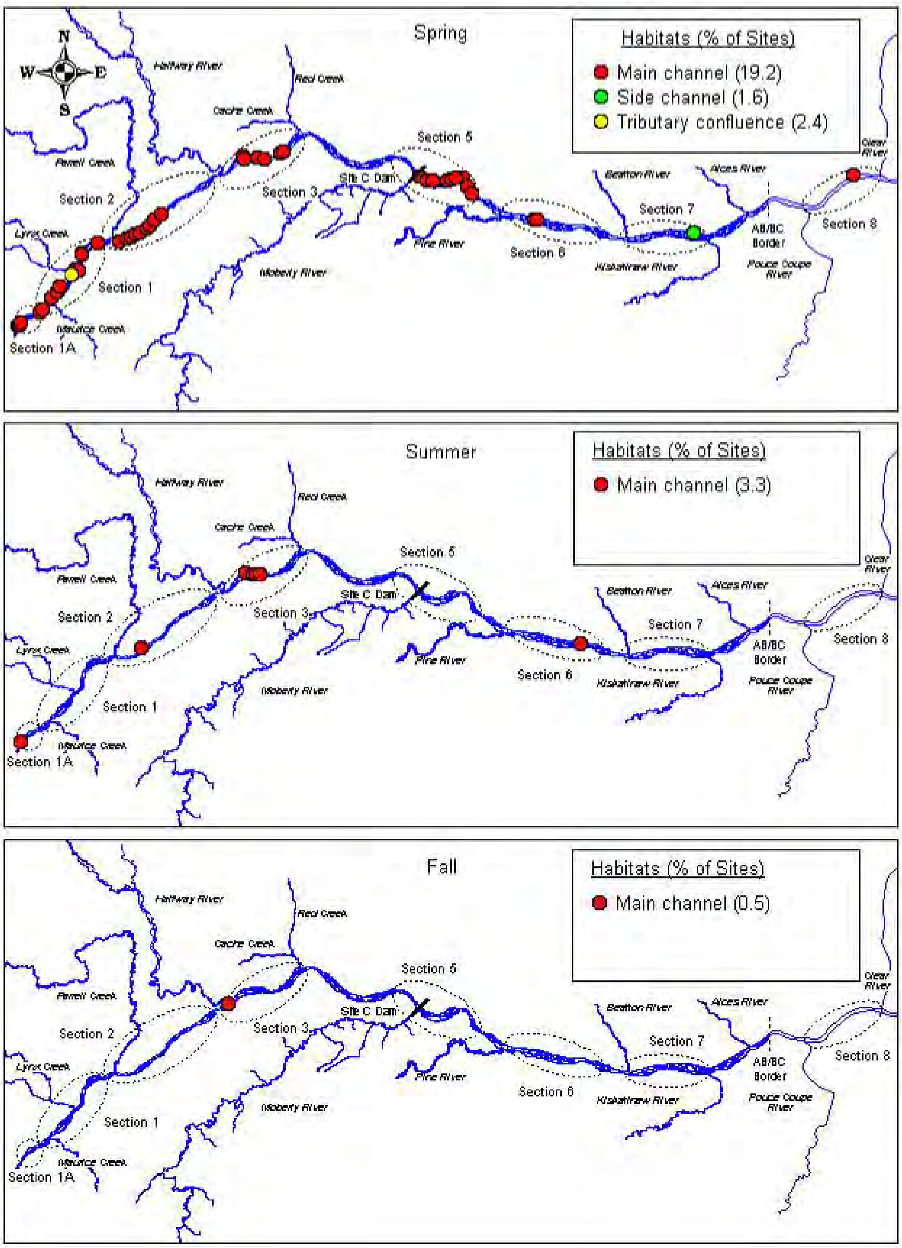


Figure 6.4.3 Distribution of young (Age 1) kokanee, 2010 Peace River Fish Inventory (from Mainstream 2011f).

<u>Mountain whitefish</u>

Age 0 mountain whitefish were widely distributed in the study area (Figure 6.4.4). Fish were recorded in most sections (all except Section 1A) during all seasons. The presence of Age 0 mountain whitefish in the Peace River in spring, which represented recently emerged fish, indicated that mountain whitefish spawning occurs as far upstream as Section 1. The absence of Age 0 mountain whitefish in Section 1A provides evidence that there is minimal or no recruitment from upstream sources. Habitat use by Age 0 mountain whitefish varied by season. In spring, fish were recorded most often in side channel habitats. In summer and fall Age 0 mountain whitefish were more likely to occur in main channel sites.

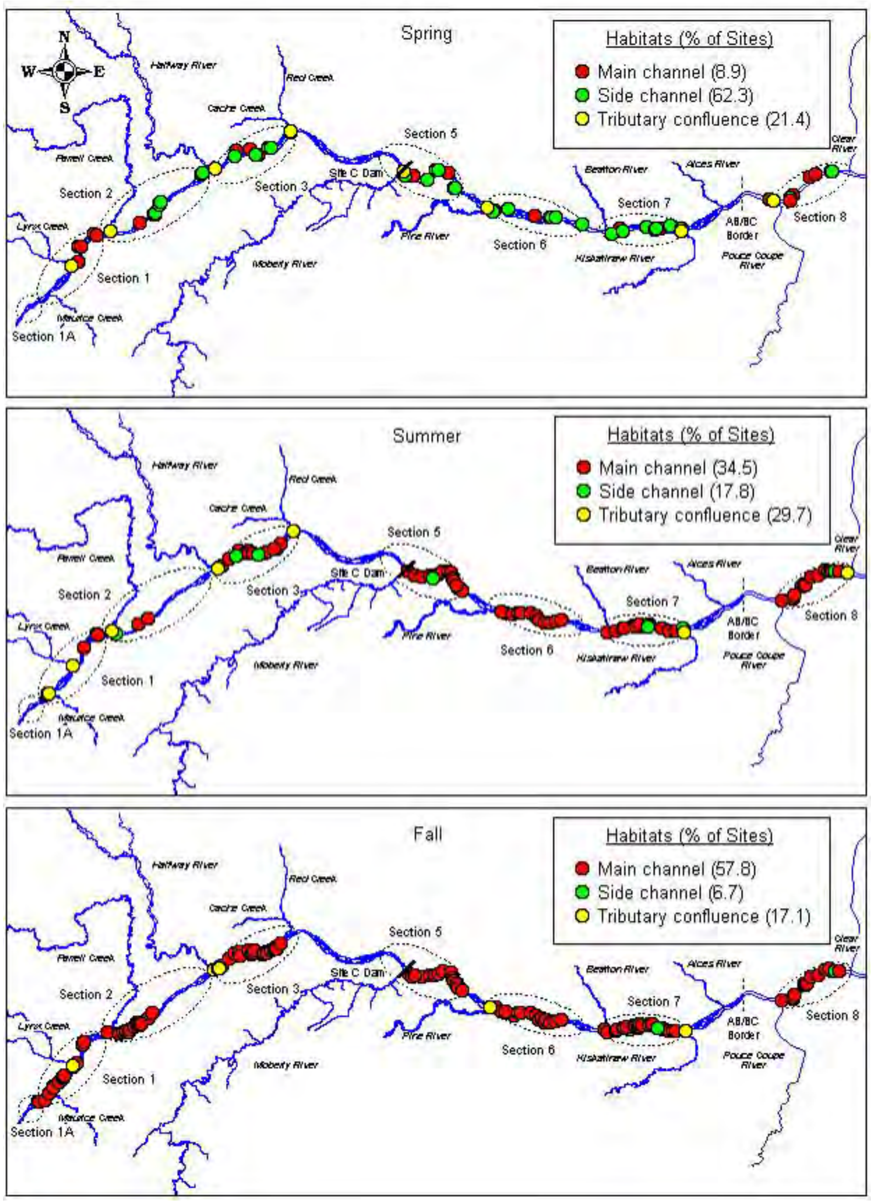


Figure 6.4.4 Distribution of Age 0 mountain whitefish, 2010 Peace River Fish Inventory (from Mainstream 2011f).

<u>Rainbow trout</u>

Age 0 fish were recorded in fall suggesting that fish rear in tributaries before entering the Peace River. Age 0 and Age 1 rainbow trout were encountered most frequently upstream of the Site C dam location (Figure 6.4.5). Most fish were recorded at sites in Sections 1A, 1, 2, and 3, with a limited number of fish occurring at sites in Sections 5 and 7. The presence of young fish in Sections 1 and 2 correspond with tributaries that provide spawning and rearing habitats (Maurice Creek, Lynx Creek, and possibly Farrell Creek). The cluster of sites containing young fish in Section 3, suggests that rainbow trout may recruit from the Halfway River or disperse from upstream areas of the Peace River. All young rainbow trout were recorded in main channel habitats.

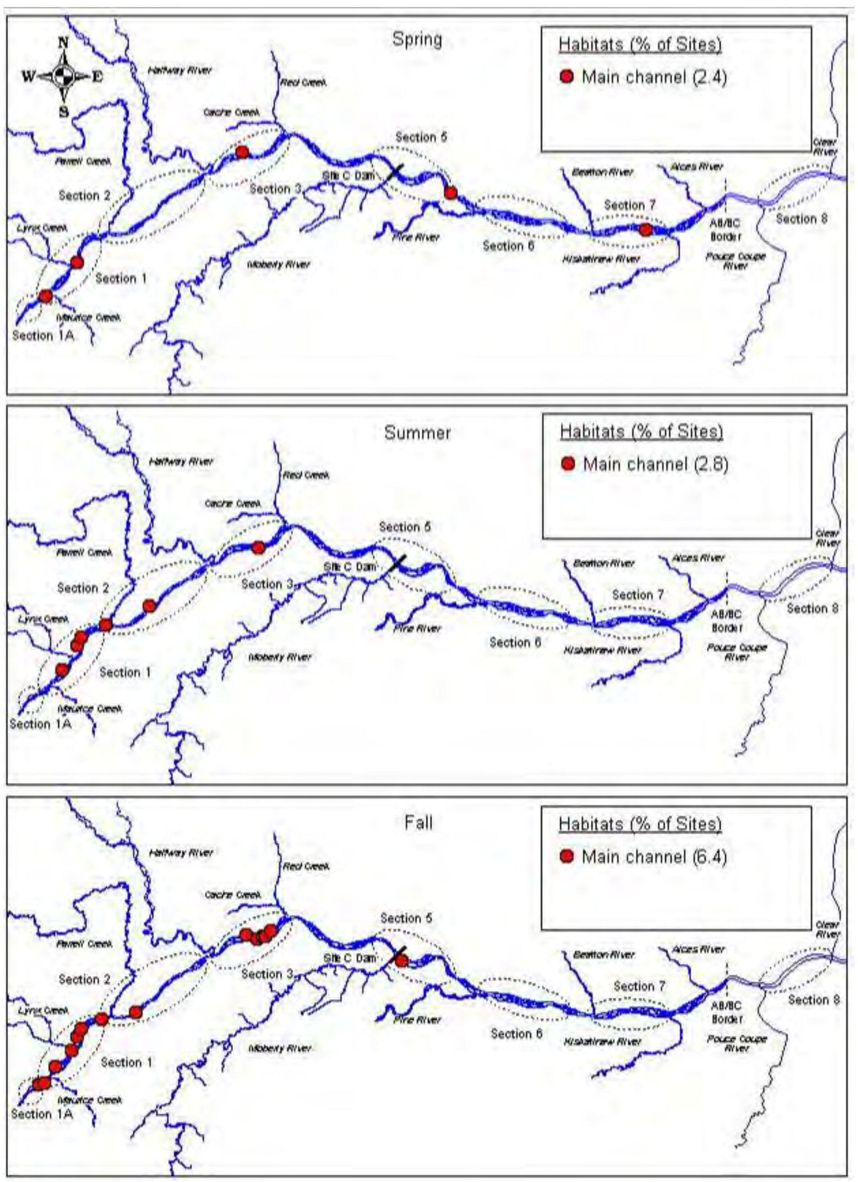


Figure 6.4.5 Distribution of young (Age 0 and Age 1) rainbow trout, 2010 Peace River Fish Inventory (from Mainstream 2011f).

Burbot

Young burbot (Age 1) were encountered in three locations during the study (Figure 6.4.6). Two fish were recorded in Section 6 and one fish was recorded in Section 3.

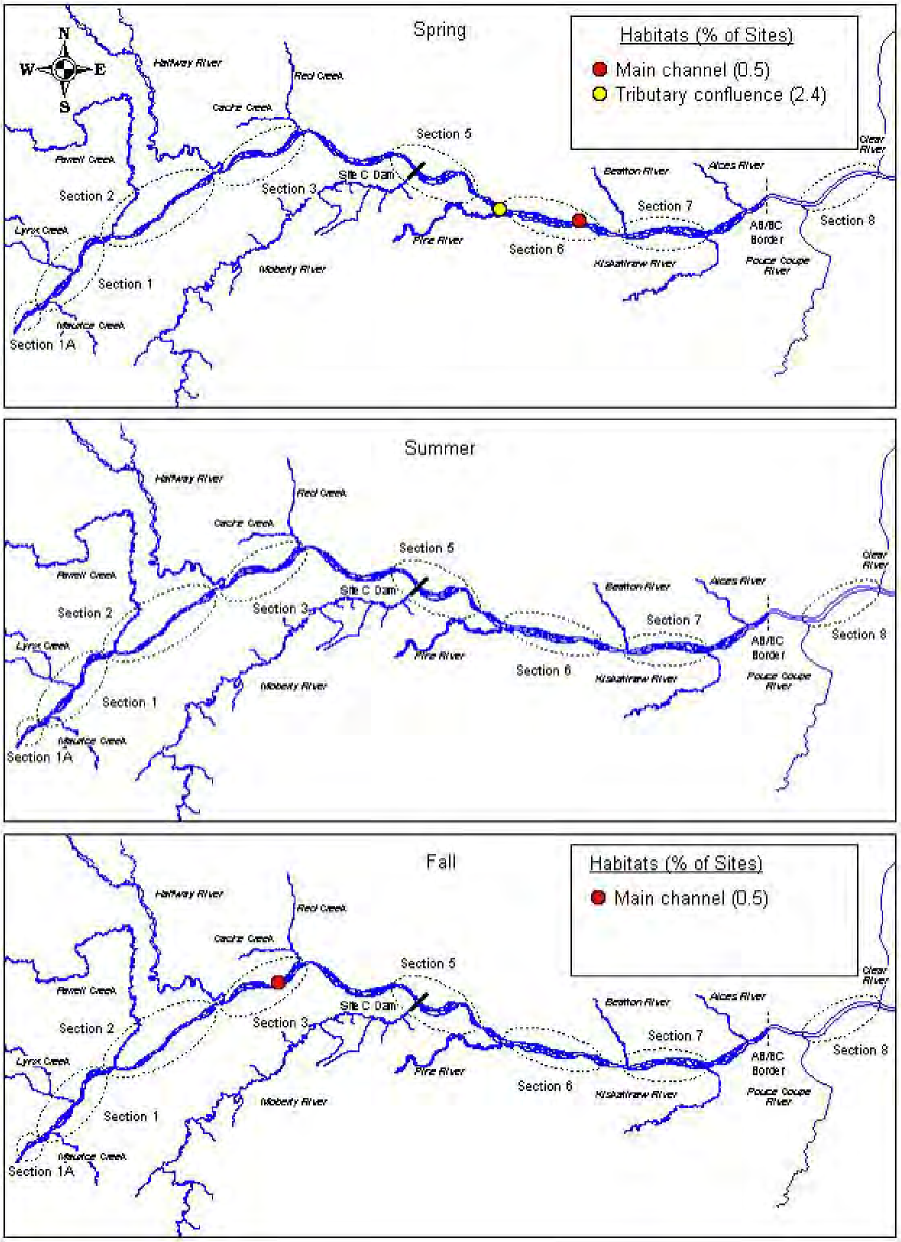


Figure 6.4.6 Distribution of young (Age 1) burbot, 2010 Peace River Fish Inventory (from Mainstream 2011f).

Goldeye

A single young (Age 0) goldeye was recorded during the study (Figure 6.4.7). This fish was encountered in Section 7 at the Beatton River confluence.

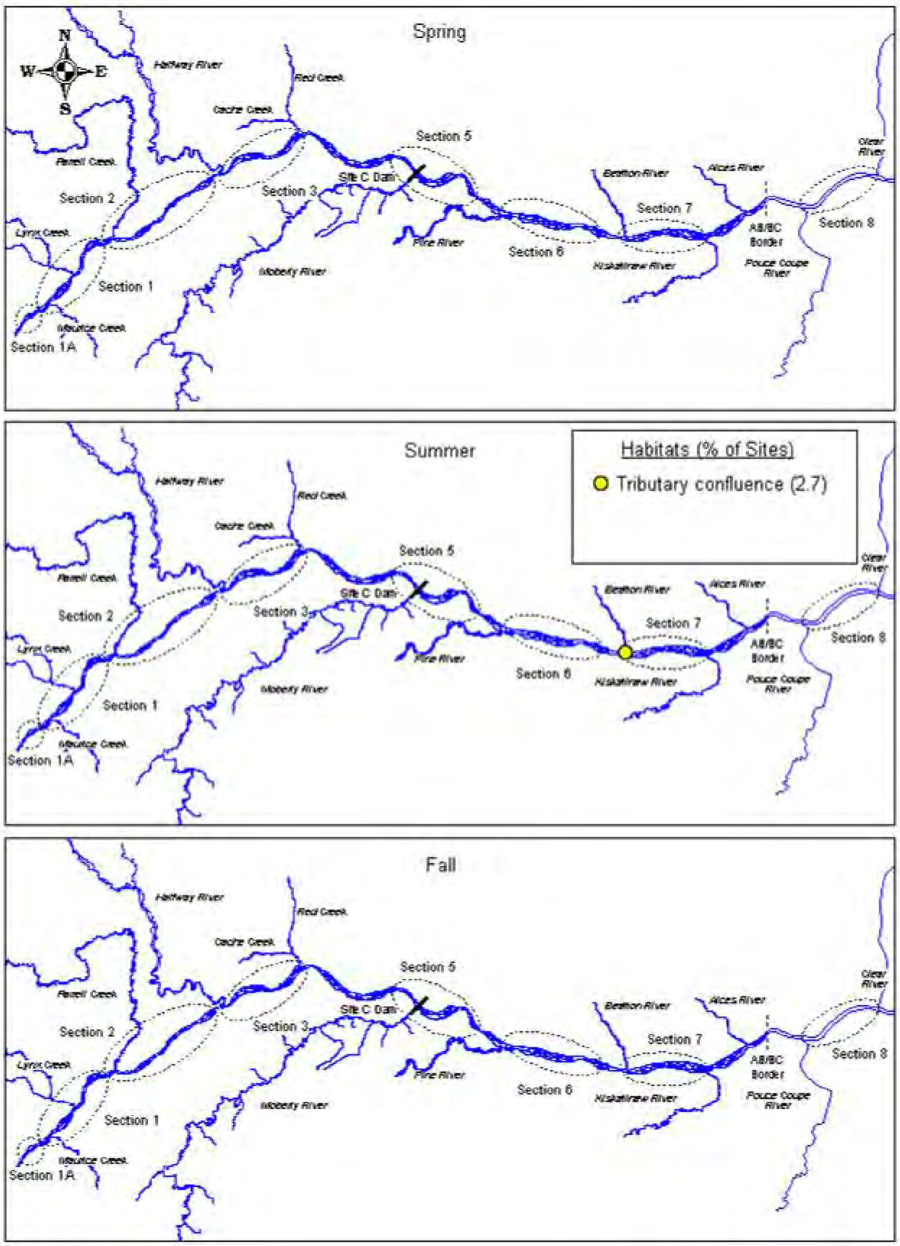


Figure 6.4.7 Distribution of young (Age 0) goldeye, 2010 Peace River Fish Inventory (from Mainstream 2011f).

<u>Northern pike</u>

There were spatial, seasonal, and habitat differences in the distribution of young (Age 0) northern pike in the study area (Figure 6.4.8). Young northern pike were recorded as far upstream as Section 2, but were most frequently recorded downstream of the proposed Site C dam location in Sections 5, 6, and 7. Young northern pike were most frequently recorded in side channel areas during all seasons. Highest fish numbers occurred in side channel areas (Appendix G in Mainstream 2011f); however, fish were also found in main channel and tributary confluence areas.

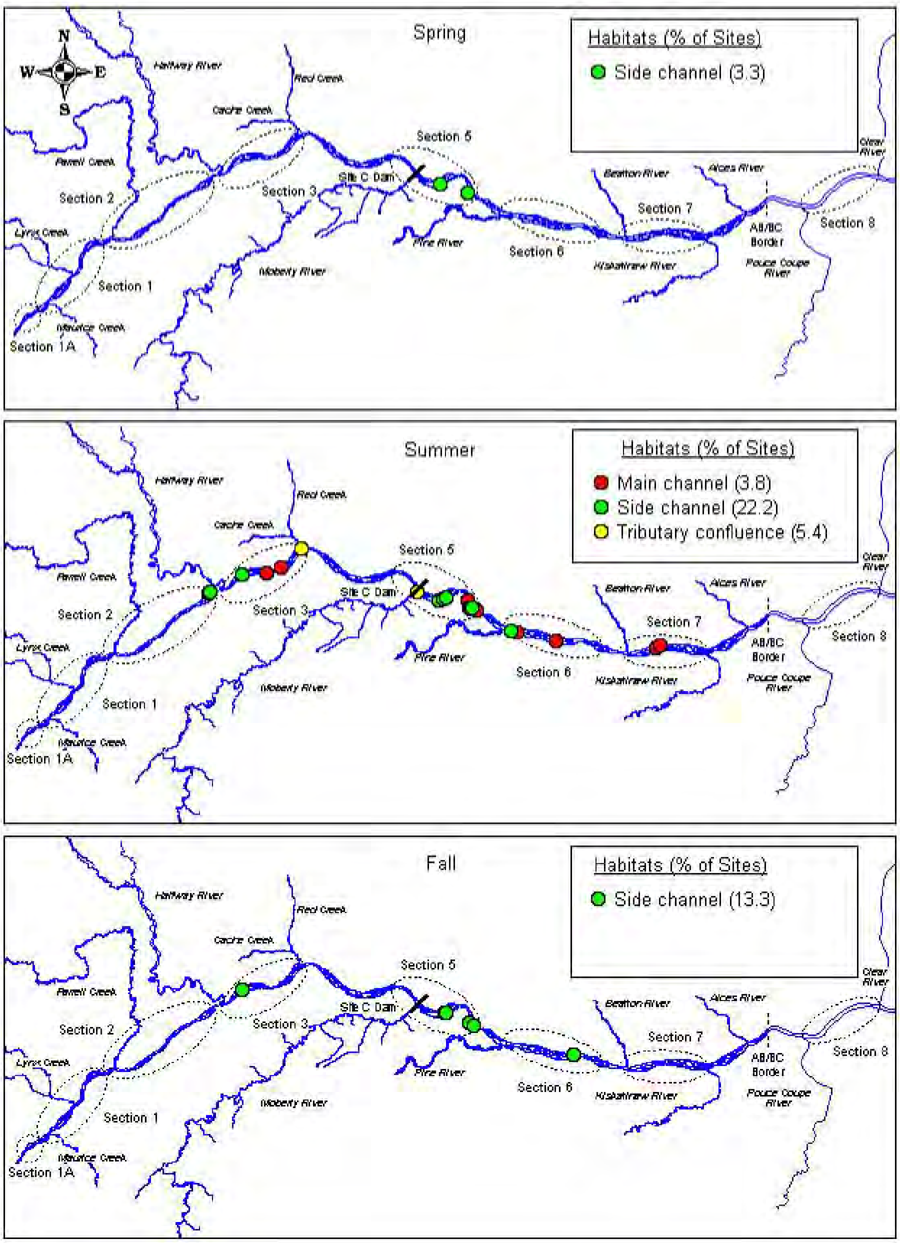


Figure 6.4.8 Distribution of young (Age 0) northern pike, 2010 Peace River Fish Inventory (from Mainstream 2011f).

Walleye

All young walleye (Age 0 and 1) were recorded in Section 7 and Section 8 (Figure 6.4.9) Age 0 fish were recorded at and immediately downstream of the Beatton River confluence in Section 7 and immediately downstream of the Pouce Coupe River confluence in Section 8. Young walleye were also recorded in main channel and side channel areas away from tributary confluences.

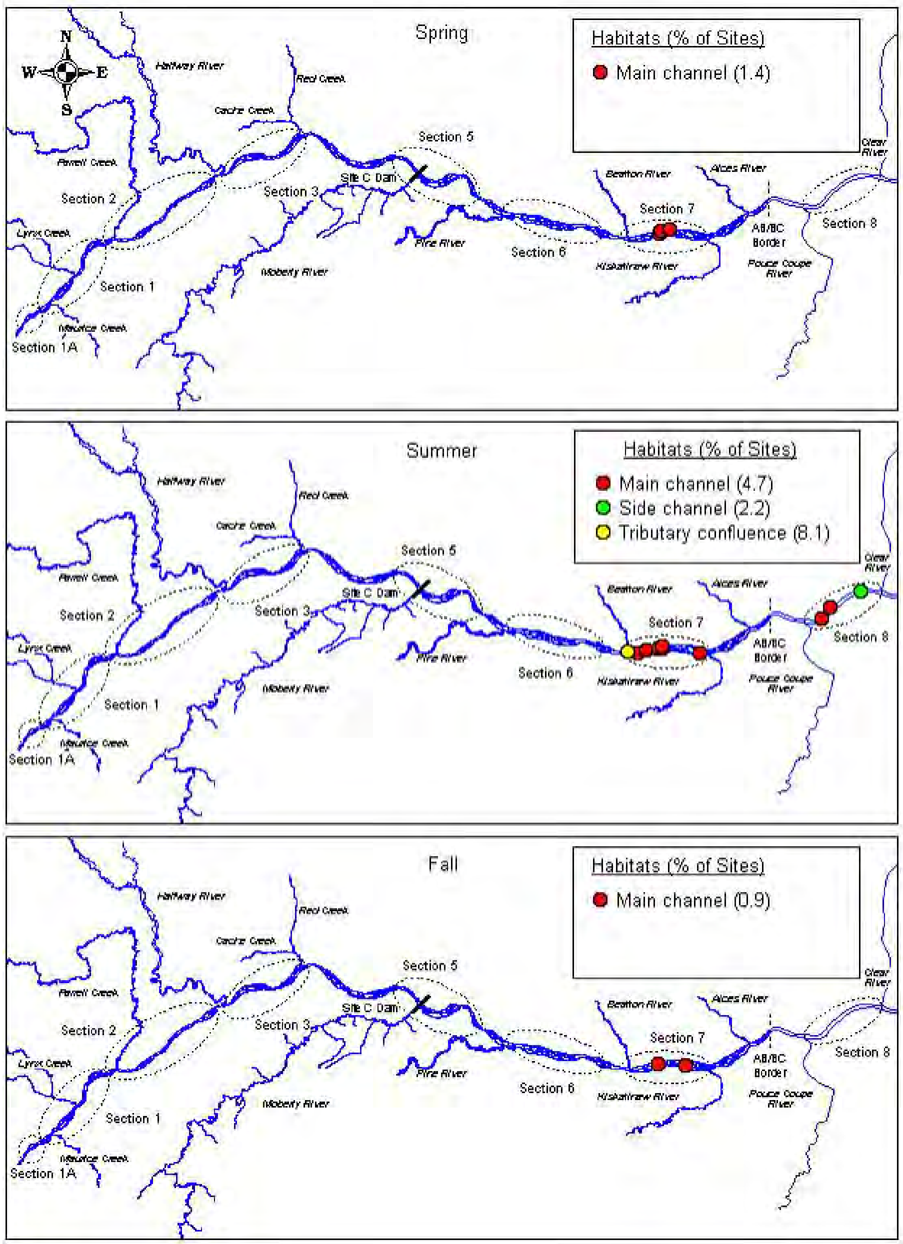


Figure 6.4.9 Distribution of young (Age 0 and Age 1) walleye, 2010 Peace River Fish Inventory (from Mainstream 2011f).

Yellow perch

All young yellow perch (Age 0 and Age 1) recorded during the study were found downstream of the proposed Site C dam location in Sections 5, 6, 7, and 8 (Figure 6.4.10). The majority of fish were recorded in side channel habitats.

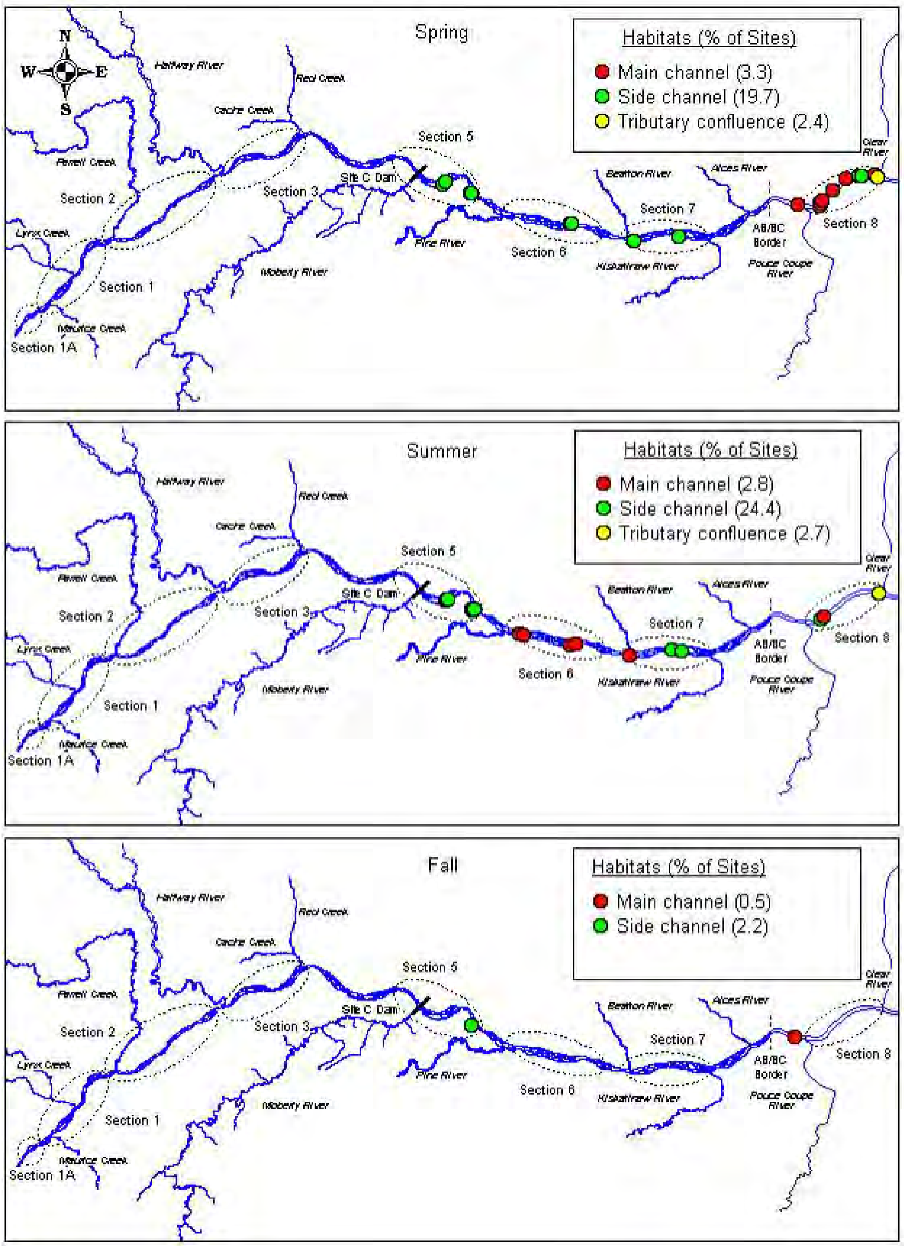


Figure 6.4.10 Distribution of young (Age 0 and Age 1) yellow perch, 2010 Peace River Fish Inventory (from Mainstream 2011f).

Longnose sucker

The distribution of Age 0 longnose suckers was examined based on the fall sample (Figure 6.4.11). During spring and summer Age 0 suckers were not differentiated to species. Age 0 longnose suckers were widespread in the study area in fall. They were found in all sections and in all habitat types.

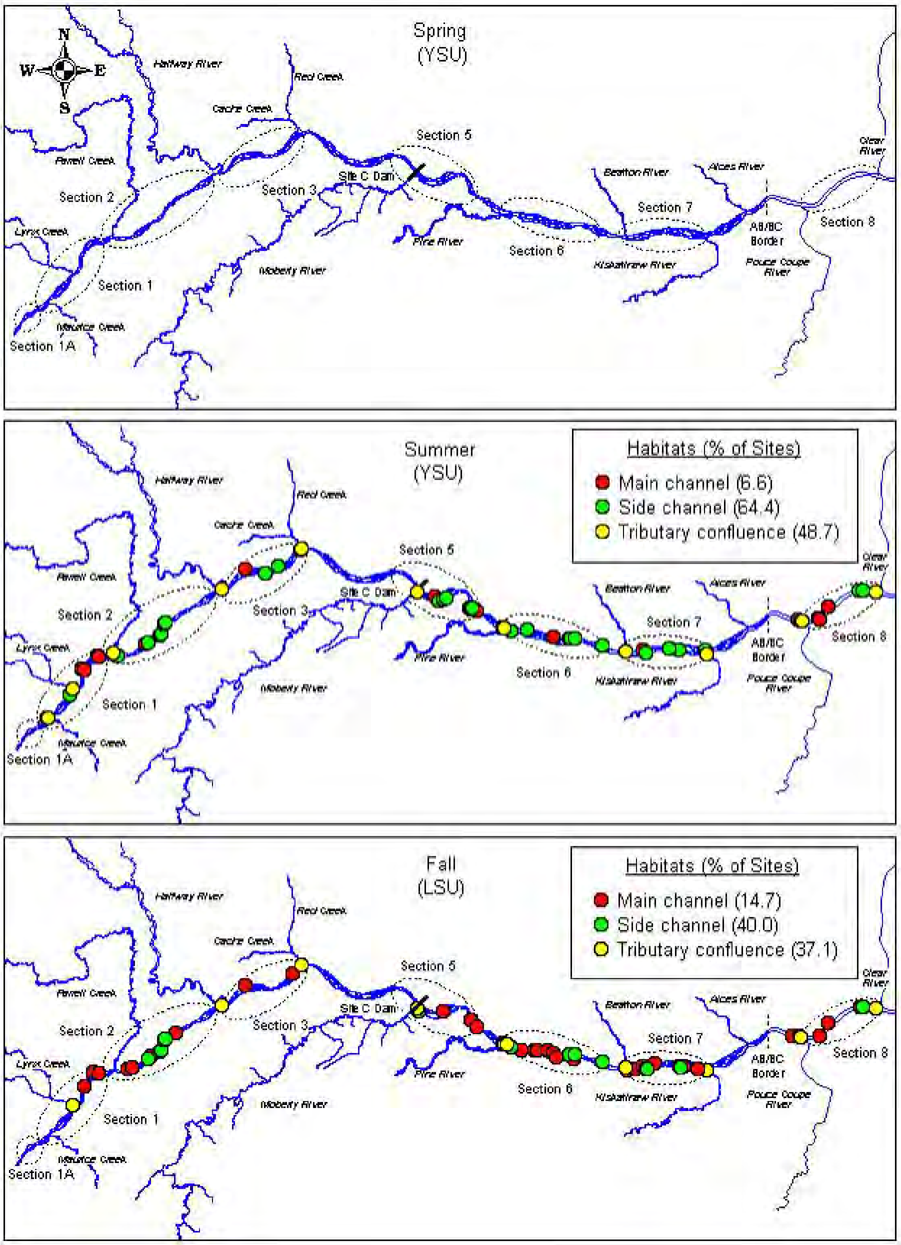


Figure 6.4.11 Distribution of unidentified Age 0 suckers in spring and summer and Age 0 longnose sucker in fall, 2010 Peace River Fish Inventory (from Mainstream 2011f).

Largescale sucker

The distribution of Age 0 largescale suckers was examined based on the fall sample (Figure 6.4.12). During spring and summer Age 0 suckers were not differentiated to species. Age 0 largescale suckers were encountered in all habitat types in Sections 2, 3, 5, and 6.

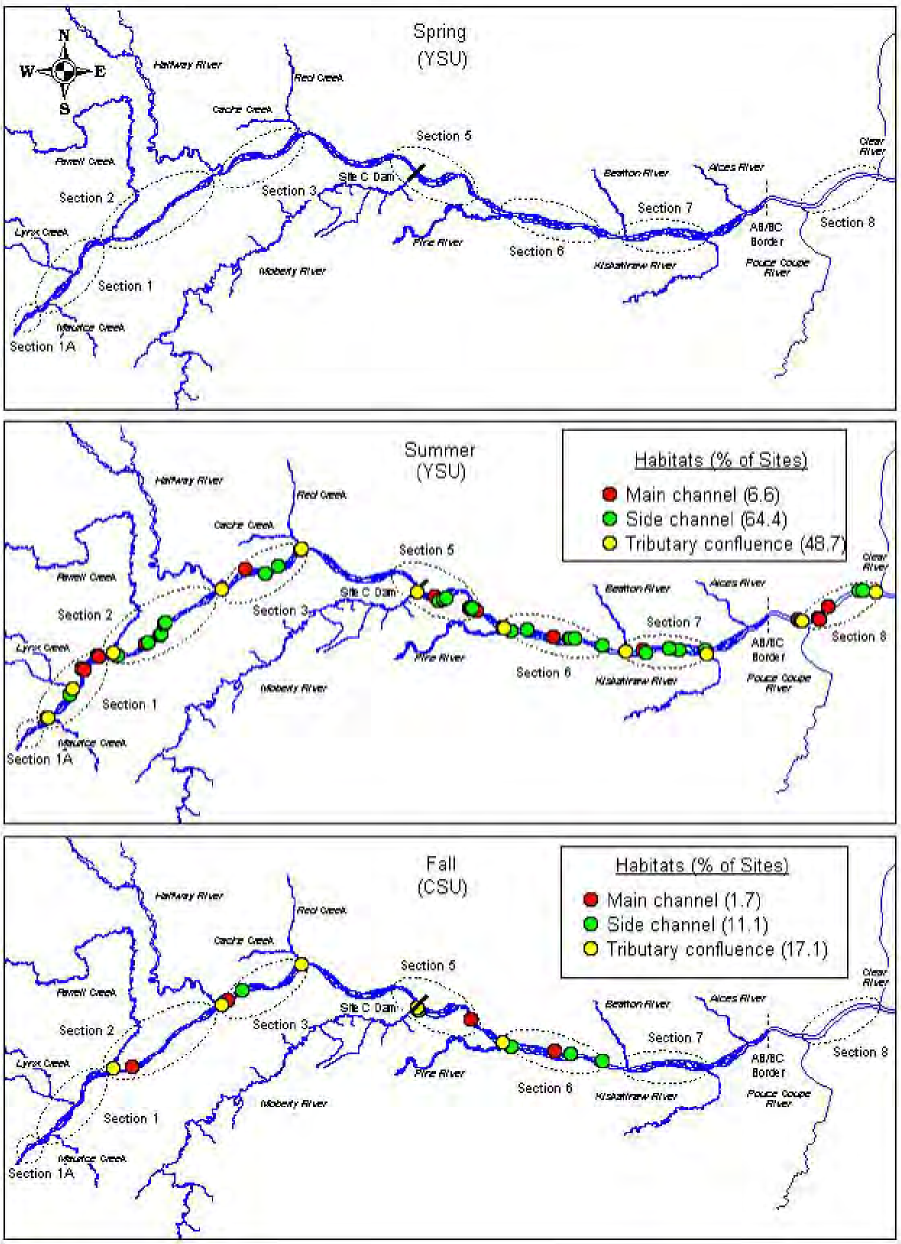


Figure 6.4.12 Distribution of unidentified Age 0 suckers in spring and summer and Age 0 largescale sucker in fall, 2010 Peace River Fish Inventory (from Mainstream 2011f).

<u>White sucker</u>

The distribution of Age 0 white suckers was examined based on the fall sample (Figure 6.4.13). During spring and summer Age 0 suckers were not differentiated to species. All Age 0 white sucker were found downstream of the proposed Site C dam location. The majority occurred in Section 6. Side channels and main channels were the dominant habitat types.

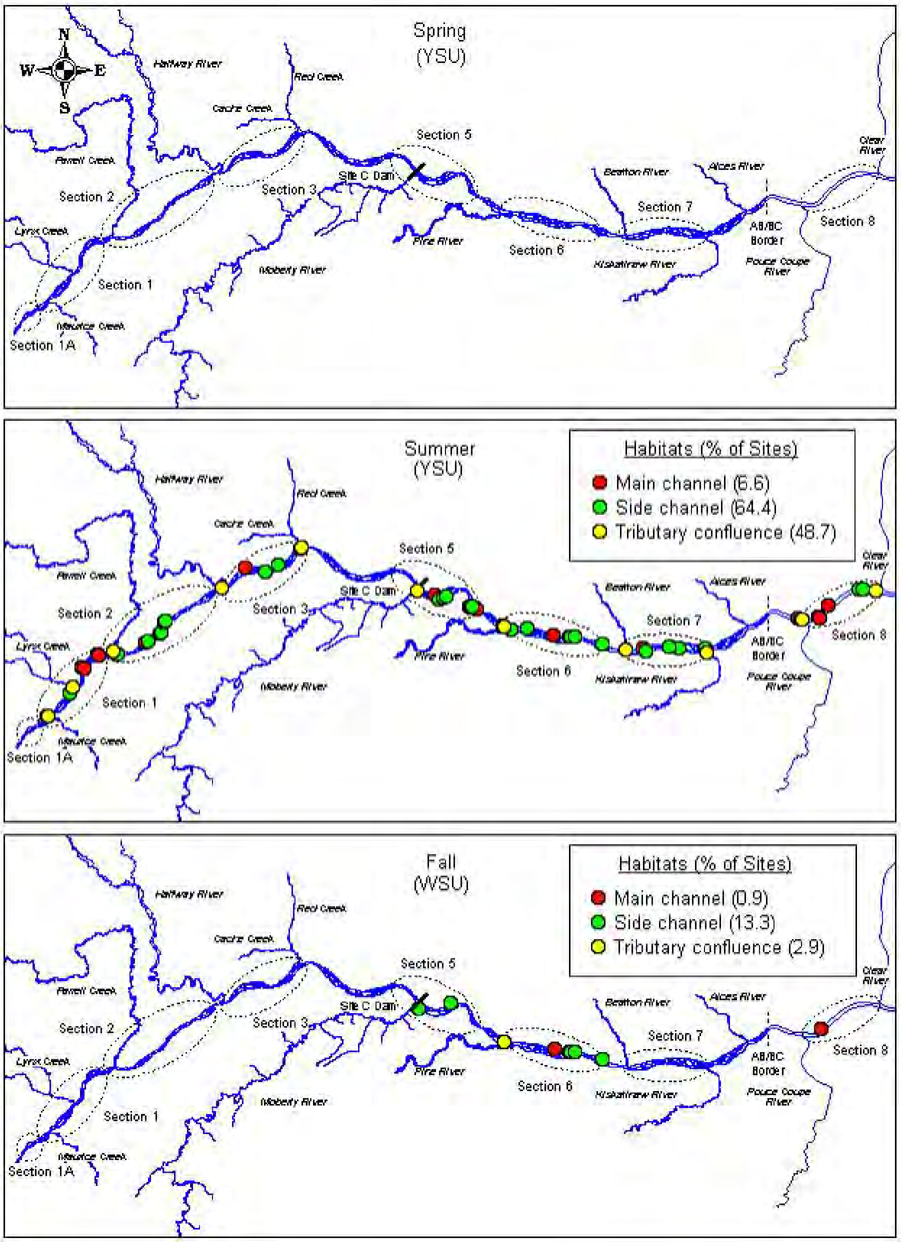


Figure 6.4.13 Distribution of unidentified Age 0 suckers in spring and summer and Age 0 white sucker in fall, 2010 Peace River Fish Inventory (from Mainstream 2011f).

<u>Northern pikeminnow</u>

Young (Age 0 and Age 1) northern pikeminnow age categories were determined by visual assessment of the length distribution data. Young pikeminnow were recorded in most sections except Sections 1A and were encountered in all three habitat types (Figure 6.4.14).

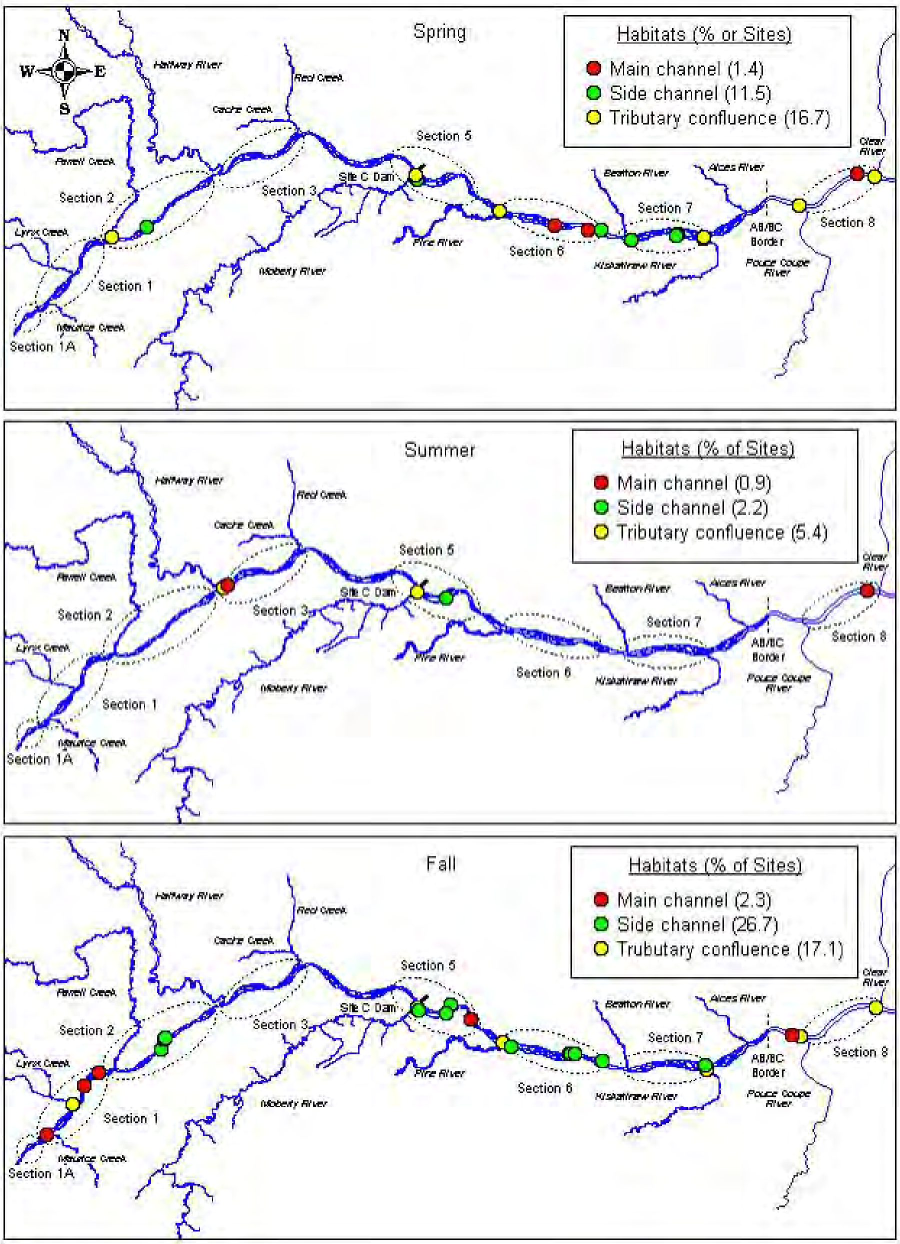


Figure 6.4.14 Distribution of young (Age 0 and Age 1) northern pikeminnow, 2010 Peace River Fish Inventory (from Mainstream 2011f).

6.4.1.2 Moberly River

The following information is presented in Mainstream 2010b. Section 5.3.2 of this document describes the study sections illustrated by the distribution maps.

Young-of-the-year (Age 0) fish of the sportfish species Arctic grayling, burbot, mountain whitefish, and northern pike were recorded during the survey (Table 6.4.1, Figure 6.4.15).

Table 6.4.1 Summary of Age 0 sportfish frequency and number encountered on the Moberly River, Halfway River and Moberly River summer fish survey 2009 (from Mainstream 2010b).

Species Z	**one**	**Sections with Fish**	**No. Sites with Fish**		**Number of Fish per Site**	
			No.	**Percent**	**Mean**	**Range**
Arctic grayling	1		0			
	2	3, 6	4	7.5	1.5	1 – 3
	3	7, 8, 9	5	13.9	1.4	1 – 3
	4	10	2	16.7	3.5	1 – 6
Burbot	1	2	2	8.0	1.0	1 – 1
	2	3, 4, 5	4	7.5	2.8	1 – 6
	3	7, 8, 9	6	16.7	1.3	1 – 2
	4	10	2	16.7	2.0	1 – 3
Mountain whitefish	1	1, 2	7	28.0	1.6	1 – 4
	2	3, 4, 5, 6	21	39.6	3.0	1 – 7
	3	7, 8, 9	11	30.6	2.8	1 – 5
	4	10	5	41.7	2.2	1 – 5
Northern pike	1	1, 2	7	28.0	1.9	1 – 3
	2	3, 4, 5, 6	16	30.2	1.8	1 – 4
	3	7	4	11.1	1.3	1 – 2
	4		0			

Age 0 Arctic grayling were not encountered from Zone 1 (Sections 1 and 2), nor from Sections 4 and 5 of Zone 2. They were recorded in all sections located in Zone 3 (Sections 7 to 9) and Zone 4 (Section 10). Age 0 Arctic grayling occurred at a low percentage of sites within each reach. Percent occurrence ranged from 7.5% in Zone 2 to 16.7% in Zone 4. The number of Age 0 Arctic grayling was low. The mean number of fish encountered per site was ≤ 3.5 and the maximum number recorded was 6 fish per site.

Age 0 burbot were widely distributed. Age 0 fish were absent only from Section 1 in Zone 1 and Section 6 in Zone 2. Although Age 0 burbot were widely distributed, they were not recorded at a large percentage of sampled sites within each reach. Percent occurrence ranged from 8.0% and 7.5% in Zones 1 and 2, respectively, to 16.7% in each of Zones 3 and 4. The mean number of Age 0 burbot recorded in each zone was low (mean range = 1.0 to 2.8 fish per site) and the maximum did not exceed 6 fish per site.

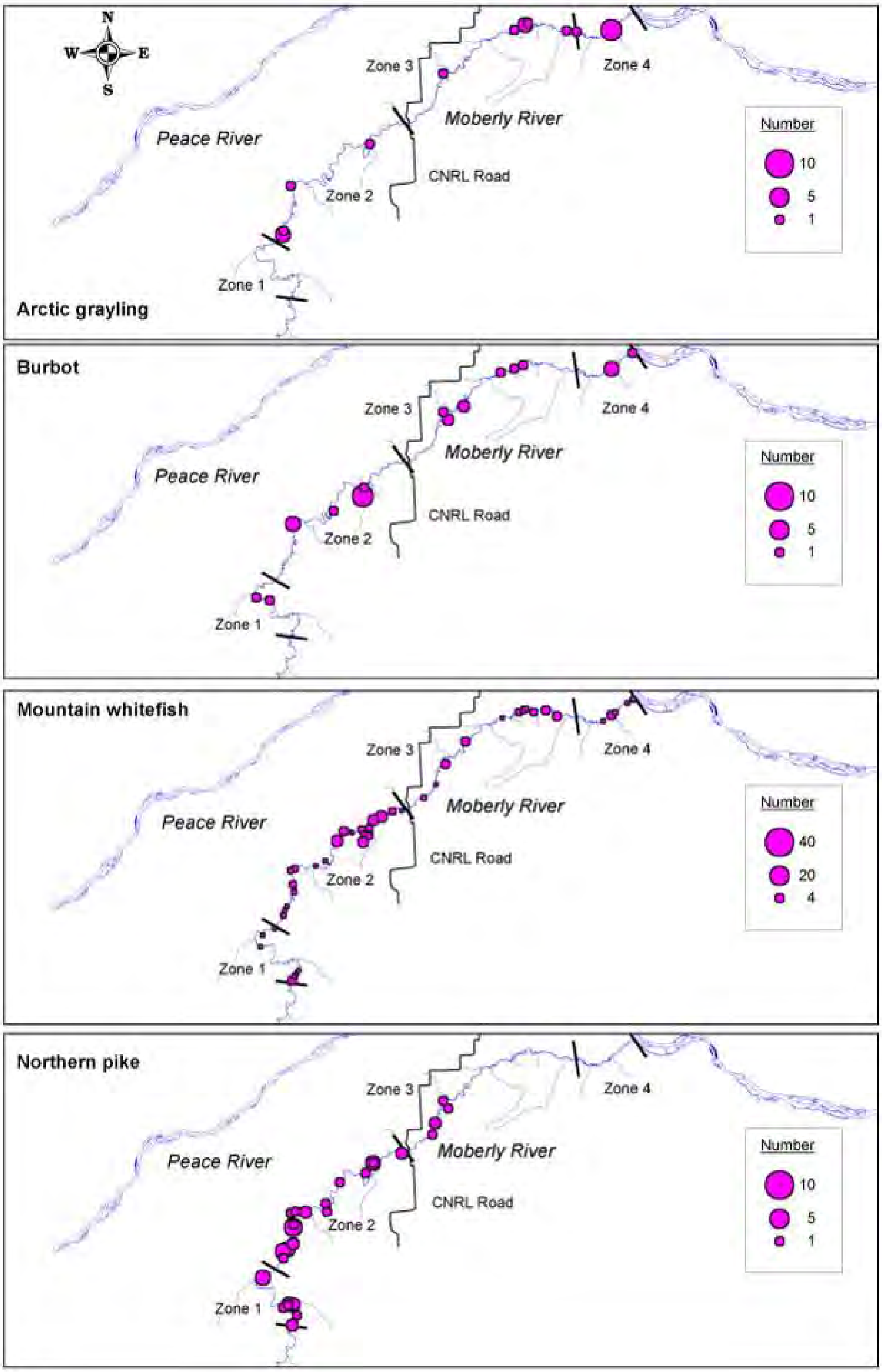


Figure 6.4.15 Distribution and number per site of Age 0 sportfish at sampled sites on the Moberly River, Halfway River and Moberly River summer fish survey 2009 (from Mainstream 2010b).

Age 0 mountain whitefish were the most widespread and numerous sportfish recorded in the study area. They were present in all sampled sections and the percent occurrence at sampled sites ranged from 28.0% (Zone 1) to 41.7% (Zone 4). The mean number of fish per site ranged from 1.6 (Zone 1) to 3.0 fish (Zone 2) and the maximum number recorded was 7 fish per site.

Age 0 northern pike were recorded from all sections of the upper portion of the study area (Sections 1 to 7), but were absent downstream of Section 7. Age 0 northern pike were more frequently encountered at sampled sites than Arctic grayling and burbot. Percent occurrence ranged from 28.0% and 30.2% in Zones 1 and 2, respectively to 11.1% in Zone 3.

6.4.1.3 Halfway River

The following information is presented in Mainstream 2011f. Section 5.3.2 of this document describes the study sections illustrated by the distribution maps.

Young Arctic grayling, bull trout, mountain whitefish, and rainbow trout were an important component of the catch. However, no young-of-the-year (Age 0) bull trout and only two Age 0 rainbow trout were encountered in the Halfway River during the survey (Table 6.4.2, Figure 6.4.16). This is of interest because it suggested that early rearing by bull trout and rainbow trout occurred in Halfway River tributaries and not in the mainstem Halfway River.

Age 0 Arctic grayling were located in Reaches 4 (Section 1), 3 (Section 5), and 2 (Section 9), but were absent from the lowermost Reach 1. The occurrence of Age 0 Arctic grayling at sampled sites was low (2.7% to 5.8%). The number of Age 0 Arctic grayling per site also was low. The mean number of fish was ≤ 1.3 fish per site and the maximum number recorded was 2 fish per site.

Age 0 mountain whitefish were widespread and abundant in the Halfway River study area. They were recorded in all reaches and in all sections. The percentage of sites with fish also was high (≥ 54.1%). The mean number of Age 0 mountain whitefish per site was high in most reaches (≥ 6.8 fish per site). A low mean value of 1.8 fish per site was recorded in Reach 4. The maximum number recorded was 40 fish per site.

Age 0 rainbow trout were recorded only at one site in Section 5 of Reach 3. Two fish were recorded at that site.

Table 6.4.2 Summary of Age 0 sportfish frequency and number encountered on the Halfway River, Moberly River and Halfway River Fish Inventory 2010 (from Mainstream 2011f).

Species Reac	h	Sections with Fish	Number of Sites with Fish		Number of Fish per Site	
			No.	Percent	Mean	Range
Arctic grayling	4	1	1	2.7	1	-
	3	5	3	5.8	1.3	1 – 2
	2	9	1	4.3	1.0	-
	1	-				
Mountain whitefish	4	1, 2	20	54.1	1.8	1 – 5
	3	3, 4, 5, 6, 7	31	59.6	6.9	1 – 40
	2	8, 9	13	56.5	12.8	1 – 26
	1	10	8	66.7	6.8	1 – 12
Rainbow trout	4	-				
	3	5	1	1.9	2.0	-
	2	-				
	1	-				

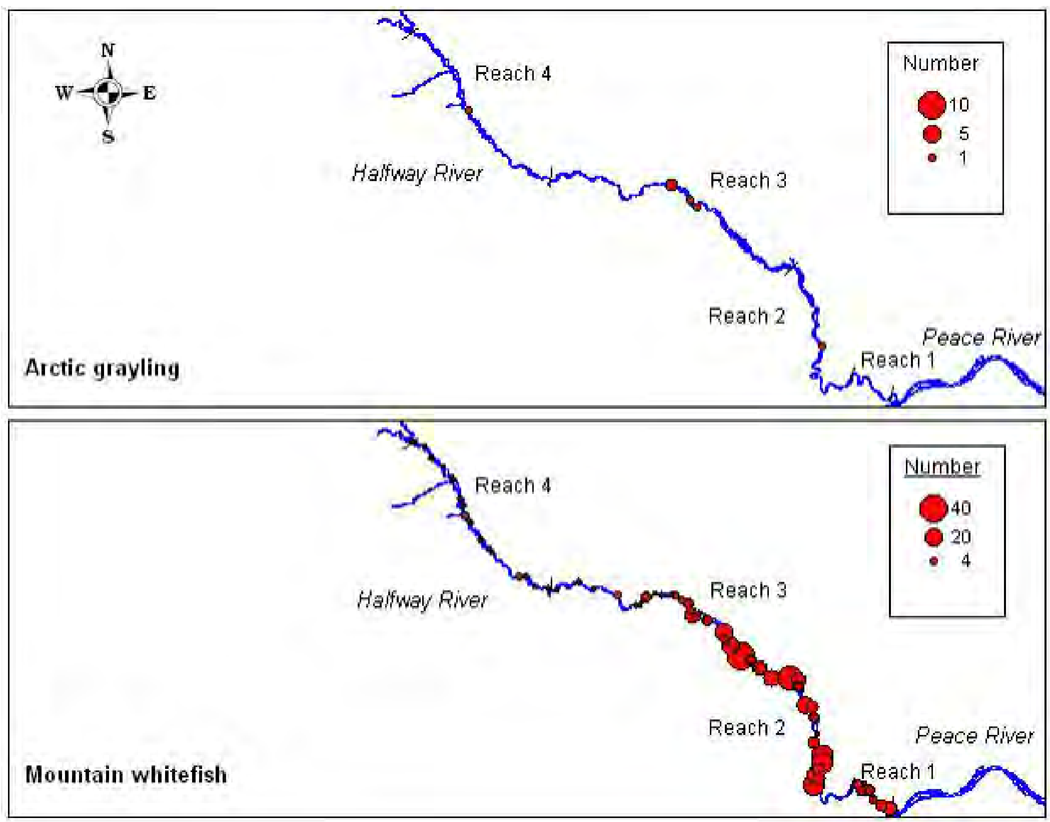


Figure 6.4.16 Distribution and number per site of selected Age 0 sportfish at sampled sites on the Halfway River, Moberly River and Halfway River Fish Inventory 2010 (from Mainstream 2011f).

6.4.2 Elemental Signature

In 2010, Clarke *et al.* (2010) completed a pilot study to investigate the efficacy of otolith microchemistry analysis, or otolith elemental signature method, as a technique to describe the life history of fish in the technical study area. Elemental signature method examines the microchemistry of fish otoliths (and other bony structures) using laser ablation-inductively coupled plasma mass spectrometry (LA-ICPMS). Because otoliths are metabolically inert and permanently retain elements incorporated through daily growth, entire individual life histories can be recorded in the structure (Campana and Neilson 1985), and as such, it is possible to analyze the otolith to determine a specific life history. Concentrations of specific elements in the otolith reflect the water chemistry of the habitat in which the fish resides. Spatial differences in the chemistry of freshwaters (e.g., tributary versus mainstem) will be reflected in the fish otolith. Based on this relationship, fish movements, habitat utilization, and fish recruitment sources can be characterized.

The purpose of the 2010 work was to complete a pilot study to establish whether otolith microchemistry analysis could be used to address data gaps in our knowledge of the Peace River fish community. The pilot study demonstrated that the elemental signature method can be applied to investigate fish life history strategies and recruitment sources in the technical study area. Main findings of the 2010 work were as follows:

1. The elemental signature method was an effective technique when applied to otoliths collected from mountain whitefish and Arctic grayling in the Peace River and the Halfway River.
2. Water chemistry data for the Peace River, Moberly River, and Halfway River provided sufficient separation of potential chemical signatures.
3. The Moberly River appears to be a major source of recruitment for Peace River Arctic grayling.
4. The Halfway River and Peace River appear to be major sources of recruitment for Peace River mountain whitefish.
5. Unknown sources of recruitment also were identified for Arctic grayling and mountain whitefish collected from the Halfway River and the Peace River.

The 2010 pilot study was followed by a broader investigation in 2011 by Earth Tone Environmental and Mainstream (2012). Otoliths used for analyses were collected from 613 fish representing six species -- Arctic grayling, bull trout, rainbow trout, mountain whitefish, goldeye and walleye (Table 6.4.3). Otoliths were collected primarily from juvenile fish during 2010 and 2011 baseline fish studies. Otolith sample locations included Dinosaur Reservoir, Peace River sites upstream and downstream of the Site C dam location and several Peace River tributary sites.

Table 6.4.3 Summary of otoliths by species and location used for microchemistry analyses (from Earth Tone Environmental and Mainstream 2012) .

Waterbody	Area/ Tributary	Arctic grayling	Bull trout	Mountain whitefish	Rainbow trout	Goldeye	Walleye
Dinosaur Reservoir				20	20		
Peace River	Upstream	32	22	53	49	0	0
	Downstream	54	15	39	1	25	40
Maurice Creek			1		21		
Halfway River		40	10	45	21		
Moberly River		30		43			
Pine River	Burnt		2				
	Fellers		3				
	Callazon		2				
	Wolverine		3				
	Pine	1	1	20			
	Total	**157 5**	**9**	**220**	**112 2**	**5 4**	**0**

The otolith microchemistry was determined using LA-ICPMS analyses. Otolith microchemistry was compared to water chemistry signatures from 38 tributary locations and multiple locations on the Peace River. The analysis used a combination of approaches including discriminant function analysis, spatial habitat maps according to natal and early life histories, and continuous time series maps.

The 2011 study established that the elemental signature method was an effective technique when applied to otoliths collected from fish located in the Peace River and tributaries. Main findings of Earth Tone Environmental and Mainstream (2012) are presented below.

<u>Arctic grayling</u>

The Moberly River watershed is an important recruitment source for Peace River Arctic grayling, with two recruitment habitats identified. The first habitat represents the mainstem Moberly River and the other represents a Moberly River side channel that is a confirmed Arctic grayling spawning and rearing area (Clarke *et al.* 2010, Earth Tone Environmental and Mainstream 2012, Mainstream 2010b). Peace River Arctic grayling also recruited from the Halfway, Pine, and Beatton Rivers. Finally, most sampled Arctic grayling spent their first summer in habitats that were chemically similar to their natal streams.

Of the 38 Arctic grayling collected from the Peace River downstream of the Site C dam location whose natal habitat could be identified, 18% originated from tributaries downstream of the Site C dam location. Of the 27 Arctic grayling collected from the Peace River upstream of the Site C dam location whose natal habitat could be identified, 93% originated from tributaries upstream of the Site C dam location.

Of the 47 Arctic grayling collected from the Peace River downstream of the Site C dam location whose first summer habitat could be identified, 27% originated from tributaries downstream of the Site C dam location. Of the 24 Arctic grayling collected from the Peace River upstream of the Site C dam location whose first summer habitat could be identified, 84% originated from tributaries upstream of the Site C dam.

<u>Bull trout</u>

Recruitment locations of bull trout could not be identified for 36% of the sample. This is an indication that the water chemistry signature was not identified by the study (i.e., fish originated from unknown tributaries). For Peace River bull trout, individuals where known locations were predicted originated primarily from the Halfway River watershed tributaries (e.g., Chowade River, Cypress Creek, Fiddes Creek). These tributaries are spawning and rearing areas for Peace River bull trout (Diversified and Mainstream 2011b). A small number of Peace River bull trout also originated from Gething Creek, which is a tributary that flows into Dinosaur Reservoir. Finally, groups of bull trout originating from small tributaries demonstrated remarkable similarities in habitat use throughout their life histories.

Of the 13 bull trout collected from the Peace River downstream of the Site C dam location whose natal habitat could be identified, 0% originated from tributaries downstream of the Site C dam location. Of the 13 bull trout collected from the Peace River upstream of the Site C dam location whose natal habitat could be identified, 100% originated from tributaries upstream of the Site C dam location.

Of the 10 bull trout collected from the Peace River downstream of the Site C dam location whose first summer habitat could be identified, 0% originated from tributaries downstream of the Site C dam location. Of the 14 bull trout collected from the Peace River tributaries upstream of the Site C dam location whose first summer habitat could be identified, 86% originated from upstream of the Site C dam location.

<u>Mountain whitefish</u>

Mountain whitefish collected from the technical study area reflected a complex life history strategy. Moberly River mountain whitefish mostly recruit from the Moberly River watershed; however, some Moberly River mountain whitefish recruit from the Halfway, Peace, and Pine Rivers. Halfway River mountain whitefish are mainly recruited from the Halfway River, but some fish recruited from the Peace, Moberly, and Beatton Rivers. Mountain whitefish collected from the Peace River originated from many locations. These included the Halfway River, Moberly River, Peace River, Pine River, and the Beatton River. The Peace River mainstem represents a significant location for first summer rearing by fish collected from the Halfway, Moberly, Peace, and Pine Rivers. The Pine River, or its confluence area, represents an important first summer rearing habitat for mountain whitefish sampled from the Peace River. Finally, a large number of sampled mountain whitefish typically move to larger mainstem habitats in their first summer.

Of the 31 mountain whitefish collected from the Peace River downstream of the Site C dam location whose natal habitat could be identified, 52% originated from tributaries downstream of the Site C dam location and 10% originated from the Peace River. Of the 50 mountain whitefish collected from the Peace River upstream of the Site C dam location whose natal habitat could be identified, 60% originated from tributaries upstream of the Site C dam location and 22% originated from the Peace River.

Of the 33 mountain whitefish collected from the Peace River downstream of the Site C dam location whose first summer habitat could be identified, 61% originated from tributaries downstream of the Site C dam and 27% originated from the Peace River. Of the 50 mountain whitefish collected from the Peace River upstream of the Site C dam location whose first summer habitat could be identified, 52% originated from tributaries upstream of the Site C dam location and 32% originated from the Peace River.

Rainbow trout

Peace River rainbow trout originated from Dinosaur Reservoir and its tributaries (approximately 28%), Maurice Creek (approximately 18%), Lynx Creek (1%), Farrell Creek (approximately 22%), and the Halfway River system (approximately 26%). Maurice Creek and Peace River rainbow trout move between the Peace River, Maurice Creek, and Farrell Creek during their life history. Both Maurice Creek and Farrell Creek appear to be important habitats used by rainbow trout collected in the Peace River.

Peace River rainbow trout were collected from upstream of the Site C dam location. Fish whose natal and first summer habitats could be identified originated from upstream of the Site C dam location.

Goldeye

Otoliths were collected from adult goldeye in the Peace River. The source of most goldeye could not be identified, suggesting that fish originated from areas downstream of the technical study area. The Smoky River watershed in Alberta provided natal and first summer habitats for 24% of the sample.

Walleye

The major source of recruitment for walleye collected from the Peace River is the Beatton River watershed. Sources from this system included the mainstem Beatton River, several of its tributaries (Milligan River, Blueberry Creek, and Fish Creek), and Charlie Lake. Peace River walleye also recruited from the Pine River watershed (mainstem Pine River and Murray River), as well as from tributaries in Alberta that included the Pouce Coupe River and Smoky River in Alberta. A portion of the sample whose source could be identified also recruited from the Peace River.

7.0 GENETIC CONNECTIVITY

Taylor and Yau (2012) summarized the genetic analysis for bull trout, Arctic grayling, and mountain whitefish populations in the technical study area from 2006 to 2011. Using microsatellite DNA analysis of fish tissue (non-lethal methods), the objectives of the study were to provide a synthesis of baseline genetic information for each of these three species to characterize genetic diversity and test for the existence of distinct populations of each species; and to determine genetic relationships among sample location to infer levels of interconnectedness.

Taylor and Yau (2012) determined fish from the "*Pine River were the most distinct in all three species*". Similarly, Arctic grayling from the Halfway River and mountain whitefish from the Moberly River were genetically distinct. Whereas, bull trout from the Halfway River and Peace River, and Arctic grayling from the Moberly River and Peace River were similar to one another and formed population mixtures. The study also showed that bull trout movements appeared to take place between the Halfway and Peace Rivers, Arctic grayling movements took place between the Moberly and Peace Rivers, and mountain whitefish movements took place between the Peace and Halfway and the Peace and Moberly Rivers. Comparatively little movement took place between the different tributaries. Taylor and Yau (2012) maintained that the study provided the baseline information required to track changes in genetic variation within, and divergence between populations of all three species. The analysis showed strong evidence of genetic distinction among the Moberly, Halfway, and Pine Rivers within all three species and for the importance of connectivity among these tributaries and the mainstem Peace River for the "*successful completion of life cycles of each species and hence their persistence across the waterscape*". However, additional sampling and analysis is required to characterize genetic variation within and genetic divergence among major spawning/rearing streams within the major Peace River tributaries (e.g. Pine, Moberly, and Halfway).

Future studies were recommended by Taylor and Yau (2012) that would "*integrate temporal replication of sampling that exceed one generation for each species to better estimate effective population sizes and temporal variation in genetic variation and genetic structure, and to examine samples from other known important spawning or feeding areas/tributaries including those within the Pine, Halfway, and Moberly Rivers as assessment of genetic populations within these systems remains inadequately surveyed.*"

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8.0 FISH COMMUNITY OUTSIDE OF STUDY AREA

This section presents information that describes fish communities that occur upstream (i.e., upstream of Peace Canyon Dam) and downstream (i.e., downstream of the Many Islands area) of the technical study area in order to better understand the ecology of fish communities within the technical study area (e.g., recruitment of fish into the technical study area from upstream). The information includes general characteristics of the aquatic environment, fish population characteristics, and a description of fish habitats.

8.1 UPSTREAM

Fish thought to have been recruited from Williston Reservoir or Dinosaur Reservoir have been captured in the Peace River downstream of Peace Canyon Dam. Kokanee, lake trout, lake whitefish, pygmy whitefish, and hatchery reared rainbow trout are examples of species captured downstream of the Peace Canyon Dam (Pattenden *et al.* 1990, 1991; Mainstream 2010b, 2011f, 2012a). If upstream reservoirs are a recruitment source for the fish community in the technical study area, then a good understanding of the system is warranted.

In August 2010, Diversified Environmental Services in association with Mainstream Aquatics Ltd. (Diversified and Mainstream 2011a) completed a review of historical information and fish survey of Dinosaur Reservoir. The following summarizes the results of the study.

Dinosaur Reservoir was impounded by the Peace Canyon Dam in 1979 and occupies the former Peace River Canyon immediately downstream of the W.A.C. Bennett Dam. The 20.5 km long reservoir is a narrow, steep-sided waterbody with limited littoral habitat and little accessible tributary habitat. Productivity is extremely low and driven largely by inputs from Williston Reservoir.

Twenty species of fish have been identified in Dinosaur Reservoir since its formation including rainbow trout, bull trout, lake trout, Arctic grayling, kokanee, mountain whitefish, pygmy whitefish, lake whitefish, burbot, longnose sucker, white sucker, largescale sucker, northern pikeminnow, peamouth, redside shiner, longnose dace, slimy sculpin, prickly sculpin, and spoonhead sculpin. Fish species composition in the reservoir has changed in response to environmental and operational conditions and fisheries management activities.

Information Review

Species present in the reservoir between 1983 and 1987, shortly after its creation, are described by Hammond (1984, 1985, 1986a, 1987a, 1987b, 1988). This work consisted of a 4-year evaluation of the Dinosaur Reservoir stocking program, which involved the production and release of approximately 50,000 yearling rainbow trout annually from the Peace Canyon Hatchery located at the Peace Canyon Dam. Sampling during the 1983-1986 evaluation program included gill netting and angling in the reservoir, backpack electrofishing and beach seining in tributaries, as well as angler creel surveys. During the evaluation, emphasis was placed primarily on the sampling of sportfish species, particularly rainbow trout. Information recorded for non-sport species and non-target sportfish species was often limited to records of species collected, whether they occurred in the reservoir or in tributaries, and qualitative comments about relative densities encountered while sampling target sportfish. Such comments were generally restricted to lake whitefish, mountain whitefish, kokanee, and longnose sucker.

Because of the extensive use of angling and the emphasis on target species during the 1983-1986 evaluation, rainbow trout were the most frequently captured sportfish, followed by bull trout. During Year 1 of the evaluation (1983) rainbow trout accounted for 88% of sampled fish while bull trout accounted for most of the balance of sportfish (Hammond 1984). Similar proportions were observed in subsequent years of the evaluation (Hammond 1986a, 1987a). Gill netting results and general observation suggested that lake whitefish were the most common and widely distributed salmonid in the reservoir (Hammond 1984), while mountain whitefish were considered uncommon and referred to as a remnant population believed to be distributed primarily in the W.A.C. Bennett Dam tailrace and at the mouths of Gething and Johnson Creeks. During Year 4 of the evaluation, it was noted that lake whitefish and mountain whitefish were captured with decreased frequency, while kokanee appeared more common (Hammond 1987a). Lake trout were captured very infrequently, with only 1 recorded angling capture between 1983 and 1986. Arctic grayling, which were abundant prior to impoundment, became increasingly rare after 1983 and by 1986, were believed to be absent from the reservoir (Hammond 1987a).

Between 1983 and 1986, longnose sucker and northern pikeminnow were reported as common in the tailrace area and at the mouths of Gething and Johnson Creeks (Hammond 1984, 1986a, 1987a). No records of numbers of other species such as redside shiners or peamouth were documented other than a reference to a "large spawning run of peamouth" in Johnson Creek (Hammond 1987a). "Sizeable populations" of slimy and spoonhead sculpin were reported in Johnson Creek in 1983, while no sculpin were collected in Gething Creek (Hammond 1984). After 1983, only slimy and prickly sculpin have been reported, suggesting that prickly sculpin may have been initially misidentified as spoonhead sculpin during Year 1 of the evaluation. Hammond (1986a) speculated that fish distribution in the reservoir was not homogenous and that most fish were concentrated in the W.A.C. Bennett Dam tailrace possibly due to factors such as food availability, water temperatures and currents, spawning activities, and the fact that the W.A.C. Bennett Dam poses a limit to upstream movement.

Since its inception in 1989, the Peace/Williston Fish and Wildlife Compensation Program (PWFWCP) has conducted additional fish sampling in the reservoir and tributaries in conjunction with periodic monitoring of fisheries enhancement projects. Between 2001 and 2006, the PWFWCP conducted sampling within shallow shoreline areas throughout the reservoir in order to assess fish use in the vicinity of shoreline debris structures installed as rearing cover in 2002 and 2003 (Blackman *et al.* 2004, Murphy and Blackman 2004, Murphy *et al.* 2004, Blackman 2005, Blackman and Cowie 2005, Blackman 2006). With the exception of daytime boat electrofishing in 2001 (Murphy *et al.* 2004) and sampling by trap nets and angling in 2004 (Blackman and Cowie 2005), sampling was conducted by boat electrofishing at night. The relative proportion of each species captured during each assessment year between 2001 and 2006 were compared to 2010 results. It should be noted that for comparability to 2010 results, only data from the early July sampling session is included in years where multiple sampling events occurred (i.e., 2001 and 2002). The 2010 data include gill netting, minnow trapping, angling, and daytime boat electrofishing conducted in the reservoir.

Rainbow trout and mountain whitefish were encountered most frequently during all sampling events between 2001 and 2010 (Blackman *et al.* 2004, Murphy and Blackman 2004, Murphy *et al.* 2004, Blackman 2005, Blackman and Cowie 2005, Blackman 2006). Longnose sucker and peamouth appeared to be moderately abundant in the reservoir during the 2001 to 2006 sampling, although neither species was encountered in abundance in 2010. Although inconsistencies in sampling methods and localized effort preclude a valid, direct comparison between data from 2001 to 2006 and the 2010 data, an increase in kokanee numbers may be most notable.

Hydroacoustic surveys were conducted in Dinosaur Reservoir by Sebastian *et al.* (2004) and Scholten *et al.* (2005) in June 2003 and August 2004 in an attempt to assess potential impacts from occasional spill events. In 2003, 8 transects were surveyed longitudinally during complete darkness. Five transects were located between the Peace Canyon Dam and Johnson Creek and three were located in the "canyon" between the W.A.C. Bennett Dam and the Johnson Creek forebay. In 2004, an additional transect was added to the lower section in the vicinity of the Johnson Creek Forebay. Based on the lack of distinct echo traces or fish targets on all transects, fish densities in Dinosaur Reservoir were described as very low in both years (Sebastian *et al.* 2004, 2005). In 2003, the distribution of echo traces led researchers to speculate that 3 distinct biological zones existed in the reservoir. The highest density of fish was estimated to be 90 to 150 fish/ha in the central portion of the reservoir, in the vicinity of the Johnson Creek forebay, while fish density in the upper or canyon section and in the lower section ranged from 5 to 27 fish/ha (Sebastian *et al.* 2004). Echo traces of fish located in the canyon and sections of the reservoir were found primarily close to the bottom, while fish in the central portion of the reservoir appeared to be distributed more widely through the water column. Based on this pattern, and an analysis of netting samples and hydroacoustic surveys of Williston Reservoir (Pillipow and Langston 2002, Sebastian *et al.* 2003, Sebastian *et al.* 2004), it was suggested that a species composition dominated by kokanee and lake whitefish may exist in the central portion of the reservoir (Sebastian *et al.* 2004). Approximately 95% of fish observed were estimated to be less than 30 cm in length (Sebastian *et al.* 2004). The remaining 5% were observed close to the bottom along submerged shelves in the central section (former riparian flat adjacent to Johnson Creek) and in the canyon section.

Similar patterns in fish density and distribution were observed during hydroacoustic surveys conducted in 2004 (Scholten *et al.* 2005), with fish density in the central section estimated 20-100 fish/ha. Higher densities of fish were also detected in the vicinity of the anti-vortex dike and the upper portion of the canyon section near Mogul Creek (Scholten *et al.* 2005). As in 2003, approximately 95% of observed fish were less than 30 cm in length and the remaining 5% were believed to be larger fish associated with shelf habitat in the central section and the upper portion of the canyon section (Scholten *et al.* 2005).

Estimated total population size was 36,000 (16,000 to 57,000) fish in 2003 (Sebastian *et al.* 2004) and 23,400 (3,000-49,000) in 2004 (Scholten *et al.* 2005). Limited sample sizes and low densities of fish did not allow for more accurate estimates.

Rainbow trout

Rainbow trout are the most frequently captured sportfish in Dinosaur Reservoir and have also been the most intensively examined and managed species in the reservoir. Both rainbow trout and Arctic grayling were abundant throughout the Peace River Canyon prior to construction of the Peace Canyon Dam (B. Culling, pers.obs.). Since impoundment, the rainbow trout population has been augmented through the release of hatchery stock. Stocking history of the reservoir has been reviewed and summarized in various forms including Pattenden and Ash (1993b) and Langston and Murphy (2008). With the exception of 1998, rainbow trout were stocked annually between 1982 and 2003. During the first 8 years, B.C. Environment and BC Hydro jointly operated the Peace Canyon Hatchery, located at the Peace Canyon Dam, as an interim measure to augment fish populations potentially impacted by dam construction and reservoir impoundment. Using brood stock from Johnson Creek and Blackwater Creek, on the Parsnip Reach of Williston Reservoir, the Peace Canyon Hatchery produced between 16,000 to 73,000 rainbow trout fingerlings annually. During this period rainbow trout were released in late April to early May at various locations including the W.A.C. Bennett Tailrace, Gething and Johnson Creeks, and the public boat launch near the Peace Canyon Dam (Pattenden and Ash 1993b).

The Peace Canyon Hatchery was closed in 1989 and fish stocked from 1990 to 2003 were produced elsewhere in the provincial hatchery system using brood from a variety of sources. The decision to close the pilot hatchery was made due to high unit cost relative to its success and the difficulty in obtaining sufficient local brood stock during the later years of operation (Hammond 1987b, Pattenden and Ash 1993b). Between 1990 and 1997, all rainbow trout released were domestic diploid. Beginning in 1999, stocking densities were reduced and experimental releases were conducted, including approximately 12,500 to 14,650 fingerling triploid and triploid all-female rainbow trout in 1999 and 2000, and 5,000 catchable sized triploid and triploid all-female rainbow trout from 2001 to 2003 (Langston and Murphy 2008).

Stocking success in the reservoir has been monitored periodically either by direct sampling or through angler creel surveys. Survival of stocked rainbow trout has been very low despite attempts to establish fish throughout the reservoir and encourage longer residency. Fish released in the W.A.C. Bennett tailrace traveled downstream through the reservoir quickly, with some taking up temporary residence in lower Gething, Mogul, Moosebar, Johnson, and Starfish Creeks (Hammond 1984, 1985, 1986a, 1987a). Limited tributary and shallow littoral refuge habitat are cited as the main factors limiting survival of juvenile rainbow trout in the reservoir. Significant entrainment of stocked fish through the Peace Canyon Dam has been documented and cited as a major factor limiting augmentation efforts (Hammond 1984, 1985, 1986a, 1986b, 1987a).

Between 1983 and 1986, rainbow trout sampled in Dinosaur Reservoir ranged from 1 to 6 years of age, with ages 2, 3, and, 4 dominating the age structure (Pattenden and Ash 1993). Rainbow trout sampled during the hatchery evaluation rarely exceeded 370 mm fork length. Rainbow trout sampled during the

1999, 2000, 2003, and 2005 sampling and summer creel surveys also ranged in age from 1 to 6 years, with age classes 3, 4, and 5 dominant (Joslin 2001a, 2001b, Cowie 2004, Blackman 2005, 2006, Stiemer 2006). While some rainbow trout exceeded 400 mm fork length during this period, the majority ranged from 300-350 mm. The slightly higher occurrence of larger, older fish may be a result of more selective angler retention or an indication of an ageing population resulting from reduced stocking densities and decreased competition. In recent years, very large rainbow trout weighing several kilograms have been captured in Dinosaur Reservoir, however little is known about these fish. It has been speculated that they may be the progeny of Gerrard stock introduced into the Nation Lakes in the Parsnip Reach of Williston Reservoir in 1989 to 1991.

Rainbow trout in Dinosaur Reservoir spawn primarily in Johnson Creek and to a lesser extent in Gething Creek (Pattenden and Ash 1993b). Fish fences operated in 1983, 1984, and 1986, combined with electrofishing, documented a small spawning run of rainbow trout using Johnson Creek. In 1983 and 1984, the estimated spawning run size was roughly 90-100 fish (Hammond 1984, 1986a). Peak spawning in Johnson Creek occurred in late May when water temperatures reached 7-10 °C (Hammond 1984). In 1986, only four mature rainbow trout were captured in a fish fence operated between June 3 and 13 (Hammond 1986a). Electrofishing upstream of the fence failed to locate additional spawners. The reduced number of adult fish in Johnson Creek in 1986 was attributed to a significant flood event in the summer of 1983 (Hammond 1986a).

In 1983, Gething Creek was electrofished five times between May 21 and June 10, from its confluence to Gething Creek falls (Hammond 1984). Approximately 30 mature rainbow trout were captured during this period. Peak spawning run timing for Gething Creek was estimated to occur during the first week of June, approximately one week later than Johnson Creek (Hammond 1984). No subsequent evaluation of spawning run size is documented for Gething Creek. The capture of YOY and yearling rainbow trout in Gething Creek during backpack electrofishing in August 2010, suggests current spawning activity.

In 2006, the PWFWCP operated the Johnson Creek fish fence from June 1 to 20. Results from 2006 were similar to those of Hammond 22 years earlier. During its operation, an estimated 203 rainbow trout ascended Johnson Creek of which 38 were classified as adult spawners (Newsholme and Euchner 2006). A total of 240 rainbow trout were captured in the downstream trap, including 46 classified as adult spawners. Rainbow trout movement into and out of Johnson Creek was ongoing when the fence was removed and the number of spawning rainbow trout was likely higher than that documented. The operation of the trap also coincided with spawning for a large number of longnose sucker and peamouth (Newsholme and Euchner 2006).

Attempts to diversify shoreline habitat and increase available rearing cover has had limited success. Brush piles established in the Johnson Creek forebay by the PWFWCP were submerged in lake sediments after only two years (Blackman 2001). Monitoring of shoreline debris structures installed in 2002 and 2003 indicate that use by rainbow trout has increased in enhanced areas versus control sites (Blackman and Cowie 2005). Presumably this equates to a net gain in usable habitat and thus an increase in reservoir-resident rainbow trout. Shoreline enhancement in the form of aquatic vegetation transplants have been considered and a small test plot was established in the Johnson Creek forebay in 1999 (AIM 2000). Frequent reservoir drawdown and exposure of the planted cuttings and sedimentation from Johnson Creek were identified as factors limiting the success of this project (AIM 2000). Some remnants of the original test plot were observed during August 2010.

The release of fingerling rainbow trout into the W.A.C. Bennett tailrace appeared to subject stocked fish to considerable predation by native bull trout and lake trout. During the release of hatchery stock in the tailrace it was common to observe large bull trout swirling at the surface as they pursued newly released rainbows (B. Culling, T. Euchner, pers. obs).

Between 1985 and 1987, angler catch rates for rainbow trout were consistently low at less than 0.4 fish/hr (Hammond 1985, 1986a, 1986b, 1987a, 1987b, 1988, Pattenden and Ash 1993a). Catches of hatchery versus wild rainbow trout fluctuated annually due to changes in stocking rate, recruitment from tributary spawning, entrainment from Williston Reservoir, and the skewing effect of rainbow trout size restrictions placed on anglers. In most years, hatchery and wild fish were captured in equal proportions (Pattenden and Ash 1993a). In the first several years after the newly-impounded reservoir was opened to fishing, angler effort declined annually while catch rates remained roughly the same. Angler discontent with the quality of the fishery was cited as the primary reason for the decline in effort (Pattenden and Ash 1993a).

Rainbow trout accounted for approximately 95% of angler-caught sportfish between 1985 and 1987. Bull trout, kokanee, lake whitefish, and mountain whitefish made up the remainder. Arctic grayling, which were frequently caught by anglers prior to impoundment of the canyon, disappeared from the creel sample by 1987. Lake trout were caught very infrequently during the same period.

Similar observations of rainbow trout catch, effort, and angler satisfaction were reported during subsequent creel surveys conducted by the PWFWCP in 1999, 2000, 2003, and 2005 (Joslin 2001a, 2001b, Cowie 2004, Stiemer 2006). Rainbow trout accounted for the majority of fish caught, ranging from 45 to 88% of the catch. Catch rates in 1999, 2000 and 2005 were estimated at 0.25, 0.31, and 0.65 fish/hr, respectively (Joslin 2001a, 2001b, Stiemer 2006). The remainder of the catch was comprised of lake trout, bull trout, and whitefish. As in earlier surveys, the hatchery contribution to the harvest was relatively low.

Between 1982 and 1985, fingerling rainbow trout produced at the Peace Canyon Hatchery were also released upstream of the impassable falls on Gething Creek and Johnson Creek. Recipient waters in these upper drainages included Gething, Dowling Gaylard, Johnson, and Burnt Trail Creeks (Langston and Murphy 2008). Rainbow trout stocking has also been conducted in Wright Lake, which forms the headwaters of Gething Creek and in Pete Lake located at the headwaters of Burnt Trail Creek. Prior to stocking, Wright Lake supported a native, resident, population of longnose suckers (McLean and Jesson 1990). The potential for escapement downstream from both waterbodies has been confirmed (Zemlak 1999, 2010, Zemlak and Cowie 2005, 2006, Langston 2008). Through a combination of ongoing escapement and naturalization, upstream-resident rainbow trout are now widely distributed throughout the upper Gething Creek and Johnson Creek watersheds. No assessments of these resident rainbow trout populations, other than reconnaissance inventories conducted by Canfor in the Johnson and Gaylard Creek drainages (ARL 1999a, 1999b) and PWFWCP sampling for bull trout in Gething and Gaylard Creeks (Harvey 1995, Langston and Zemlak 1998a, Langston 2008) have occurred since their introduction.

Bull trout

Bull trout in Dinosaur Reservoir are members of a remnant fluvial population trapped between the W.A.C. Bennett and Peace Canyon dams (Hammond 1987a, Langston 2008). The extent to which the population may be supplemented by entrainment from Williston Reservoir or reduced by entrainment through the Peace Canyon Dam is unknown. With the exception of the Gething Creek spawning component of the population, the life history of this species within Dinosaur Reservoir is not well understood. Adult and sub-adult bull trout are captured throughout the reservoir in very low densities. Sampling during the Peace Canyon Hatchery evaluation, indicated that the highest densities of bull trout occurred in the tailrace upstream of Gething Creek and that these fish tended to be large adults ranging in size from 425-770 mm fork length (Hammond 1984, 1986a, 1987a). Smaller sub-adult bull trout have been captured, in low densities, along shallow shoreline areas of the reservoir (Blackman *et al.* 2004, Murphy and Blackman 2004, Murphy *et al.* 2004, Blackman 2005, Blackman and Cowie 2005, Blackman 2006). Mean size of bull trout captured in nearshore areas excluding the tailrace, range from 177 to 413 mm fork length (Blackman *et al.* 2004, Murphy and Blackman 2004, Murphy *et al.* 2004). During the same sampling events, the proportion of bull trout in the catch ranged from 2.8 to 10%. Bull trout appear to contribute minimally to the Dinosaur Reservoir sport fishery. During creel surveys conducted between 1985 and 1987, and 1999 to 2005, anglers reported catching few bull trout. In most survey years, only one to two bull trout were reportedly captured by anglers in total (Hammond 1985, 1986a, 1987a, 1987a, 1988, Joslin 2001a,b, Cowie 2004, Stiemer 2006). The W.A.C. Bennett Dam tailrace, where adult bull trout densities appears highest, is closed to recreational angling.

Spawning habitat for this population is limited to the lower several hundred metres of Gething Creek. Between the 1983-1986 Peace Canyon Hatchery evaluation, portions of lower Gething Creek, including the plunge pool below Gething Falls, were electrofished and beach seined periodically in late August to mid-September in order to assess the spawning run size of this population. Sampling was conducted between August 27 and September 20. Between 18 and 40 mature, adult bull trout were captured during these sampling events (Hammond 1984, 1986a, 1987a). Fork lengths of the fish collected ranged from 423 to 767 mm (Hammond 1984, 1986a). Up to 30% of the fish captured were recaptures from the previous year (Hammond 1986a). Actual redd building has been observed infrequently and the exact timing of spawning is uncertain. Seven pairs of adult spawners were observed downstream of the falls pool on September 27, 1984 (Hammond 1986a).

Annual recruitment of bull trout from lower Gething Creek is assumed to be low due to the low spawner numbers and limited availability of high quality spawning and juvenile rearing habitat. Repeated sampling of Gething Creek in May to July 1983 to 1986 resulted in the capture of very few YOY or yearling bull trout (Hammond 1984, 1986a, 1987a). The only notable occurrence of juvenile bull trout was in 1986 when higher than usual densities on yearlings were encountered in the main reservoir (Hammond 1987a).

Monitoring of the Gething Creek bull trout spawning population has been conducted periodically by the PWFWCP since 1987. Between 1993 and 2002 the PWFWCP embarked on a project intended to establish an upstream-resident bull trout population in upper Gething and Gaylard Creeks and augment reservoir recruitment. Adult bull trout in spawning condition were captured below the Gething Creek falls and translocated by helicopter above impassable barriers to selected reaches of upper Gething Creek in

1993, 1997, and 1999 and Gaylard Creek in 1994 (Langston and Zemlak 1998a, Newsholme 1999, Langston 2008). After spawning, spent bull trout were recaptured in a downstream trap and moved by truck back to Dinosaur Reservoir.

A total of 63 bull trout were translocated, including 12 in 1993, 16 in 1994, 14 in 1997, and 21 in 1999 (Langston 2008). During the 1999 operation, 45 adult bull trout were captured in a fish fence while ascending lower Gething Creek between August 27 and September 14. An inspection of the Gething Creek falls pool prior to fence installation on August 26, 1999, revealed that 17 bull trout had already entered Gething Creek (Newsholme 1999). Bull trout sampled during the translocation efforts ranged in age from 3 to 12 years based on analysis of fin ray sections. Mean fork length and weight were 633 mm and 2,800 g respectively (Langston 2008).

The capture of juvenile bull trout in the upper Gething Creek drainage, including Wright Lake, between 1994 and 2002 indicated successful spawning by the translocated adults, however, subsequent sampling in 2005 and 2008 suggests that a viable self-sustaining population may not have established itself (Langston 2008).

Bull trout do not appear to spawn in Johnson Creek. Repeated sampling of Johnson Creek between 1983 and 1986 failed to locate either YOY or adult bull trout (Hammond 1984, 1986a, 1987a). Occasional feeding forays by yearling to three-year-old sub-adults into Johnson Creek were noted.

Kokanee

Kokanee in Williston and Dinosaur reservoirs originate from two possible sources: native populations in headwater lakes in both the Finlay and Parsnip drainages (Langston and Zemlak 1998b) and introduction of fry to tributaries of Williston Reservoir by PWFWCP.

Very low numbers of kokanee were reported in the Peace River prior to the construction of the Peace Canyon Dam in 1979 and in Dinosaur Reservoir in the years immediately following impoundment (Hammond 1984, 1986a, 1987a).

Between 1990 and 1998, more than 3.3 million kokanee fry were planted in tributaries to Williston Reservoir, including Dunlevy Creek, Carbon Creek, Manson River, and Davis River in an attempt to establish self-sustaining spawning populations (Langston and Zemlak 1998b, B.C. Environment 2011). Subsequent aerial surveys conducted by the PWFWCP have confirmed significant spawning runs of kokanee in several Williston Reservoir tributaries and reservoir sampling between 1994 and 2000 indicates that kokanee abundance in the Williston Reservoir has increased dramatically (Langston 1998b, Pillipow and Langston 2002, Sebastian *et al.* 2003). It is assumed that entrainment of kokanee through the W.A.C. Bennett Dam into Dinosaur Reservoir has increased with the expanded Williston population.

During the 1983-1986 Peace Canyon Hatchery evaluation, kokanee comprised less than 0.3% of the Dinosaur Reservoir fish sample and were not reported in tributaries to the reservoir (Hammond 1986a). In 1999, a fish fence installed on Gething Creek from August 25 to September 20 intercepted small numbers of ripe kokanee ascending the stream. During kokanee spawner surveys conducted by PWFWCP on October 3 and 4, 2007, schools of mature kokanee and redds were observed in both Gething and Johnson Creeks (A. Langston pers. comm.). Most recently, several hundred mature kokanee were observed in Gething Creek on August 27, 2010.

Hydroacoustic surveys of the Dinosaur Reservoir conducted in 2003 and 2004 identified significant numbers of fish suspected to be kokanee occupying pelagic habitat in the central section of the reservoir (Sebastian *et al.* 2004, Scholten *et al.* 2005). During the August 2001 sampling, kokanee accounted for approximately 13% of the overall catch.

Kokanee in the Dinosaur Reservoir appear to have undergone a size shift since becoming common. Average fork length of 3 year old kokanee sampled between 1983 and 1987 ranged from 283 to 324 mm while 4 year old kokanee, which were less common, ranged from 292 to 350 mm fork length (Hammond 1986a, 1987a, 1988). Mean fork length of 3 year old kokanee sampled in 2010 was 221 mm and 4 year old fish were not encountered. This is likely a consequence of the Williston kokanee stocking program undertaken from 1990 to 1998, which may have resulted in the prevalence of the smaller introduced Hill Creek strain as opposed to the larger native Finlay and Parsnip strain (Langston and Zemlak 1998b).

Lake trout

Lake trout were rarely recorded in the Peace River prior to formation of the Dinosaur Reservoir (Hammond 1984). Lake trout were infrequently encountered during sampling for the hatchery evaluation, with only 1 fish captured between 1983 and 1986 (Hammond 1984, 1986a, 1987a). None were reported by anglers participating in creel surveys conducted from 1984 to 1988 (Pattenden and Ash 1993a).

More recent inventory work and creel surveys and numerous anecdotal reports indicate that lake trout have increased in abundance in Dinosaur Reservoir. In creel surveys conducted by the PWFWCP in 1999, 2000, and 2005, lake trout accounted for 3.5%, 4.5%, and 28.0% of the angler catch, respectively (Joslin 2001a, 2001b, Cowie 2004, Stiemer 2006). In addition to increasing abundance, several other factors may have contributed to the dramatic increase in angler harvest between 2000 and 2005. These include preference of anglers for larger fish species, a growing knowledge that large lake trout were available in Dinosaur Reservoir, and the use of angling techniques that specifically target lake trout. Although lake trout are now distributed throughout the reservoir, they appear concentrated upstream of the Johnson Creek forebay and in particular, in the tailrace of the W.A.C. Bennett Dam.

YOY and yearling lake trout ranging in length from 80 to 185 mm were captured by boat electrofishing in 2002 and 2003 suggesting lake trout may spawn in the reservoir (Blackman *et al.* 2004; Murphy *et al.* 2004). In 2003, the PWFWCP initiated a lake trout telemetry project to determine if lake trout spawning occurred in Dinosaur Reservoir and if so, identify potential spawning sites. From May to October 2003 and 2004, nine lake trout implanted with ultra-sonic radio transmitters were tracked in the reservoir (Euchner 2006). All but one lake trout, which travelled downstream as far as Starfish Creek, stayed in the upper nine kilometres of the reservoir, spending the majority of their time in the W.A.C. Bennett Dam tailrace and canyon section above Moosebar Creek. Increased movement was noted during September and October, which was believed to coincide with spawning activity. Fall activity appeared to focus on 3 sites, including the Gething Creek delta, the scour hole below the W.A.C. Bennett Dam spillway, and a submerged rock ledge near the outlet of the decommissioned diversion tunnels. No spawning activity was confirmed although night monitoring in early October 2004 confirmed the presence of groups of lake trout in the vicinity of radio-tagged individuals at these sites (Euchner 2006).

During the course of transmitter implanting activities, 77 lake trout, ranging in length from 330 to 745 mm and aged from 6 to 26 years, were captured by angling. All were captured upstream of the sportfishing boundary located near the mouth of Gething Creek. Modal size of the angled sample was 385 mm and the most commonly encountered age class was 7 years (Euchner 2006).

During the period in which lake trout have become common in Dinosaur Reservoir, anglers in Williston Reservoir have also seen increased success rates for this species, with some fish reportedly reaching 13 kg (G. Gieger pers. comm.). It is unknown to what degree entrainment through the W.A.C. Bennett Dam accounts for Dinosaur Reservoir recruitment.

Whitefish Species

Relatively little information is available for lake or mountain whitefish in Dinosaur Reservoir. During the 1983-1986 Peace Canyon Hatchery evaluation both fish were regarded as non-target species and not sampled or enumerated as part of the fishery assessment program. It was noted in 1983 and 1984 however, that lake whitefish were considered the most abundant salmonid in the reservoir, especially in the W.A.C. Bennett Dam tailrace (Hammond 1984, 1986a) and by 1986, the species was observed with less frequency (Hammond 1987a).

Lake whitefish have not contributed significantly to the sport fishery in Dinosaur Reservoir. During creel surveys conducted between 1984 and 1988, catches of lake whitefish were reported infrequently (Hammond 1984, 1985a, 1986a, 1987a, 1988, Pattenden and Ash 1993a). The majority of lake whitefish reported by anglers were observed floating on the surface of the reservoir during the operation of the W.A.C. Bennett Dam spillway (Hammond 1984). No lake whitefish have been reported in creel surveys conducted by the PWFWCP (Joslin 2001a,b, Cowie 2004, Steiner 2005).

During PWFWCP assessments of enhancement structures from 2001 to 2006, lake whitefish accounted for less than 5% of the catch at most sites (Blackman *et al.* 2004, Murphy and Blackman 2004, Murphy *et al.* 2004, Blackman 2005, Blackman and Cowie 2005, Blackman 2006).

No direct evidence of lake whitefish spawning has been documented in Dinosaur Reservoir, although Blackman observed high densities of lake whitefish in the tailrace in mid-October 2002 and speculated that this may have been a spawning aggregation (Murphy *et al.* 2004). It is likely that the population is partially maintained by recruitment from Williston Reservoir, as this species appears particularly susceptible to entrainment. During the 1996 spill, lake whitefish made up 94% of approximately 4,500 dead or injured fish enumerated during spillway mortality surveys conducted on Dinosaur Reservoir over a 39 day period (B.C. Environment 1996).

Even less is known of mountain whitefish populations in Dinosaur Reservoir. During the 1983-1986 Peace Canyon Hatchery evaluation they were believed to be less abundant than lake whitefish (Hammond 1984, 1986a, 1987a). During creel surveys between 1984 and 1988, mountain whitefish accounted for less than 10% of the catch (Hammond 1984, 1986a, 1987a, 1988, Pattenden and Ash 1993a). In more recent creel surveys conducted by PWFWCP, mountain whitefish were reported with less frequency (< 5 fish sampled per survey; Blackman *et al.* 2004, Murphy and Blackman 2004, Murphy *et al.* 2004, Blackman 2005, Blackman and Cowie 2005, Blackman 2006).

More recently, mountain whitefish appeared to be the second most abundant species, after rainbow trout, during sampling of near-shore reservoir habitats for PWFWCP enhancement structure monitoring between 2001 to 2006 (Blackman *et al.* 2004, Murphy and Blackman 2004, Murphy *et al.* 2004, Blackman 2005, Blackman and Cowie 2005, Blackman 2006). Mountain whitefish were the most numerous species captured during gill netting and boat electrofishing in 2010.

Non-sport and Other Species

Longnose sucker appear to be the most abundant non-sport species in Dinosaur Reservoir. During early assessments, Hammond (1984. 1986a, 1987a) noted that longnose sucker were commonly captured in the W.A.C. Bennett Dam tailrace area and in the vicinity of Gething and Johnson Creeks using a variety of capture methods including gill nets, electrofishing and fish fences. Large numbers of mature longnose sucker were observed ascending Johnson Creek during operation of the 1986 Johnson Creek fish fence (Hammond 1987a). In 2006, more than 3,000 adult longnose sucker passed through the Johnson Creek fish fence (Newsholme and Euchner 2006) and while some longnose sucker were known to have ascended Johnson Creek before installation of the fence, several thousands more were still staged below the fence when it was removed. The mean fork length of longnose sucker processed at the Johnson Creek fish fence in 2006 was 359 mm (Newsholme and Euchner 2006). The unusually low occurrence of adult longnose sucker in the 2010 sample could not be explained.

The distribution and relative density of largescale and white sucker in Dinosaur Reservoir is unknown. Both species were sampled by Hammond (1984, 1986a, 1987a) between 1983 and 1986 and both were recorded infrequently during monitoring activities conducted by the PWFWCP (Blackman *et al.* 2004, Murphy and Blackman 2004, Murphy *et al.* 2004, Blackman 2005, Blackman and Cowie 2005, Blackman 2006). Only 6 adult largescale suckers passed through the Johnson Creek fish fence in 2006 (Newsholme and Euchner 2006).

The presence of peamouth was noted throughout the reservoir during the 1983-1986 Peace Canyon Hatchery evaluation and Hammond (1987a) makes reference to a large spawning run that ascended Johnson Creek to spawn during the operation of the Johnson Creek fish fence in 1986. Peamouth were commonly captured in the reservoir during PWFWCP sampling between 2001 and 2006 (Blackman *et al.* 2004, Murphy and Blackman 2004, Murphy *et al.* 2004, Blackman 2005, Blackman and Cowie 2005, Blackman 2006). More than 9,800 peamouth passed though the Johnson Creek fish fence between June 1 and 20, 2006 and schools numbering in the thousands were observed staging on the mud flats located downstream of the fence (Newsholme and Euchner 2006). The relative abundance of peamouth in the reservoir, based on the results of the 2010 sampling, may be under-estimated.

Redside shiners were recorded during the 1983-1986 Peace Canyon Hatchery evaluation (Hammond 1984, 1986a, 1987a) and during subsequent monitoring by the PWFWCP (Blackman *et al.* 2004, Murphy and Blackman 2004, Murphy *et al.* 2004, Blackman 2005, Blackman and Cowie 2005, Blackman 2006). Adult and juvenile redside shiner were recorded ascending and descending Johnson Creek during the operation of the 2006 Johnson Creek fish fence (Newsholme and Euchner 2006). No evidence linking this movement to spawning activity was noted. Only a single redside shiner was sampled in 2010 suggesting that their density in Dinosaur Reservoir may be relatively low.

Additional species documented infrequently include burbot, northern pikeminnow, longnose dace, lake chub, and pygmy whitefish. Burbot, northern pikeminnow, and longnose dace were sampled during the 1983-1986 Peace Canyon Hatchery evaluation (Hammond 1984, 1986a, 1987a) and have been encountered infrequently since. Their rare appearance suggests they may be present in very low densities and that their presence in Dinosaur Reservoir may be largely dependent on entrainment from Williston Reservoir.

Lake chub and pygmy whitefish, which are known to occur in Williston Reservoir, are sampled less frequently in Dinosaur Reservoir. Records for these species appear limited to mortalities recovered during the 1996 spill event (B.C. Environment 1996). Both species are encountered downstream in the Peace River (P&E 2002) indicating a continuous distribution throughout the mainstem Peace River. Neither species however, appears to have become established in Dinosaur Reservoir.

<u>Fish Survey Results</u>

A total of 562 fish representing 12 species were sampled in the reservoir and its tributaries. Listed in order of abundance, sportfish species included rainbow trout, mountain whitefish, kokanee, lake whitefish, lake trout, and bull trout. Nonsport species included prickly sculpin, slimy sculpin, longnose sucker, white sucker, peamouth, and redside shiner.

Comparison of historical and 2010 sampling results suggest that kokanee and lake trout population levels have increased while Arctic grayling, lake whitefish, and bull trout numbers have declined.

8.2 DOWNSTREAM

The fish community and fish habitats of the Peace River downstream of the technical study area were examined extensively between 1999 to 2009 in relation to the Dunvegan Hydroelectric Project (the Dunvegan project). The Dunvegan project is to be located 129 km downstream of the B.C./AB boundary and 66 km downstream of the technical study area boundary (i.e., Many Islands). The following information was presented in Glacier Power (2006).

8.2.1 General Characteristics

The characteristics of the Peace River and its tributaries affect the existing fish species assemblage and fish abundance in the Dunvegan project area. The following are factors that have a major influence on the fish populations and their habitats.

<u>Flow Regime</u>

The Peace River is subjected to flow regulation by the W.A.C. Bennett Dam in B.C. (Prowse and Conly 1996). Peak annual flows are reduced while there are large diurnal fluctuations in flow. According to Prowse and Conly (1996), flow regulation of the Peace River has affected the fish community as follows:

- an altered temperature regime that has permitted coldwater species to extend their downstream limit of distribution
- a reduced capacity to transport sediments, which has caused a narrowing of the river channel and altered habitats
- an ice regime that severely restricts the availability of overwintering habitat
- diurnal fluctuations in water level that reduces the availability of habitats

<u>Sediment Load</u>

The Peace River has a high sediment load (MMA 2000a). Post-Bennett Dam suspended sediment concentrations in the Dunvegan project area have ranged as high as 4,730 mg/L. The associated daily suspended sediment load was estimated to be 1.3 Mt/d. Suspended sediment concentrations (and turbidity levels) tend to be highest in spring and decline throughout summer and fall. These constituents regularly exceed the Canadian Water Quality Guidelines (CWQG) criteria for Aquatic Life, particularly in spring.

There is a generally accepted body of literature that demonstrates the severity of effects of suspended solids on fish increases as a function of both sediment concentration and duration of exposure (Anderson *et al.* 1995; Newcombe and Jensen 1996). High suspended sediment loads can also affect other aquatic biota; for example, high TSS levels can result in abrasion of benthic algal communities and decreased light penetration, both of which result in reduced primary productivity (Stevenson *et al.* 1996). The sediment concentration and duration of exposure in the Peace River presently exceed the threshold deemed to cause adverse effects.

Tributaries

The tributaries flowing into the Peace River in the Dunvegan project area have been influenced by land use activities such as agriculture and logging. Stream flow in the tributaries is highly variable, with extreme discharge occurring in spring or during large rainfall events, followed by subsequent intermittent or zero flow conditions. This discharge regime has reduced the quality and availability of fish habitats. These effects have influenced the structure of the fish community that resides in the Dunvegan project area. Fish populations that require tributary habitats for spawning and rearing purposes during summer and fall are severely restricted. Similarly, the tributaries cannot provide overwintering habitat for fish or areas of refuge from adverse conditions in the mainstem Peace River.

8.2.2 Fish Community

Species Composition and Abundance

In total, 36 fish species have been recorded in the Peace River basin from its headwaters to its confluence with the Peace-Athabasca Delta (Mill *et al.*1997). Within the vicinity of the Dunvegan project area, 23 species of fish were encountered during investigations, including 10 sportfish and 13 non-sportfish species (Table 8.2.1).

Table 8.2.1 Fish species present in the Peace River basin, those recorded in the Dunvegan project area, expected spawning period, and provincial status (from Glacier Power 2006).

Family	Common Name	Scientific Name	Dunvegan project area	Spawning Period	Alberta Provincial Status[b]
Sportfish					
Salmonidae	Cisco	*Coregonus artedi*		Oct. to Dec.	Secure
	Arctic grayling	*Thymallus arcticus*)	*	April to May	Sensitive
	Bull trout	*Salvelinus confluentus*	*	Aug. to Sept.	Sensitive
	Brook trout	*Salvelinus fontinalis*		Sept. to Nov.	Exotic/Alien
	Lake trout	*Salvelinus namaycush*		Sept. to Nov.	Sensitive
	Cutthroat trout	*Oncorhynchus clarki*		April to May	Secure
	Rainbow trout	*Oncorhynchus mykiss*	*	May to June	Secure
	Mountain whitefish	*Prosopium williamsoni*	*	Sept. to Oct.	Secure
	Lake whitefish	*Coregonus clupeaformis*	*	Oct. to Dec.	Secure
	Kokanee	*Oncorhynchus nerka*	*	Sept. to Oct.	Exotic/Alien
Hiodontidae	Goldeye	*Hiodon alosoides*	*	May to June	Secure
Esocidae	Northern pike	*Esox lucius*	*	April to May	Secure
Percidae	Walleye	*Sander vitreus*	*	April to June	Secure
	Yellow perch	*Perca flavescens*		April to May	Secure
Gadidae	Burbot	*Lota lota*	*	Jan. to Mar.	Secure
Non-sportfish					
Catostomidae	White sucker	*Catostomus commersonii*	*	April to May	Secure
	Longnose sucker	*Catostomus catostomus*	*	April to May	Secure
	Largescale sucker	*Catostomus macrocheilus*		April to May	Sensitive
Cyprinidae	Lake chub	*Couesius plumbeus*	*	June to Aug.	Secure
	Brassy minnow	*Hybognathus hankinsoni*		May to June	Undetermined
	Pearl dace	*Margariscus margarita*		May to July	Undetermined
	Emerald shiner	*Notropis atherinoides*		June to Aug.	Secure
	Spottail shiner	*Notropis hudsonius*	*	June to Aug.	Secure
	Northern redbelly dace	*Phoxinus eos*		June to July	Sensitive
	Finescale dace	*Phoxinus neogaeus*		May to June	Undetermined
	Fathead minnow	*Pimephales promelas*	*	June to Aug.	Secure
	Flathead chub	*Platygobio gracilis*	*	June to Aug.	Secure
	Northern pikeminnow	*Ptychocheilus oregonensis*	*	May to July	Sensitive
	Longnose dace	*Rhinichthys cataractae*	*	May to Aug.	Secure
	Redside shiner	*Richardsonius balteatus*	*	June to July	Secure
Percopsidae	Trout-perch	*Percopsis omiscomaycus*	*	May to Aug.	Secure
Percidae	Iowa darter	*Etheostoma exile*		May to June	Secure
Gasterosteidae	Brook stickleback	*Culaea inconstans*	*	April to July	Secure
	Ninespine stickleback	*Pungitius pungitius*		June to Aug.	Undetermined
Cottidae	Spoonhead sculpin	*Cottus ricei*	*	April to May	May be at Risk
	Slimy sculpin	*Cottus cognatus*	*	May to June	Secure
	Prickly sculpin	*Cottus asper*		April to July	Not Assessed

[b] May Be At Risk: any species that “May Be At Risk” of extinction or extirpation, and is therefore a candidate for detailed risk assessment; Sensitive: any species that is not at risk of extinction or extirpation but may require special attention or protection to prevent it from becoming at risk; Secure: a species that is not “At Risk,” “May Be At Risk” or “Sensitive.”; Exotic/Alien: any species that has been introduced as a result of human activities.

None of the 36 species known to occur in the Peace River drainage within Alberta are listed under the Species at Risk Act (SARA) Public Registry (http://www.sararegistry.gc.ca/default_e.cfm, 12 February 2006)

The Alberta Government, Sustainable Resource Development, Alberta Species at Risk Program provides a status listing of each fish species found in the province (ASRD 2000). The majority of fish species recorded in the study area (18 of 23) are considered secure (Table 8.2.1), while one species is categorized as alien/exotic (kokanee). Three species are designated as sensitive: bull trout, Arctic grayling, and northern pikeminnow. Individuals of all three originate from viable populations upstream of the B.C./Alberta boundary. Spoonhead sculpin is the only species that received a “May be at Risk” designation under the provincial listing.

Only one unique species population, fathead minnow (*Pimephales promelas*), was recorded in the Dunvegan project area downstream of the proposed facility. The species is widespread in Alberta river basins south of the Peace River and is present in the Slave River drainage, but it has been identified only from one other location in the Peace River system: One Island Lake near Tupper, B.C. (Smith and Lamb [1976] in Nelson and Paetz 1992). Sixteen fathead minnows were recorded in the mainstem Peace River during the 1999 investigation. These fish likely originated from nearby tributaries.

In terms of overall fish abundance in the Dunvegan project area, fish numbers are low. Sampling for large-sized fish (> 200 mm length) using boat electrofishing, set lines, and trap nets established that the majority of fish consisted of non-sportfish species. The numerically dominant species were longnose sucker and flathead chub. Sportfish were much less abundant than non-sportfish in the large-fish sample. The dominant species in this group were mountain whitefish, walleye, burbot, and goldeye.

During small fish sampling using beach seining and backpack electrofishing, 11 non-sportfish and 4 sportfish species were recorded. Most of the sample consisted of non-sportfish, with lake chub and longnose sucker being the dominant species. The remaining non-sportfish species captured included flathead chub, longnose dace, white sucker, redside shiner, spoonhead sculpin, slimy sculpin, spottail shiner, trout-perch, and fathead minnow. Sportfish encountered in very low numbers included mountain whitefish, bull trout, burbot, and kokanee.

All major sport and non-sportfish species were recorded in each of the three study zones sampled in the Dunvegan project area (upstream, headpond, and downstream). Catch rates were similar among each of the three zones, but the abundance of some species varied between seasons. Goldeye and flathead chub were most numerous in spring, but were absent during fall. This change in abundance may have reflected movements of fish through the area (goldeye) or changes in gear capture efficiency (flathead chub).

During sampling of upper and lower tributary sections, one sportfish and seven non-sportfish species were captured. Most fish were recorded in the lower sites; lake chub was the dominant species. Other non-sportfish species captured in the tributaries included, in decreasing order of abundance, longnose sucker, longnose dace, white sucker, flathead chub, spottail shiner, and brook stickleback. Burbot was the only sportfish recorded in Dunvegan project area tributaries.

Distribution

Information from this investigation, as well as information from other studies, indicate that the Dunvegan project area is a transition zone between coldwater and coolwater fish communities. The fish community in the Dunvegan project area is dominated by coolwater species that are adapted to high water turbidity (*e.g.,* goldeye, walleye, northern pike and longnose sucker), but coldwater species (mountain whitefish and bull trout) also are present. The coldwater species populations mountain whitefish and bull trout are at the downstream extent of their range in the Dunvegan project area due to a combination of factors that include exceedence of critical temperature thresholds and marginal quality habitat that severely limit the productive capacity of local fish (*e.g.,* spawning habitat).

Life History

The majority of sportfish in the Dunvegan project area are adults. The only exceptions are mountain whitefish (juveniles, adults, and few young-of-the-year fish) and bull trout (mainly subadults). Seasonal changes in the size distribution of mountain whitefish in the Dunvegan project area in 1999 and 2004 indicated that these fish likely dispersed from upstream areas of the Peace River. In contrast to sportfish, all life stages of several non-sportfish species, including longnose sucker, flathead chub and white sucker, are well represented.

Most non-sportfish in tributaries consist of young-of-the-year and juvenile fish, and cyprinids of all life stages. Adult non-sportfish present in the tributaries include spawning longnose and white suckers.

Most fish species in the Dunvegan project area are spring or early summer spawners that have short egg incubation periods. This life history strategy maximizes the probability of reproductive success by taking advantage of suitable water conditions. Burbot is the only species that spawns during winter (January or February), but the egg incubation period is brief. Only two species are fall spawners with an extended egg incubation period -- bull trout and mountain whitefish. This strategy is not appropriate for the Dunvegan project area due to unfavourable sediment loads and ice conditions, which limit reproductive success.

Movements

The information presented in this section is based on site-specific data that include: seasonal catch rates, floy tag returns, and radio telemetry data, information from other studies, and the author's knowledge of the Peace River fish species populations.

Goldeye that occur in the Dunvegan project area are part of a migratory population. Radio telemetry movement studies from 2002 to 2004 indicate that goldeye overwinter in the Peace River downstream of the Smoky River confluence. A portion of the population migrates upstream into and through the Dunvegan project area to spawn and/or feed. Other goldeye remain downstream of the Dunvegan project area during their annual migration cycle. Differences in seasonal abundance documented during fish inventories in 1999 and 2004 support the radio telemetry results.

Other species populations in the Dunvegan project area are non-migratory. Radio telemetry data for burbot, walleye, and longnose sucker indicate that most fish undertake only local movements within a discrete section of the Peace River between the confluence of the Smoky River and the Many Islands area. Seasonal movement patterns were documented, but distances traveled were generally short (< 20 km). Movement data for walleye, burbot, and longnose suckers indicate that at least a portion of each population spawns outside of the Dunvegan project area.

It is likely that most populations of other large-fish species not examined using radio telemetry are non-migratory. Seasonal differences in abundance of flathead chub documented during fish inventories indicate that this population may be migratory. It is unclear whether the results were representative of a migratory population or whether seasonal differences in abundance were an artifact of changes in fish capture efficiency.

Low numbers of adult mountain whitefish and bull trout precluded an assessment of movements of these populations in the Dunvegan project area. Studies have documented viable populations of both species in the Peace River in British Columbia (Mainstream and Gazey 2004) and the scarcity of these species in the Peace River downstream of the Dunvegan project area (Hildebrand 1990). Seasonal changes in size distribution of mountain whitefish and the presence of primarily subadult bull trout suggest that fish of these species disperse into the Dunvegan project area from upstream populations. These fish either die or move back upstream to complete their life requisites.

Movement data were not collected for small-fish species recorded in the Dunvegan project area, but it is likely that these species populations are resident given their small size. A study completed by Gibbons *et al.* (1995) documented very little movement by spoonhead sculpin and lake chub in the upper Athabasca River. This provides evidence that small-fish species undertake only restricted movements to complete their life requisites.

For most fish species expected to occur in the Dunvegan project area, upstream movements commence in April and end in October. Downstream movements generally occur from August to November. During the months of December to March, fish tend to be stationary. Within this general pattern there are species-specific movement strategies that are illustrated in Table 8.2.2.

The only strong exception to the general pattern described above is burbot. The Dunvegan project area population completes its annual movements in winter. Burbot move downstream in December and January then undertake upstream movements in February and March; all under ice. For the remainder of the year burbot in the Dunvegan project area tend to be stationary.

8.2.3 Habitat

Fish habitats in the Dunvegan project area were documented in terms of their quality and quantity during the 1999 investigation (RL&L 2001). The information was supplemented by additional field investigations completed in 2000 that examined specific habitat sites within the Dunvegan project area (Glacier 2001, MMA 2000a) and comparisons to other studies (Mainstream 2006a). This work was followed by a detailed evaluation of habitat losses and gains in preparation for a No Net Loss Habitat Plan for the Project (Mainstream 2006c). The survey methods used during each study are described in the respective documents. The following summarizes the general findings.

The results of field investigations show that fish habitat in the Peace River in the Dunvegan project area is uniform and exhibits low complexity. In general, river bank mesohabitats provide limited amounts of cover for fish, and unique instream mesohabitats are restricted in distribution. Backwaters that provide protected, low velocity areas for fish, although present, are not abundant. Shoal and riffle/rapid habitats that could potentially be used for feeding and spawning purposes are present, but they provide small amounts of habitat relative to other lower quality habitats such as deep exposed runs. No protected back channels or side channels are present.

Table 8.2.2 Predicted movement patterns of the dominant fish species life stages in the Dunvegan project area (from Glacier Power 2006).

Species/ Life Stage	**January**		**February**		**March**		**April**		**May**		**June**		**July**		**August**		**September**		**October**		**November**		**December**	
	D[a]	**U**[a]	**D**	**U**	**D**	**U**	**D**	**U**	**D**	**U**	**D**	**U**	**D**	**U**	**D**	**U**	**D**	**U**	**D**	**U**	**D**	**U**	**D**	**U**
Bull trout										J,A		J,A		J,A		J,A	J,A		J,A					
Flathead chub									F		F													
Goldeye								A	E	**A**	E	**A**	A	A	**A**		**A**		**A**					
Walleye								A	F,A	J,**A**	F,A	J,**A**		J,**A**		J,**A**	J,A	A	J,**A**		**A**		A	
Burbot	F[c],**A**		F	**A**[d]	F	**A**		A													A		**A**	
Longnose sucker							A	A	F,A	J,A	F,A	J,A	A	J,A	J,A	A	J,A	A	A	A	A	A		
Mountain whitefish							F,J,A		F,J,A		F,J,A		F,J,A		F,J,A		F,J,A		F,J,A					
Northern pike								A		A		A		A	A		A		A					
White sucker							A	A	F,A	J,A	F,A	J,A	A	J,A	J,A	A	J,A	A	A	A	A	A		
Small-fish spp.[b]								*		*		*		*		*	*		*		*			
Egg									1		1													
Fry	1[e]		1		1		1		5		5		1		1		1		1					
Juvenile							1		1	4	1	4	1	4	3	2	5		3					
Adult	1			1		1	3	6	4	6	4	6	4	6	5	4	7	3	7	2	4	2	2	

[a] D: downstream; U: upstream
[b] Includes all small-sized species populations.
[c] Life stage abbreviations Egg (E), Fry (F), Juvenile (J), Adult (A), and Combined (*). Note that juvenile life stage for bull trout includes the subadult age-class.
[d] Bold letter indicate core movement period for adults in the Dunvegan project area.
[e] Number of species, excluding small-fish spp.

The mainstem Peace River provides limited amounts of high-quality fish habitat. The channel is relatively shallow throughout, which limits its potential as overwintering habitat, and water velocities are generally high. There is a paucity of instream cover, as a result of smooth river banks and channel bottom (caused by embedded large-textured materials). As such, habitats that provide refuge from high water velocities are not abundant. This situation is exacerbated by daily fluctuations in the flow regime that further reduce the quality of available habitat.

Tributaries in the Dunvegan project area are characterized by variable flows. In summer and fall habitat is frequently limited to isolated pools with no surface connection to the mainstem Peace River. Channel characteristics of Dunvegan project area tributaries indicate that they are subject to significant flow events and extensive bedload movement. Stream channels are laterally unstable as evidenced by extensive bank erosion. Due to low (spring) and negligible flows (summer and fall), an absence of deep-water habitat capable of supporting overwintering fish, and the prevalence of fine substrates, the tributaries provided poor habitat for most fish species. Resident stream populations were not recorded and the tributaries had limited value to sport and nonsportfish populations originating from in the mainstem Peace River. However, the tributaries did provide seasonal habitat for cyprinid and sucker species.

Two important habitats were located in the Dunvegan project area during the 1999 and 2004 investigations. A walleye spawning site was identified at a shoal located within the proposed headpond area. A small number of fish (n = 9) in spawning condition and walleye eggs were recorded at the site in 1999. The shoal consisted of unconsolidated gravels and cobbles that were not infilled by sediments. Walleye in spawning condition (9 fish) were recorded at the site again in 2004. Although used for spawning, the shoal is subjected to dewatering due to flow regulation. In 1999, the shoal and incubating walleye eggs were dewatered.

In 1999, a northern pike spawning area was located in the proposed headpond area adjacent to a nonactive side channel of the Peace River. Northern pike appeared to be utilizing submerged shoreline vegetation as spawning substrate. Flow regulation caused the site to dewater shortly after it was identified. A subsequent survey in 2004 established that the site was completely destroyed by ice scour caused by the unconsolidated ice sheet during winter of 2003/04.

Longnose sucker, white sucker, and a number of cyprinid species used tributary habitats in the Dunvegan project area for spawning and rearing. These included areas in Hines Creek, Dunvegan Creek, and the Ksituan River.

Fish habitat quantity and quality were quantified in order to evaluate habitat losses and gains associated with the Dunvegan project using the Habitat Suitability Matrix protocol (Mainstream 2006c). In the headpond, the majority of existing instream habitats consist of deep run (93% by area) interspersed with small, discrete units of shoal (2%), and backwater (2%) habitats. Banks are dominated by erosional habitats dominated by sands (58%), armoured habitats that consist of rock (34%), and depositional habitats dominated by sands (6%).

Habitat suitability ratings for individual species and life stages indicate that habitat quality within the Dunvegan project area is low. The exceptions are shoal and backwater habitats, which have a moderate or high habitat suitability rating; however, these specific habitats are not abundant. The evaluation established that a small number of habitat types dominate in the Dunvegan project area and these habitats are low quality, which confirms the findings of the field investigations completed in 1999 and 2004.

The majority of habitats required by fish species expected to occur in the Dunvegan project area exhibit widespread distributions (Table 8.2.3).

Table 8.2.3 Distribution of habitats for selected fish species in the mainstem Peace River between Vermilion Chutes and Peace Canyon Dam (from Glacier Power 2006).

Species	Upstream of Project				Dunvegan project area				Downstream of Project			
	Spawning	Rearing	Feeding	Wintering	Spawning	Rearing	Feeding	Wintering	Spawning	Rearing	Feeding	Wintering
Bull trout		✔	✔	✔		✔	✔					
Burbot	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Goldeye	✔		✔		✔		✔		✔	✔	✔	✔
Kokanee	✔	✔	✔	✔								
Mountain whitefish	✔	✔	✔	✔		✔	✔			✔	✔	
Northern pike	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Walleye	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Fathead minnow	✔	✔	✔	✔	✔	✔	✔	✔				
Flathead chub	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Lake chub	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Longnose dace	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Longnose sucker	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Northern pikeminnow	✔	✔	✔	✔		✔	✔			✔	✔	
Redside shiner	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Slimy sculpin	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Spoonhead sculpin	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Spottail shiner	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Trout-perch	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
White sucker	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔

Species populations with habitats limited primarily to areas upstream of the Dunvegan project area include bull trout, kokanee, mountain whitefish, and northern pikeminnow. Only fathead minnow has a restricted distribution. Scott and Crossman (1973) recorded fathead minnows at one site in Alberta upstream from the Dunvegan project area. Nelson and Paetz (1992) noted that records of this species in the mainstem Peace River were lacking, but noted that populations may exist. A survey by Hildebrand (1990) recorded fathead minnows in the Peace River at the mouth of the Montagneuse River, which is situated approximately 25 km upstream of Dunvegan. During the present study, sixteen individuals of this species were recorded in the mainstem Peace River downstream of the proposed facility.

Goldeye is the only relatively abundant species with habitats that are limited primarily to areas downstream of Dunvegan. Spawning and feeding habitats likely occur as far upstream as the B.C./Alberta boundary, but younger life stages that require rearing habitat have been recorded only as far upstream as the confluence with the Smoky River. This is a similar situation for fish that require wintering habitat.

9.0 SUMMARY

9.1 SPECIES AND REGULATORY STATUS

In total, 32 fish populations have been recorded in the technical study area (Table 9.1.1). None of the 32 populations are officially listed as endangered, threatened, or a special concern under Schedule 1 of the federal *Species at Risk Act (SARA)*, or are being considered for listing under Schedule 2 or 3 of the *Act*.

Table 9.1.1 Fish species recorded in the technical study area and their provincial status.

Group	Species			Provincial Status	
	Common Name	**Latin Name**	**Label**	**B.C.[a]**	**AB[b]**
Sportfish (cold-clear water)	Arctic grayling	*Thymallus arcticus*	GR	Yellow	Sensitive
	Bull trout	*Salvelinus confluentus*	BT	Blue	Sensitive
	Brook trout	*Salvelinus fontinalis*	AEB	Exotic	Exotic
	Kokanee	*Oncorhynchus nerka*	KO	Yellow	Not assessed
	Lake whitefish	*Coregonus clupeaformis*	LT	Yellow	Secure
	Lake trout	*Salvelinus namaycush*	LW	Yellow	Sensitive
	Mountain whitefish	*Prosopium williamsoni*	MW	Yellow	Secure
	Pygmy whitefish	*Prosopium coulteri*	PW	Yellow	May be at risk
	Rainbow trout	*Oncorhynchus mykiss*	RB	Yellow	At risk
Sportfish (cool-turbid water)	Burbot	*Lota lota*	BB	Yellow	Secure
	Goldeye	*Hiodon alosoides*	GE	Blue	Secure
	Northern pike	*Esox lucius*	NP	Yellow	Secure
	Yellow perch	*Perca flavescens*	~~W~~YP	Yellow	Secure
	Walleye	*Sander vitreus*	~~Y~~WP	Yellow	Secure
Suckers	Largescale sucker	*Catostomus macrocheilus*	CSU	Yellow	Sensitive
	Longnose sucker	*Catostomus catostomus*	LSU	Yellow	Secure
	White sucker	*Catostomus commersoni*	WSC	Yellow	Secure
Minnows	Brook stickleback	*Culea inconstans*	BSB	Yellow	Secure
	Finescale dace	*Chrosomus neogaeus*	FDC	Unknown	Undetermined
	Flathead chub	*Platygobio gracilis*	FHC	Yellow	Secure
	Lake chub	*Couesius plumbeus*	LKC	Yellow	Secure
	Longnose dace	*Rhinichthys cataractae*	LNC	Yellow	Secure
	Northern pikeminnow	*Ptychocheilus oregonensis*	NSC	Yellow	Sensitive
	Northern redbelly dace	*Phoxinus eos*	RDC	Unknown	Sensitive
	Peamouth	*Mylcheilus caurinus*	PCC	Yellow	
	Pearl dace	*Margariscus margarita*	PDC	Blue	Undetermined
	Redside shiner	*Richardsonius balteatus*	RSC	Yellow	Secure
	Spottail shiner	*Notropis hudsonius*	STC	Red	Secure
	Trout-perch	*Percopsis omiscomaycus*	TP	Yellow	Secure
Sculpins	Prickly sculpin	*Cottus asper*	CAS	Yellow	Not assessed
	Slimy sculpin	*Cottus cognatus*	CCG	Yellow	Secure
	Spoonhead sculpin	*Cottus ricei*	CRI	Yellow	May be at risk

[a] Red - Indigenous species or subspecies that have- or are candidates for- Extirpated, Endangered, or Threatened status.
Blue - Indigenous species or subspecies considered to be of Special Concern.
Yellow - Species that are apparently secure and not at risk of extinction.
Unknown - Designation highlights species where more inventory and/or data gathering is needed
Exotic - Species that have been moved beyond their natural range as a result of human activity.

In British Columbia the technical study area contains one species listed as “red” (endangered or threatened); spottail shiner, and three are listed as “blue” (special concern); bull trout, goldeye, and pearl dace. The remaining species are designated as “yellow”, described as secure and not at risk of extinction.

In Alberta, the technical study area contains two species identified as “may be at risk” -- pygmy whitefish and spoonhead sculpin. A total of 6 species have “sensitive” designations including; bull trout, Arctic grayling, lake trout, brook stickleback, northern pikeminnow, and northern redbelly dace. The rainbow trout designation as “at risk” refers to the Athabasca River population. The remaining fish species are “secure”, “not assessed”, or “not determined”.

9.2 FISH POPULATION ECOLOGY

The technical study area fish community is composed of fish populations that use one or more ecological strategies. Factors that influence the ecology of a fish population include the species characteristics, environmental conditions, location and availability of important habitats, predation, competitors, and food resources. The following discusses important aspects of the ecology of fish populations recorded in the technical study area. This is used as the basis on which Project effects on the Fish and Fish Habitat VC will be examined. Table 9.2.1 presents a general summary of the ecology of fish species populations recorded in the technical study area. A more detailed summary of fish population distribution, habitat use, movement strategy, and recruitment sources within the technical study area are provided for large-fish species (Table 9.2.2) and small-fish species (9.2.3).

Coldwater versus Coolwater Fish Groups

There are two primary groups of fish in the technical study area -- coldwater and coolwater fish. As the name implies, coldwater species reside in coldwater habitats, and in general, require large-textured sediments and clean, well-oxygenated water to complete their life requisites. These species typically spawn in summer or fall and have extended egg incubation periods. Coolwater species are able to tolerate higher water temperatures and are better adapted to inhabit turbid water and cope with higher fine sediment loads. These species typically spawn in spring and have short egg incubation periods.

The technical study area is a transition zone for these two groups of fish. Coldwater species dominate the fish community primarily upstream of the Pine River confluence, but coolwater fish also reside in the area. The importance of the coolwater fish group increases downstream of the Pine River confluence until it becomes the dominant fish group at the British Columbia/Alberta boundary.

Table 9.2.1 Summary of the general ecology of fish species populations recorded in the technical study area.

Group	Species[a]	Distribution[b] and Relative Abundance[c]		Important Habitats[d]				Recruitment Source[e]			Movement Strategy[f]
				Upst.		Dwst.		Type	Stream Resident Populations		
		Upst.	Dwst.	Peace R.	Tribs.	Peace R.	Tribs.		Upst.	Dwst.	
Sportfish (coldwater)	Arctic grayling	S	S	F, W	**S**, **R**, F, W	F, W	S, R, F, W	N	x	x	E
	Bull trout	P	S	F, W	**S**, **R**, F, W	F, W	S, R, F, W	**N**, E	x	x	E
	Brook trout										
	Kokanee	S	I	F, W				E			D
	Lake whitefish	S	S	F, W		S, R, F, W		N, **E**			L
	Lake trout	S	I	F, W				E			L
	Mountain whitefish	**A**	A	S, R, F, W	**S**, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L, E
	Pygmy whitefish										
	Rainbow trout	P	I	F, W	**S**, **R**, F, W			N, **E**	x		L
Sportfish (coolwater)	Burbot	S	P		S, R, F, W	F, W	**S**, **R**, F, W	N	x	x	L
	Goldeye	S	P	-		F, W	**S**, R, F, W	N			E
	Northern pike	S	P	U	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Yellow perch	S				Unique		N			L
	Walleye	S	P	F, W	F, W	F, W	**S**, **R**, F, W	N			E
Suckers	Largescale sucker	A	A	F, W	**S**, **R**, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Longnose sucker	A	**A**	F, W	**S**, **R**, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	White sucker	S	P	F, W	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
Minnows	*Brook stickleback*										
	Finescale dace										
	Flathead chub	S	P		S, R, F, W	F, W	**S**, **R**, F, W	N	x	x	E,L
	Lake chub	A	A	U	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Longnose dace	A	A	U	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Northern pikeminnow	P	A	F, W	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Northern redbelly dace										
	Peamouth										
	Pearl dace										
	Redside shiner	**A A**		U	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Spottail shiner	S	P	U	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Trout-perch	I	P		S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
Sculpins	Prickly sculpin	A	A	F,W	S, R, F, W	F,W	S, R, F, W	N	x	x	L
	Slimy sculpin	A	A	F,W	S, R, F, W	F,W	S, R, F, W	N	x	x	L
	Spoonhead sculpin	I	R		S, R, F, W	F,W	S, R, F, W	N	x	x	L

[a] Species: Italics indicates incidental species recorded in the technical study area but that are not part of the existing fish community.
[b] Distribution: Upst. (Upstream of the Site C dam Location); Dwst. (Downstream of Site C dam location); + (Present); - (Not present)
[c] Relative Abundance: A (Abundant); P (Present); S (Scarce); I (Incidental)
[d] Important Habitats: S (Spawning); R (Rearing); F (Feeding); W (Wintering); bold indicates required use of tributary habitat by Peace River population; "U" refers to a small number of side channels that provide all important habitats.
[e] Recruitment Source: N (Natural); E (Entrainment); bold indicates primary source.
[f] Movement Strategy: E (Extended movements); L (Local movements); (D) Unidirectional downstream dispersal.

Table 9.2.2 Summary of large-fish population distribution, habitat use, movement strategy, and recruitment sources within the technical study area.

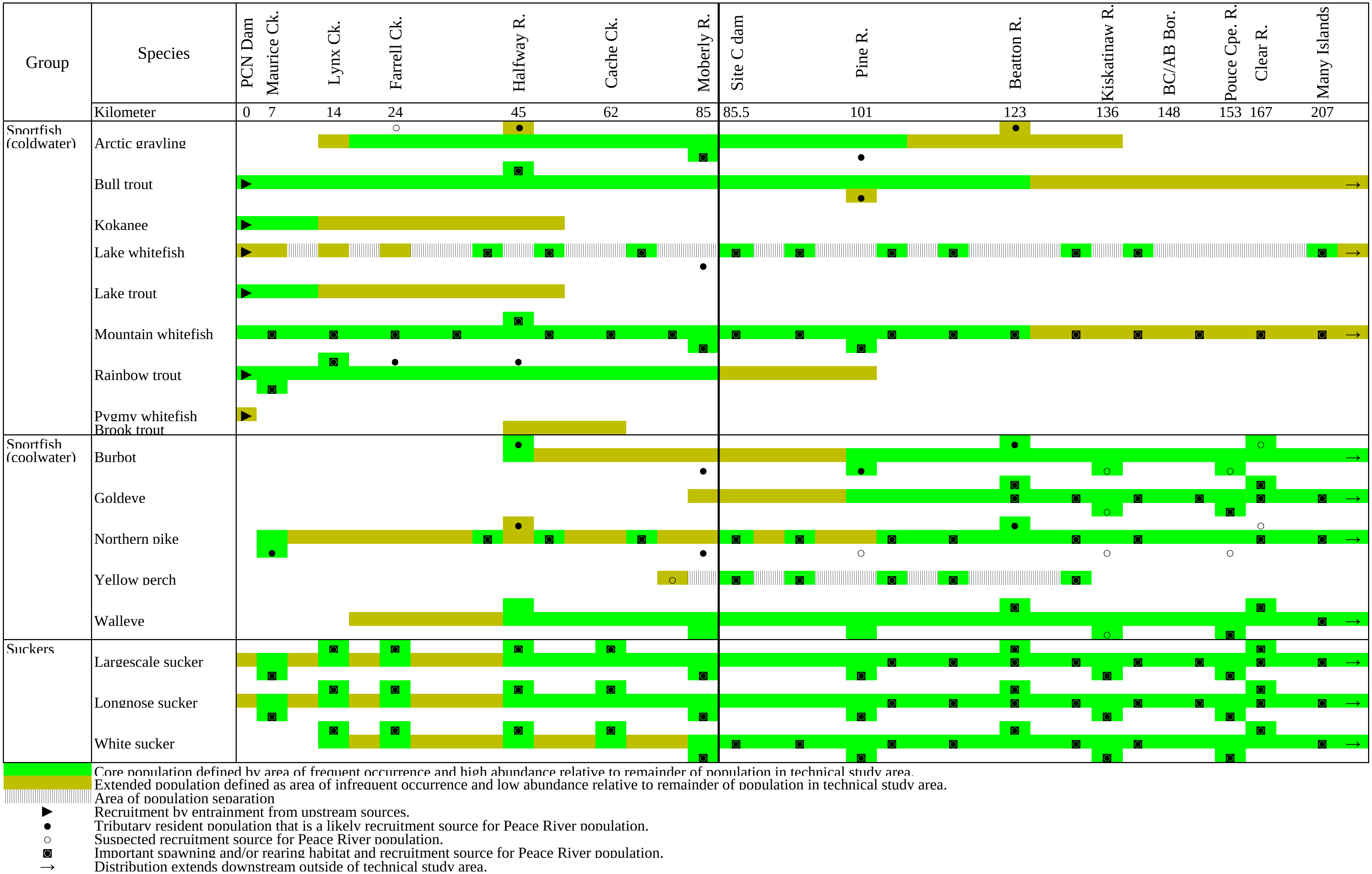
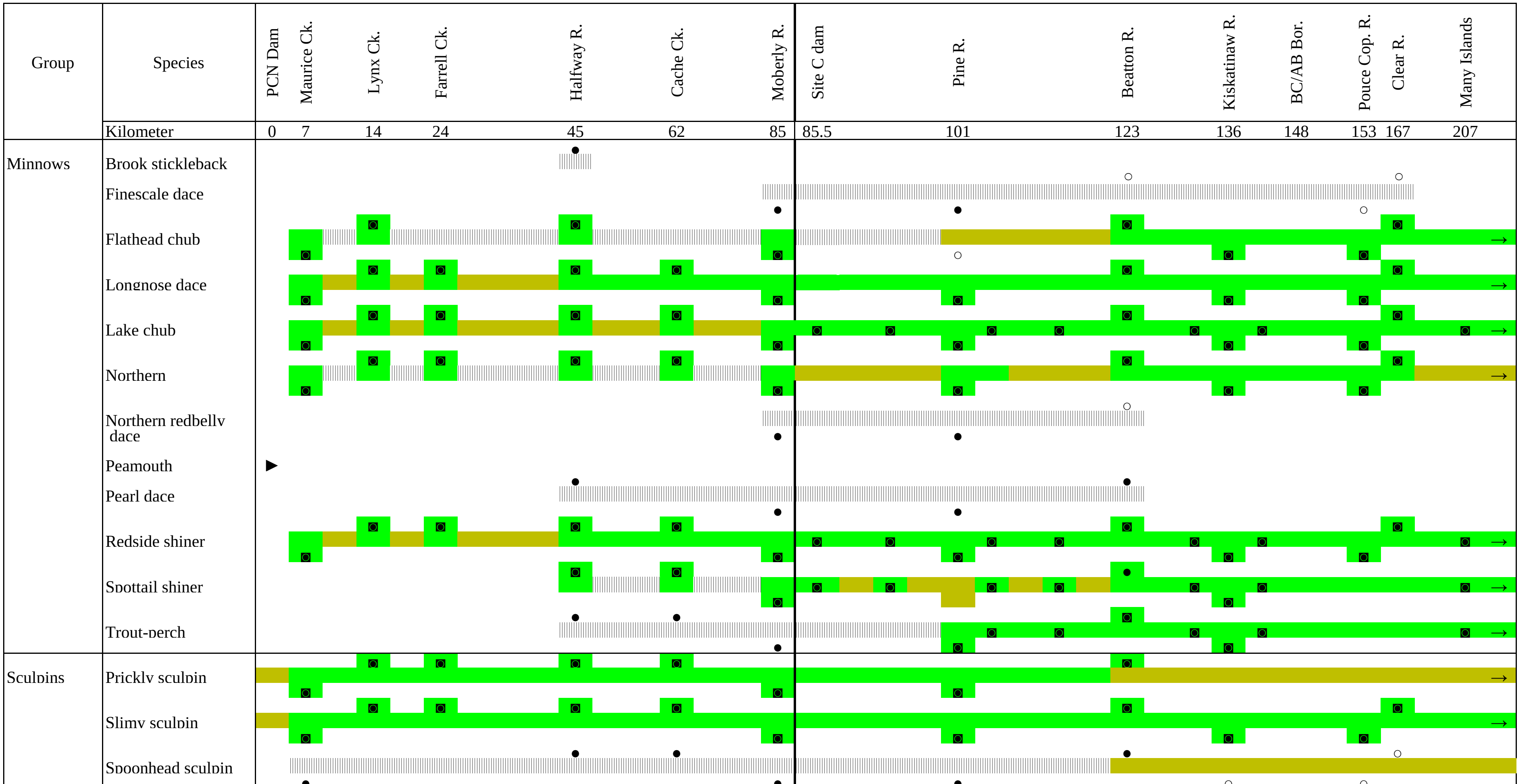


Table 9.2.3 Summary of small-fish population distribution, habitat use, movement strategy, and recruitment sources within the technical study area.



Core population defined by area of frequent occurrence and high abundance relative to remainder of population in technical study area.
Extended population defined as area of infrequent occurrence and low abundance relative to remainder of population in technical study area.
Area of population separation
▶ Recruitment by entrainment from upstream sources.
● Tributary resident population that is a likely recruitment source for Peace River population.
○ Suspected recruitment source for Peace River population.
◙ Important spawning and/or rearing habitat and recruitment source for Peace River population.
→ Distribution extends downstream outside of technical study area.

Seven sportfish species that are part of the fish community belong to the coldwater group. They include Arctic grayling, bull trout, kokanee, lake whitefish, lake trout, mountain whitefish, and rainbow trout. Arctic grayling and rainbow trout are the only species in the group that are spring spawners. Rainbow trout is also a species that has limited natural recruitment within the technical study area.

Coolwater fish species that are part of the fish community include the three sucker species and nine species listed in the minnow group. They are largescale sucker, longnose sucker, white sucker, flathead chub, lake chub, longnose dace, northern pikeminnow, redside shiner, spottail shiner, and trout-perch.

The three sculpin species appear to do well in both types of environments. Slimy sculpin and prickly sculpin tend to do better in cold, clear water systems, while spoonhead sculpin do better in cool, turbid water systems.

A number of species recorded in the technical study area are very rare and are not considered part of the existing fish community. These include brook trout, pygmy whitefish, brook stickleback, finescale dace, northern redbelly dace, peamouth, and pearl dace. They are present, but individuals of these species represent transients from populations that reside outside the influence of the Project.

Small Fish versus Large Fish

The technical study area fish community can be divided in two groups based on maximum fish size – large and small-fish species. Large-fish species generally attain a length of at least 200 mm at maturity, but are also represented by smaller age classes (i.e., young-of-the-year and juveniles). The large-fish category in the technical study area includes sportfish and suckers. In the small-fish group, all age classes are typically smaller than 200 mm. This category includes minnows and sculpins. The only exception to this length criterion is northern pikeminnow in the minnow group, which can attain a length in excess of 600 mm.

The rationale for the size distinction relates to the relative difference between large-fish species and small-fish species in their ability to move extended distances. In fluvial systems like the regulated Peace River, adults of large-fish species are capable of moving long distances upstream against the current. Given their small size, small-fish species typically undertake much smaller movements. The exception to this statement is downstream dispersal of small-fish species and younger age classes of large-fish species, which can involve long distances.

Movements -- Extended versus Local

Fish that reside in north temperate climates use migration (movement) as a strategy to cope with harsh and unpredictable environments. Migration is defined as movements resulting in alterations between two or more separate habitats occurring with regular periodicity (seasonal or annual) and involving a large fraction of the population (Northcote 1998). The patterns of movement can vary between species and even between groups within the same population (Northcote 1998). Fish residing in the Peace River use movement as a strategy to access important habitats (McPhail 2007, Nelson and Paetz 1992; Mill *et al.* 1997); however, certain species are known to undertake extensive movements (extended), whereas others undertake only local movements (local).

Within the technical study area, several species demonstrate extended upstream movements. These include Arctic grayling, bull trout, and mountain whitefish. Movements by adults typically involve long distance migrations to tributary spawning habitats. Arctic grayling migrate to the Moberly River where they likely spawn 20 to 60 km upstream from the Peace River confluence. Bull trout travel as much as 300 km in order to access spawning habitats in upper Halfway River tributaries. Walleye is another species that can move extensive upstream distances. This species undertakes post-spawning feeding movements in the Peace River from spawning areas in the Beatton River, Clear River, and Pouce Coupe River of the lower technical study area to as far upstream as the Halfway River, which is a distance of 100 km. Some of these walleye enter and move upstream into larger tributaries such as the Pine River, Moberly River, and Halfway River. Goldeye is a highly migratory species that can travel approximately 500 km from wintering habitats downstream of the Town of Peace River to as far upstream as the Moberly River. The goldeye population likely spawns in the Peace River and in several tributaries, primarily in Alberta. Goldeye spawning and early rearing has been confirmed in the Beatton River by the capture of Age 0 fish. Flathead chub, which inhabit the Peace River and tributaries, is thought to undertake extensive movements in river systems, but there is no information to support this hypothesis for Peace River populations.

The remaining fish species in the technical study area likely undertake local movements around focal areas. For example, all three sucker species and most species in the minnow group have populations in the Peace River that reside in the immediate vicinity of tributary confluences. During spring and early summer large numbers of fish belonging to these populations are recorded moving upstream to suspected spawning and feeding areas in the tributaries.

Some species residing in the Peace River technical study area utilize both local and extended movement strategies depending on the availability of important habitats. These include all three sucker species and mountain whitefish. For example some mountain whitefish complete all life history actives within a 1 or 2 km section of the Peace River, while other mountain whitefish migrate many kilometers (from upstream and downstream) in order to access tributary spawning habitats in the Pine River, Moberly River, and Halfway River.

A third movement strategy includes downstream dispersal by small-fish species and younger age classes of large-fish species. Downstream dispersal, which can be active or passive, has been recorded for most species present in the technical study area within the Peace River and from all tributaries. This movement strategy is a major source of recruitment for some fish populations (e.g., Arctic grayling). For other populations, it represents a major loss (e.g., kokanee). Examples are as follows. Concentrations of juvenile Arctic grayling are consistently recorded immediately downstream of major tributaries from the Halfway River to the Beatton River indicating downstream dispersal from each system. Large numbers of Age 0 mountain whitefish are known to emigrate from rearing tributaries such as the Moberly River and Halfway River. Kokanee that appear in the Peace River in early summer, presumably from upstream sources, continually disperse downstream and are likely lost to the technical study area. Finally, recently emerged mountain whitefish fry in the upper Peace River disperse downstream in spring and by mid-summer are largely absent from that section of the Peace River upstream of the Halfway River confluence.

Habitats -- Peace River versus Tributary

The Peace River fish community in much of the technical study area is dominated by adults and older juveniles of large-fish species, with a paucity of younger fish in the large-fish species group and most small-fish species. This is most apparent upstream of the Halfway River confluence. The mechanism thought to drive this outcome is the absence of suitable habitats needed by small-sized fish in the Peace River. This is caused by the regulated flow regime of the Peace River and/or life history strategies that rely heavily on tributary habitats for important life requisites such as spawning and early rearing. Downstream of the Halfway River, this pattern of large-versus small fish gradually lessens, but still remains the primary feature of technical study area Peace River fish community. Species populations that appear not to follow this pattern are rainbow trout and kokanee, which likely receive recruitment from upstream sources, and sculpins. Prickly sculpin and slimy sculpin are widely distributed in the Peace River in areas that contain large amounts of physical cover in the channel bed that is not dewatered by flow regulation.

In contrast to the Peace River, tributaries in the technical study area support a diverse number of small and large-fish species. The fish species populations that utilize Site C tributaries depend on the environmental characteristics of the watercourse. Smaller tributaries and the lower sections of larger tributaries tend to have limited coldwater fish habitats due to water flow regimes that are dominated by large spring freshets and low summer and winter flows, high summer water temperatures and elevated suspended sediment loads caused by watercourse down cutting through the Peace River valley wall. These areas support populations of minnows and suckers, which tend to use tributary confluence areas as population focal points.

Farther up in the watersheds of larger tributaries such as the Halfway River and Pine River, there is an abundance of habitats that can support coldwater fish populations. These habitats are utilized by some Peace River fish populations (e.g., bull trout) and resident populations may provide recruitment to Peace River populations by downstream dispersal (e.g., Arctic grayling).

<u>Habitats -- Main Channel versus Side Channel</u>

The Peace River fish community within the technical study area utilizes two primary habitat areas – main channel and side channel. Fish populations use one or both habitat areas depending on species life stage requirements, the physical characteristics of the side channel area, and the Peace River flow regime. Side channels typically provide more benign habitats than habitats in main channel areas. Side channels are important habitats for smaller-sized fish species and younger age-classes of large-fish species. Side channel areas provide critical refuge during high river flows and during periods of fry emergence.

A small number of side channels provide unique fish habitats that exhibit specific physical characteristics. These side channels are sheltered from high water velocities (i.e., one inlet at the downstream end), have low water turbidity during much of the year, and support growth of aquatic vegetation. These side channel habitats are restricted in distribution and few in number within the technical study area.

These unique side channel areas support a unique fish assemblage consisting of five species (i.e., lake whitefish, northern pike, yellow perch, white sucker, and spottail shiner). Populations of these species have specialized habitat requirements and can complete all their life history requisites in these areas.

Recruitment Sources – Natural versus Entrainment

Natural recruitment to fish populations in the technical study area may originate from the mainstem Peace River and/or Peace River tributaries. Tributaries provide spawning and early rearing habitats for most species populations that reside in the Peace River. In addition, several tributaries contain resident populations that provide recruitment to the Peace River via downstream dispersal. This is true for most fish populations in the technical study area. Baseline studies suggest that resident fish in Maurice Creek are an important recruitment source for Peace River rainbow trout. The Halfway River, Pine River, and Beatton River appear to be important source for recruitment of Arctic grayling.

Few fish populations in the technical study area rely entirely on mainstem Peace River recruitment sources. Spawning by sculpin species, mountain whitefish, sucker species, and possibly walleye occurs in the mainstem Peace River. However, the contribution of mainstem spawning to recruitment is minimal given the temperature, flow, and ice regime of the system and evidence of rapid downstream dispersal of recently emerged fry. Sculpin, mountain whitefish, sucker, and walleye populations in the technical study area all utilize tributary spawning and early rearing habitats that are located outside of the influence of the Peace River.

As indicated earlier a small number of side channels are unique areas that provide important habitats for a select number of species. The value of these areas for recruitment depends largely on the flow regime during critical periods. For example, northern pike eggs that are deposited on emergent vegetation are highly susceptible to dewatering by the regulated flow regime.

An importance source of recruitment for some technical study area fish populations is entrainment. Recruitment via entrainment likely maintains the rainbow trout, kokanee, and lake trout populations. Other species known to recruit from sources upstream of the Peace Canyon Dam include bull trout, lake whitefish, and peamouth.

9.3 FISH ABUNDANCE AND DISTRIBUTION

In terms of overall abundance of large-fish and small-fish species, fish numbers are much higher in the technical study area compared to downstream. Extensive work in the Dunvegan area of the Peace River, which is approximately 120 km downstream of the technical study area, recorded an order of magnitude lower abundance of large fish and of small fish.

Mountain whitefish is the dominant large-fish species in the technical study area. Longnose sucker replaces mountain whitefish as the dominant large-fish species in the lower section of the Peace River technical study area. Redside shiner is the numerically dominant small-fish species in the Peace River technical study area upstream and downstream of the Site C dam.

In general smaller tributaries in the technical study area contain fish communities numerically dominated by suckers and minnows. Spring trapping studies recorded several thousands of fish belonging to these groups in monitored streams. These included Lynx Creek, Farrell Creek, and Cache Creek. An exception is Maurice Creek, which supports a rainbow trout population. The lower portions of larger tributaries contain fish communities dominated by suckers and minnows, but the upper watersheds also support coldwater sportfish such as Arctic grayling, bull trout, and rainbow trout.

9.4 POPULATION STRUCTURE

Population structure refers to the size and age distribution of a population. A balanced population structure would include all size or age groups in appropriate proportions necessary to sustain a fish population. The Peace River fish community is dominated by large-sized fish, particularly upstream of the Halfway River confluence. Younger fish of large-fish species (and most small-fish species) exhibit low abundance. It is assumed that the Peace River flow regime is the cause by limiting the availability and quantity of small-fish habitats. Small-fish do occur upstream of the Halfway River, but are typically found in protected backwaters and side channels away from the main influence of Peace River flows. The frequency of occurrence and abundance of small-sized fish increases downstream of the Halfway River. This is caused by a combination of factors including fish recruitment from tributaries and greater availability and quantity of small-fish habitat. If the technical study area is considered as a whole, the existence of sustainable fish populations is evidence of a balanced population structure for most recorded species. Exceptions include kokanee and lake trout populations that receive all recruitment from upstream sources.

9.5 IMPORTANT HABITATS

Fish habitat is defined as any spawning grounds and nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly to carry out their life processes (DFO 1998). A distinction is made for important habitat, which is defined as habitat that is essential for the maintenance of a self-sustaining, fish population. Removal of important habitat from production, by alteration, destruction or elimination of access, would severely reduce the sustainability of the population. Important habitats are present throughout the technical study area. Depending on the species, important habitats are located in the Peace River upstream and downstream of the Site C dam location and in Peace River tributaries within and outside of the inundation zone of the Site C reservoir. In general, the lower sections of Peace River tributaries provide important spawning and early rearing habitats for suckers and minnows. Important spawning and rearing habitats for sportfish have been recorded only in upstream areas of large tributaries.

The upper Halfway River watershed provides important spawning and rearing habitats for the Peace River bull trout population. The Moberly River provides important spawning and rearing habitats for the Peace River Arctic grayling population. Maurice Creek provides important spawning and rearing habitats for the Peace River rainbow trout population. The Halfway River, Moberly River, and Pine River provide important spawning habitats for the Peace River mountain whitefish population. The Beatton River provides important spawning and rearing habitats for walleye. All tributaries to the Peace River provide important spawning and rearing habitats for suckers, minnows, and sculpins. The Peace River downstream of the Halfway River confluence provides important rearing habitat for mountain whitefish. Unique side channels provide important habitats for several fish species, in particular northern pike and yellow perch, and spottail shiner. Finally, the mainstem Peace River is an important migration area for several species by providing an upstream and/or downstream movement corridor between important habitats. Several populations require the Peace River as a movement corridor. They include Arctic grayling, bull trout, mountain whitefish, burbot, goldeye, walleye, largescale sucker, and longnose sucker.

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11.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

Prepared:

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APPENDICES

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Appendix A1 Waterbodies located in the Peace River drainage.

Waterbody Descripti	on
Williston Reservoir	Reservoir created by Bennett Dam
Blackwater Creek	Tributary on Parsnip Reach of Williston Reservoir
Nations Lake	Lake on Parsnip Reach of Williston Reservoir
Dunlevy Creek	Tributary to Williston Reservoir
Carbon Creek	Tributary to Williston Reservoir
Manson River	Tributary to Williston Reservoir
Davis River	Tributary to Williston Reservoir
Dinosaur Reservoir	Reservoir created by Peace Canyon Dam
Johnson Creek	Tributary to Dinosaur Reservoir
Gething Creek	Tributary to Dinosaur Reservoir
Mogul Creek	Tributary to Dinosaur Reservoir
Strarfish Creek	Tributary to Dinosaur Reservoir
Moosebar Creek	Tributary to Dinosaur Reservoir
Dowling Creek	Tributary to Dinosaur Reservoir
Gaylard Creek	Tributary to Dinosaur Reservoir
Burnt trail Creek	Tributary to Dinosaur Reservoir
Wright Lake	Headwater lake for Gething Creek
Pete Lake	Headwater lake for Burnt Trail Creek
Maurice Creek	Tributary to Peace River (Km 7.3)[a]
Lynx Creek	Tributary to Peace River (Km 13.6)
Brenot Creek	Tributary to Lynx Creek
Mackie Creek	Tributary to Lynx Creek
Farrell Creek	Tributary to Peace River (Km 23.7)
Chinaman Lake	Headwater lake for Farrell Creek
Beany Creek	Tributary to Farrell Creek
Ruby Creek	Tributary to Farrell Creek
Robb Lake	Headwater lake for Halfway River
Halfway River	Tributary to Peace River (Km 45.2)
Chowade River	Tributary to Upper Halfway River
Fiddes Creek	Tributary to Halfway River
Ground Birch Creek	Tributary to Halfway River
Blue Grave Creek	Tributary to Halfway River
Kobe Creek	Tributary to Halfway River
Cypress Creek	Tributary to Halfway River
Needham Creek	Tributary to Halfway River
Graham River	Tributary to Halfway River
Horseshoe Creek	Tributary to Halfway River
Horn Creek	Tributary to Halfway River
Cameron River	Tributary to Halfway River
Inga Lake	Headwater lake for Cache Creek
Coplin Creek	Tributary to Cache Creek
Cache Creek	Tributary to Peace River (Km 61.7)
Red Creek	Tributary to Cache Creek
North Cache Creek	Tributary to Cache Creek
East Cache Creek	Tributary to Cache Creek
West Cache Creek	Tributary to Cache Creek
Wilder Creek	Tributary to Peace River (Km 72.6)
Moberly Lake	Headwater lake of Moberly River 120 km upst. of Peace River confluence
Moberly River	Tributary to Peace River (Km 84.5)

Appendix A1 Waterbodies located in the Peace River drainage.

Waterbody Descripti	**on**
West Moberly River	Tributary to Moberly River
Azouzetta Lake	Headwater lake for Pine River
Pine River	Tributary to Peace River (Km 101.0)
Gwillim Lake	Headwater lake of the Pine River
Lemoray Creek	Tributary to Pine River
Falling Creek	Tributary to Pine River
Halser Creek	Tributary to Pine River
Beaudette Creek	Tributary to Pine River
Sukunka River	Tributary to Pine River
Dickebusch Creek	Tributary to Sukunka River
Zonnebeke Creek	Tributary to Sukunka River
Brazion Creek	Tributary to Sukunka River
Burnt River	Tributary to Pine River
Murray River	Tributary to Pine River
Stewart Creek	Tributary to Pine River
Kinuseo Creek	Tributary to Pine River
Lily Lake	Headwater lake to the Beatton River
Beatton River	Tributary to Peace River (Km 122.5)
Lifeline Lake	Headwater lake of the Beatton River
Blueberry River	Tributary to Beatton River
Montney Creek	Tributary to Beatton River
La Prise Creek	Tributary to Beatton River
Nig Creek	Tributary to Beatton River
Doig River	Tributary to Beatton River
Milligan Creek	Tributary to Beatton River
Big Arrow Creek	Tributary to Beatton River
Black Creek	Tributary to Beatton River
Bratland Creek	Tributary to Beatton River
Charlie Lake	Headwater lake to Beatton River
Fish Creek	Tributary to Beatton River
Bearhole Lake	Headwater lake for Kiskatinaw River
Kiskatinaw River	Tributary to Peace River (Km 135.5)
One Island Lake	Headwater lake of the Kiskatinaw River
Boot Lake	Headwater lake of the Kiskatinaw River
West Kiskatinaw River	Tributary to Kiskatinaw River
Oetata Creek	Tributary to Kiskatinaw River
Alces River	Tributary to Peace River (Km 143.4)
Pouce Coupe River	Tributary to Peace River (Km 153.4)
Clear River	Tributary to Peace River (Km 167.4)
Hines Creek	Tributary to Peace River
Kitsuan River	Tributary to Peace River
Dunvegan Creek	Tributary to Peace River
Burnt River	Tributary to Peace River
Smoky River	Tributary to Peace River (Km 368.2)

[a] Kilometer designation indicates distance downstream of Peace Canyon Dam.

Appendix A2 Information source data type and location.

			Reservoirs			Upper Peace			Upper Tribs			Lower Peace			Lower Tribs			Alberta Peace			Alberta Tribs						
Year Work Done	Title Cita	tion	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Movement	Signature Elemental	Genetics	Riparian
2009	2009 Burbot Study – Dunvegan Hydroelectric Project	Mainstream Aquatics Ltd. 2010. 2009 Burbot Study – Dunvegan Hydroelectric Project (Final). Prepared for TransAlta Corporation. Report No. 09006F: 52 p. + appendices.																X	X	X							
2010	2010 Dinosaur Reservoir Sampling and Literature Review	Diversified Environmental Services and Mainstream Aquatics Ltd. 2011. Dinosaur Reservoir Sampling and literature Review 2010. Prepared for BC Hydro. Report No.10017: 27 p. + Appendices		X	X																						
1992	A general fish and riverine habitat inventory, Peace and Slave Rivers, April to June, 1992.	Boag, T. 1993. A general fish and riverine habitat inventory, Peace and Slave Rivers, April to June, 1992. Northern River Basins Study Technical Report No. 9: 85 pp. + appendices.																									
1996-1999	Bull trout movement patterns: Halfway River and Peace River	Burrows, J., T. Euchner, and N. Baccante. 2001. Bull trout movement patterns: Halfway River and Peace River progress. Bull Trout II Conference Proceedings. 99-99.																						x			
2008	Burbot mercury study in the Dunvegan area of the Peace River	Mainstream Aquatics Ltd. 2009. Burbot (Lota lota) mercury study in the Dunvegan area of the Peace River – Data Report. Prepared for TransAlta Corporation. Report No. 08014F: 11 p. + appendices.																						X			
2004	Dinosaur Reservoir 2002 Fish Collection Summary	Murphy et al.		X	X																						
2011	Dinosaur Reservoir Demonstration Tributary- Environmental Impact Assessment for the Proposed Portage and Bullrun Creek Diversions	Triton Environmental Consultants Ltd. 2011.Dinosaur Reservoir Demonstration Tributary- Environmental Impact Assessment for the Proposed Portage and Bullrun Creek Diversions. Prepared for BC Hydro. Report No. GMSWORKS #8. 79 p + appendices	X	X	X																						
2004	Dinosaur Reservoir Fish Collection Summary 2001	Murphy and Blackman		X	X																						
2011	Dinosaur Reservoir Tributary Habitat - Effectiveness Monitoring for the Portage and Bullrun Creek Diversions: Year 1 – Baseline Conditions	Triton Environmental Consultants Ltd. 2011. Dinosaur Reservoir Tributary Habitat - Effectiveness Monitoring for the Portage and Bullrun Creek Diversions: Year 1 – Baseline Conditions. Prepared for BC Hydro. Report No. GMSMON - 14. 22 p + appendices	X	X	X																						

Appendix A2 Information source data type and location.

			Reservoirs			Upper Peace			Upper Tribs			Lower Peace			Lower Tribs			Alberta Peace			Alberta Tribs						
Year Work Done	Title Citation		Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Movement	Signature Elemental	Genetics	Riparian
2004	Dunvegan Baseline Fish Inventory Study (2004)	Mainstream Aquatics Ltd. 2006. Baseline Fish Inventory Study. Dunvegan Hydroelectric Project. Prepared for Glacier Power Ltd. Report No. 04011F: 100 pp.																	X	X		X	X				
2008	Dunvegan Fish Community Monitoring Program – 2008 Interim Report	Mainstream Aquatics Ltd. 2009. Dunvegan Fish Community Monitoring Program - 2008 Studies Interim Report. Prepared for Glacier Power Ltd. Report No. 08009F: 59 pp. + Appendices.																	X	X							
2003	Dunvegan Fish Movement Study (2002 – 2003)	Mainstream Aquatics Ltd. 2004. Fish movement study (2002 – 2003) – Dunvegan Hydroelectric Project. Prepared for Canadian Hydro Developers Inc. Mainstream Report No. 03009F: 49 p + Plates and Appendices.																						X			
2005	Dunvegan Fish Movement Study (2004/05)	Mainstream Aquatics Ltd. 2006. Fish movement study (2004/05) – Dunvegan Hydroelectric Project. Prepared for Glacier Power Ltd. Mainstream Report No. 05011F: 70 pp. + appendices																						X			
2009	Dunvegan Fish Movement Study (2008/09)	Mainstream Aquatics Ltd. 2009. Fish movement study (2008/09) – Dunvegan Hydroelectric Project. Prepared for Glacier Power Ltd. Mainstream Report No. 08010F: 64 pp. + appendices.																						X			
2000	Dunvegan Hydroelectric Project- Fish and Habitat Inventory Comprehensive Report	RL & L Environmental Services Ltd. 2000. Dunvegan Hydroelectric Project- Fish and Habitat Inventory Comprehensive Report. Prepared for Glacier Power Ltd. RL&L Report No. 809F: 123 p + 4 Appendices and Plates.																X	X	X	X	X	X				
2011	Dunvegan Project – Fish Data Synthesis Report	Mainstream Aquatics Ltd. 2011. Fish data synthesis report for the Dunvegan Hydroelectric Project. Prepared for Transalta Corporation. Report No. 10020F01: 82 pp. + appendix.																				X	X				
1994	Fish Migrations in the Chowade River - Fall 1994	RL & L Environmental Services Ltd. 1995. Fish Migrations in the Chowade River - Fall 1994. Prepared for B.C. Ministry of Environment. 33 p + appendices and plates.									X																

Appendix A2 Information source data type and location.

			Reservoirs			Upper Peace			Upper Tribs			Lower Peace			Lower Tribs			Alberta Peace			Alberta Tribs						
Year Work Done	**Title Cita**	**tion**	**Habitat**	**Small-fish**	**Large-fish**	**Habitat**	**Small-fish**	**Large-fish**	**Habitat**	**Small-fish**	**Large-fish**	**Habitat**	**Small-fish**	**Large-fish**	**Habitat**	**Small-fish**	**Large-fish**	**Habitat**	**Small-fish**	**Large-fish**	**Habitat**	**Small-fish**	**Large-fish**	**Movement**	**Signature Elemental**	**Genetics**	**Riparian**
1996 - 1999	Further Analysis and Assessment of the Ministry of Environment's Peace River Bull Trout and Arctic Grayling Radio Telemetry Database 1996 to 1999.	Amec Earth & Environmental and LGL Limited 2010b. Further Analysis and Assessment of the Ministry of Environment's Peace River Bull Trout and Arctic Grayling Radio Telemetry Database 1996 to 1999. Prepared for BC Hydro. 48 p.																									
1999	Glacier Power Project - Peace River Fish and Habitat Inventory (Preliminary Draft)	RL & L Environmental Services Ltd. 1999. Glacier Power Project- Fish and Habitat Inventory. Prepared for Canadian Hydro Developers Inc. RL& L Report No. 752D: 89 p.																X	X	X	X	X	X				
1990	Investigations of Fish and Habitat Resources in the Peace River in Alberta	Hildebrand, L. 1990. Investigations of fish and habitat resources of the Peace River in Alberta. Prepared for Alberta Environment, Planning Division and Alberta Fish and Wildlife Division. Peace River Regions. RL&L Report No. 245F. 148 pp. + appendices.																X	X	X	X	X	X				
	Peace River Angling and Recreational-Use Creel Survey	Robichaud, M. Mathews, A. Blakley and R. Bocking																									
2005	Peace River Fish and Aquatics Investigations - Peace River and Tributary Summer Fish Distribution, Habitat Assessment and Radio Telemetry Studies 2005	Amec Earth & Environmental and LGL Limited 2008. Peace River Fish and Aquatics Investigations - Peace River and Tributary Summer Fish Distribution, Habitat Assessment and Radio Telemetry Studies 2005. Prepared for BC Hydro. 93 p.				X	X					X	X											X			
2008	Peace River Fish Community Indexing Program – 2008	Mainstream Aquatics Ltd. and W.J. Gazey Research. 2009. Peace River Fish Community Indexing Program - 2008 Studies. Prepared for BC Hydro. Report No. 08011F: 93 pp. + Appendices.						X																			
2002	Peace River Fish Community Indexing Program - Phase 2 Studies.	P&E Environmental Consultants Ltd. and W.J. Gazey Research. 2003. Peace River Fish Community Indexing Program - Phase 2 Studies. Prepared for BC Hydro. P&E Report No. 02011F: 86 p. + Appendices.						X																			
2003	Peace River Fish Community Indexing Program - Phase 3	Mainstream Aquatics Ltd. and W.J. Gazey Research. 2004. Peace River Fish Community Indexing Program - Phase 3 Studies. Prepared for BC Hydro. Report No. 03008F: 104 p. + Appendices.						X																			

Appendix A2 Information source data type and location.

			Reservoirs			Upper Peace			Upper Tribs			Lower Peace			Lower Tribs			Alberta Peace			Alberta Tribs						
Year Work Done	Title Cita	tion	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Movement	Elemental Signature	Genetics	Riparian
2004	Peace River Fish Community Indexing Program - Phase 4	Mainstream Aquatics Ltd. and W.J. Gazey Research. 2005. Peace River Fish Community Indexing Program - Phase 4 Studies. Prepared for BC Hydro. Report No. 04008F: 134 p. + Appendices.						X																				
2005	Peace River Fish Community Indexing Program - Phase 5	Mainstream Aquatics Ltd. and W.J. Gazey Research. 2006. Peace River Fish Community Indexing Program - Phase 5 Studies. Prepared for BC Hydro. Report No. 05016F: 118 p. + Appendices.										X																
2006	Peace River Fish Community Indexing Program - Phase 6	Mainstream Aquatics Ltd. and W.J. Gazey Research. 2007. Peace River Fish Community Indexing Program - Phase 6 Studies. Prepared for BC Hydro. Report No. 06011F: 116 p. + Appendices.										X																
2007	Peace River Fish Community Indexing Program - Phase 7	Mainstream Aquatics Ltd. and W.J. Gazey Research. 2008. Peace River Fish Community Indexing Program - Phase 7 Studies. Prepared for BC Hydro. Report No. 07011F: 106 p. + Appendices.					X																					
2001	Peace River Fish Community Indexing Program - Phase I Studies	P&E Environmental Consultants Ltd. 2002. Peace River Fish Community Indexing Program - Phase I Studies. Prepared for BC Hydro. P&E Report No. 01005F: 76 p. + Appendices					X	X		X	X		X	X		X	X											
1999	Peace River fish habitat utilization study.	RL&L Environmental Services Ltd. 2001. Peace River fish habiat utilization study. Prepared for BC Hydro - Environmental Services Burnaby, BC. RL&L Report No. 725F: 72p. + appendices.				X	X	X				X	X	X														
2009	Peace River Fish Index Project – 2009	Mainstream Aquatics Ltd. and W.J. Gazey Research. 2010. Peace River Fish Index Project - 2009 Studies. Prepared for BC Hydro. Report No. 09011F: 80 pp. + appendices.						X																				
2010	Peace River Fish Index Project – 2010	Mainstream Aquatics Ltd. and W.J. Gazey Research. 2011. Peace River Fish Index Project - 2010 Studies. Prepared for BC Hydro. Report No. 010011F: 96 pp. + appendices.						X																				

Appendix A2 Information source data type and location.

			Reservoirs			Upper Peace			Upper Tribs			Lower Peace			Lower Tribs			Alberta Peace			Alberta Tribs						
Year Work Done	**Title Cita**	**tion**	**Habitat**	**Small-fish**	**Large-fish**	**Habitat**	**Small-fish**	**Large-fish**	**Habitat**	**Small-fish**	**Large-fish**	**Habitat**	**Small-fish**	**Large-fish**	**Habitat**	**Small-fish**	**Large-fish**	**Habitat**	**Small-fish**	**Large-fish**	**Habitat**	**Small-fish**	**Large-fish**	**Movement**	**Signature Elemental**	**Genetics**	**Riparian**
2011	Peace River Fish Index Project – 2011	Mainstream Aquatics Ltd. and W.J. Gazey Research. 2012. Peace River Fish Index Project - 2011 Studies. Prepared for BC Hydro. Report No. 11011F: 86 pp. + appendices.						X																				
2008	Peace River Fisheries & Aquatic Resources Literature Summary	Amec Earth & Environmental 2008. Peace River Fisheries and Aquatic Resources Literature Summary. Prepared for BC Hydro. 72 p.																										
2008	Peace River Fisheries Investigation -- Peace River and Pine River Radio Telemetry Study 2009.	Amec Earth & Environmental and LGL Limited 2010a. Peace River Fisheries Investigation -- Peace River and Pine River Radio Telemetry Study 2009. Prepared for BC Hydro. 135 p. + appendices																										
2007	Peace River Fisheries Investigation - Peace River and Pine River Radio Telemetry Study 2007	Amec Earth & Environmental and LGL Limited 2008. Peace River Fisheries Investigation - Peace River and Pine River Radio Telemetry Study 2007. Prepared for BC Hydro. 148 p.																						X			
2006	Peace River Fisheries Investigation - Peace River Tributary Spring Spawning Migration, Tributary Summer Juvenile Rearing and Radio Telemetry Studies 2006	Amec Earth & Environmental and LGL Limited 2008. Peace River Fish and Aquatics Investigations - Peace River and Tributary Summer Fish Distribution, Habitat Assessment and Radio Telemetry Studies 2006. Prepared for BC Hydro. 181 p.							X	X	X													X			
2007	Peace River Fisheries Investigation- 2007	Amec Earth & Environmental and LGL Limited 2008. Peace River Fisheries Investigations - 2007. Prepared for BC Hydro. 148 p. + appendices																						X			
2009 - 2011	Peace River Hydraulic Habitat Study	Mainstream Aquatics Ltd., M. Miles and Associates Ltd, Integrated Mapping Technologies Inc., and Northwest Hydraulic Consultants. 2012. Peace River Hydraulic Habitat Study (Contract Q9-9105). Prepared for BC Hydro. Report No. 09005D: 65 pp. + Plates and Appendices.				X						X															
2010	Peace River Riparian Habitat Assessment Year 1 Data Report	MacInnis, A.M., K. Bachmann, and R. Gill. 2011. GMSWORKS-7: Peace River Riparian Habitat Assessment Year 1 Data Report. Unpublished report by Cooper Beauchesne and Associates Ltd., Errington, BC, for BC Hydro Generation, Water Licence Requirements, Hudson's Hope, BC. 19 pp. + Appendices.																									X

Appendix A2 Information source data type and location.

			Reservoirs			Upper Peace			Upper Tribs			Lower Peace			Lower Tribs			Alberta Peace			Alberta Tribs						
Year Work Done	Title Cita	tion	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Movement	Signature Elemental	Genetics	Riparian
2010	Peace River Side Channel Restoration	NHC. Mainstream Aquatics and M. Miles and Associates. 2010. *Peace River Side Channel Restoration.* Prepared for BC Hydro. May 10, 2010.				X																					
1989	Peace River Site C Development: Fisheries Habitat and Tributary Surveys- 1989	Aquatic Resources Ltd. 1991. Peace River Site C Development: Fisheries Habitat and Tributary Surveys- 1989. Prepared for BC Hydro. 106 p + appendices.							X	X	X																
1990	Peace River Site C Development: Fisheries Habitat and Tributary Surveys- 1990	Aquatic Resources Ltd. 1991. Peace River Site C Development: Fisheries Habitat and Tributary Surveys- 1990. Prepared for BC Hydro. 81 p + appendices.							X	X	X																
1989	Peace River Site C Hydro Development Pre-construction Fisheries Studies. Fish movements and population status. 1989 studies	Pattenden, R., C. McLeod, G. Ash, and K. English. 1990. Peace River Site C Hydro Development Pre-construction Fisheries Studies. Fish movements and population status. 1989 studies. Report prepared for BC Hydro by R.L. & L. Environmental Services Ltd., Edmonton, Alberta, in association with K. English of LGL Ltd., Sidney, B.C. 97 p. + Appendices.						X			X			X										X			
1990	Peace River Site C Hydro Development Pre-construction Fisheries Studies. Fish movements and population status. 1990 studies.	Pattenden, R., C. McLeod, G. Ash, and K. English. 1991. Peace River Site C Hydro Development Pre-construction Fisheries Studies. Fish movements and population status. 1990 studies. Report prepared for BC Hydro by R.L. & L. Environmental Services Ltd., Edmonton, Alberta, in association with K. English of LGL Ltd., Sidney, B.C. 121 p. + Appendices.						X						X										X			
1991	Peace River Site C Hydro Development, Pre-construction fisheries studies. Data Summary Report 1991	Pattenden, R. 1992. Peace River Site C Hydro Development, Pre-construction fisheries studies. Data Summary Report 1991. Report prepared for BC Hydro by R.L. & L. Environmental Services Ltd. 23 p. + 1 Appendix.																						X			

Appendix A2 Information source data type and location.

			Reservoirs			Upper Peace			Upper Tribs			Lower Peace			Lower Tribs			Alberta Peace			Alberta Tribs						
Year Work Done	Title	Citation	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Movement	Signature Elemental	Genetics	Riparian
2011	SITE C CLEAN ENERGY PROJECT FISHERIES STUDIES Microsatellite DNA analysis of bull trout (Salvelinus confluentus), Arctic grayling (Thymallus arcticus), and mountain whitefish (Prosopium williamsoni) in the Peace River and tributaries near the proposed BC Hydro Site C hydroelectric development in northeastern British Columbia: 2006-2011	E.B. Talor and M. Yau. 2012. SITE C CLEAN ENERGY PROJECT FISHERIES STUDIES Microsatellite DNA analysis of bull trout (Salvelinus confluentus), Arctic grayling (Thymallus arcticus), and mountain whitefish (Prosopium williamsoni) in the Peace River and tributaries near the proposed BC Hydro Site C hydroelectric development in northeastern British Columbia: 2006-2011. Prepared for BC Hydro. 51p + appendices.																									X	
2009	Site C Fisheries Studies – 2009 Halfway and Moberly Rivers summer fish survey	Mainstream Aquatics Ltd. 2010. Halfway River and Moberly River summer fish survey – 2009. Prepared for BC Hydro Engineering Services. Report No. 09008BF: 61 p. + plates and appendices.								X	X																
2009	Site C Fisheries Studies – 2009 Peace River Fish Inventory	Mainstream Aquatics Ltd. 2010. Site C fisheries studies – Peace River Fish Inventory. Prepared for BC Hydro Site C Project, Corporate Affairs Report No. 09008AF: 90 p. + plates (Volume 1) and appendices (Volume 2).					X	X					X	X					X	X							
2010	Site C Fisheries Studies – 2010 Coldwater Species Fish Survey	Mainstream Aquatics Ltd. 2011. Site C Fisheries Studies – 2010 Coldwater Species Fish Survey. Prepared for BC Hydro, Site C, Corporate Affairs. Report No. 10015F: 34 p. + appendices.							X	X	X																
2010	Site C Fisheries Studies – 2010 Elemental Signature Pilot Study	Adrian Clarke, Nicole LaForge, and Kevin Telmer. 2010. Site C Fisheries Studies – 2010 Elemental Signature Pilot Study. Prepared for BC Hydro Site C Project, Corporate Affairs Report No. 10007F: 39 p.																								X		
2010	Site C Fisheries Studies – 2010 Moberly and Halfway Rivers Fish Inventory	Mainstream Aquatics Ltd. 2011. Site C Fisheries Studies – 2010 Moberly River and Halfway River Summer Fish Inventory. Report No. 10006F: 59 p. + plates and appendices								X	X																
2010	Site C Fisheries Studies – 2010 Peace River Fish Inventory	Mainstream Aquatics Ltd. 2011. Site C fisheries studies - 2010 Peace River Fish Inventory. Prepared for BC Hydro Site C Project, Corporate Affairs Report No. 10005F: 102 p. + plates and appendices					X	X					X	X					X	X							

Appendix A2 Information source data type and location.

			Reservoirs			Upper Peace			Upper Tribs			Lower Peace			Lower Tribs			Alberta Peace			Alberta Tribs						
Year Work Done	Title Cita	tion	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Movement	Elemental Signature	Genetics	Riparian
2010	Site C Fisheries Studies – 2010 Pilot Rotary Screw Trap Study	Mainstream Aquatics Ltd. 2010. Site C Fisheries Studies – 2010 Pilot Rotary Screw Trap Study. Report No. 10004F: 63 p. + Appendices.					X			X																	
2011	Site C Fisheries Studies – 2011 Elemental Signatures Study	Earth Tone Environmental R&D and Mainstream Aquatics Ltd. 2012. Site C Fisheries Studies 2011 Elemental Signature Study - Draft Interim Report. Prepared for BC Hydro Site C Project, Corporate Affairs Report No. 11007D: 104 p.																								X		
2011	Site C Fisheries Studies – 2011 Moberly and Halfway Rivers Fish Inventory	Mainstream Aquatics Ltd. 2012. Site C Fisheries Studies – 2011 Moberly River and Halfway River Summer Fish Inventory. Report No. 11006D: 51 p. + appendices.								X	X																	
2011	Site C Fisheries Studies – 2011 Peace River Fish Inventory	Mainstream Aquatics Ltd. 2012. Site C fisheries studies – 2011 Peace River Fish Inventory. Prepared for BC Hydro Site C Project, Corporate Affairs Report No. 11005D: 98 p. + plates and appendices.					X	X					X	X														
2011	Site C Fisheries Studies – 2011 Rotary Screw Trap Study	Mainstream Aquatics Ltd. 2011. Site C Fisheries Studies – 2011 Rotary Screw Trap Study (Draft. Report No. 11004F					X			X																		
2008	Site C fisheries studies – Baseline Peace River tributaries fish use assessments in spring and fall 2008	Mainstream Aquatics Ltd. 2009. Site C fisheries studies – Baseline Peace River tributaries fish use assessments in spring and fall 2008. Prepared for BC Hydro. Report No. 08008BF: 64 p. + Appendices								X	X																	
2009	Site C fisheries studies – Halfway and Moberly Rivers mountain whitefish migration and spawning study 2009	Mainstream Aquatics Ltd. 2010. Site C fisheries studies – Halfway River and Moberly River fall mountain whitefish migration and spawning study 2009. Prepared for BC Hydro. Report No. 09008CF: 31 p. + appendices.								X	X																	
2008	Site C fisheries studies – Juvenile fish use and habitat inventory of tributaries in summer 2008	Mainstream Aquatics Ltd. 2009. Site C fisheries studies – Juvenile fish use and habitat inventory of Peace River tributaries in summer 2008. Prepared for BC Hydro. Report No. 08008CF: 78 p. + Appendices.							X	X	X																	

Appendix A2 Information source data type and location.

			Reservoirs			Upper Peace			Upper Tribs			Lower Peace			Lower Tribs			Alberta Peace			Alberta Tribs						
Year Work Done	Title Cita	tion	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Habitat	Small-fish	Large-fish	Movement	Elemental Signature	Genetics	Riparian
2006	Small Fish Surveys – Halfway and Peace Rivers	Mainstream Aquatics Ltd. 2009. Small fish surveys in the Halfway River and Peace River – 2006. Prepared for BC Hydro Engineering Services. Report No. 06019F01: 41 p. + Appendices					X						X														
1992	Stream Surveys of the West (Upper) Moberly River Watershed (Summer, 1992)	H. Hohndorf, G. Hopcraft and T. Down. February 1993. Stream surveys of the west (Upper) Moberly River Watershed (Summer, 1992). Peace/Williston Fish and Wildlife Compensation Program, Report No. 67. 17pp plus appendices.				X	X	X																			
2002	The distribution and abundance of goldeye in the Peace River, B.C.	P&E Environmental Consultants Ltd. 2003. The distribution and abundance of goldeye in the Peace River, B.C. Report prepared for B.C. Ministry of Water, land & Air Protection. 13 pp + appendices.												X													
2000	The Limnology of Williston Reservoir	J. G. Stockner, A. R. Langston and G. A. Wilson. May 2001. The Limnology of Williston Reservoir. Peace/Williston Fish and Wildlife Compensation Program, Report No. 242. 51pp plus appendices.																									
2008	Upper Halfway River Watershed Bull Trout Spawning Survey 2008	Diversified Environmental Services and Mainstream Aquatics Ltd. 2009. Upper Halfway River Watershed Bull trout Spawning Survey 2008. Prepared for BC Hydro. Report No.08008: 14 p. + Appendices									X																
2010	Upper Halfway River Watershed Bull Trout Spawning Survey 2010	Diversified Environmental Services and Mainstream Aquatics Ltd. 2011. Upper Halfway River Watershed Bull trout Spawning Survey 2010. Prepared for BC Hydro. Report No.10016: 21 p. + Appendices									X																
2000	Williston Reservoir Fish Assessment: Results of Hydroacoustic, Trawl and Gill Net Surveys in August 2000	Sebastian, D.C., G.H. Scholten and P.E. Woodruff. 2003. Williston Reservoir fish assessment: Results of hydroacoustic, trawl and gill net surveys in August 2000. Peace/ Williston Fish and Wildlife Compensation Program Report No. 274. 34pp plus appendices.		X	X																						
2008	Williston Reservoir Fish Index-2008	D. Sebastian, G. Andrusak, G. Scholten and A. Langston. 2009. Williston Reservoir Fish Index-2008. Prepared for BC Hydro. 42 p + appendices		X	X																						