10 EFFECTS ASSESSMENT METHODOLOGY

The potential adverse effects of the Project have been assessed using the methodology set out in Section 8 of the EIS Guidelines (The Minister of the Environment of Canada and the Executive Director of the BCEAO 2012). The methodology is outlined in Figure 10.1 at the end of this section and described in detail in the sections below.

The scope of the Project in relation to which the potential environmental effects have been assessed in accordance with the method described below is the Project, as proposed by BC Hydro in the Project Description Report (BC Hydro 2011) except to the extent that the descriptions of the components are superseded by those set out in Volume 1 Section 4 Project Description. In order to predict certain potential changes to the environment and to assess certain effects resulting from the Project, detail beyond that set out in Section 4 was required. The circumstances where further detail was required is described at various points in Volume 2 Section 11 Environmental Background, Volume 2 Sections 12 to 15, Volume 3 Sections 16 to 27, and Volume 4 Sections 28 to 33.

10.1 Technical Studies and Planning

To conduct an effects assessment of the Project, planning and technical studies, including a review of background information, were undertaken, resulting in the preparation of technical reports. This work was completed as a preliminary step in the effects assessment process. With this information in hand, it was possible to identify and assess potential project effects on valued components (VCs).

The planning and technical studies fall within these general categories:

- Reports summarizing consultation with government agencies, Aboriginal groups, and the public
- Investigations that documented baseline conditions
- Traditional land use studies
- Predictive studies
- Project engineering, planning, and conceptual design to derive estimates used to complete the effects assessment, such as estimates of labour requirements
- A framework for environmental management to be implemented during construction and operation of the Project

10.2 Selection of Valued Components

Valued components (VCs) have been identified in accordance with the three-step process set out in Section 8.3 of the EIS Guidelines. The decision process for the selection of VCs is described below (Sections 10.2.1 to 10.2.3) and illustrated in Figure 10.2.

VCs are aspects of the Project's biophysical and human setting that are considered important by BC Hydro, Aboriginal groups, the public, the scientific community, and government agencies. For the purpose of formal effects assessment in British Columbia, VCs can be categorized under what are referred to as the five “pillars”: 1) environmental, 2) economic, 3) social, 4) heritage, and 5) health, which are referred to in BCEAA. The term “valued components” in the EIS incorporates and is consistent with the federal government’s terminology of “valued ecosystem components”.

The three steps are described below. The results of the three-step process are presented in Volume 2 Appendix A Project Interaction Matrix, Table 1.

10.2.1 Identification of Candidate Valued Components – Step 1

Step 1 in the process was to identify candidate VCs. In doing so, BC Hydro identified components that are valued:

- For environmental, economic, social, heritage, or human health reasons
- As land or resources currently used by Aboriginal persons for traditional purposes
- As land or resources reasonably anticipated to be used in the future by Aboriginal persons for traditional purposes

To help generate a list of candidate VCs, the following questions were considered:

- What are the interests and concerns raised by Aboriginal groups that may be affected by the Project?
- What are the interests and concerns raised by the public that may be affected by the Project?
- What are the interests and concerns raised by federal, provincial, and local governments that may be affected by the Project?
- What is the regulatory status, if any, of the candidate VC?
- What is the protected status, if any, of the candidate VC?
- How does the candidate VC contribute to the preservation of biodiversity?
- Is the candidate VC rare or does it have special federal or provincial status?
- Is the candidate VC sensitive to disturbance or pollution?
- What important ecological role does the candidate VC play?
- Are there transboundary issues to consider?
- Might human health be affected, and if so, how?

Candidate VCs were identified during development and final issuance of the EIS Guidelines. Identification of candidate VCs was also based on interests and concerns raised by the public, government agencies, and Aboriginal groups, and on input from the Agency and the BCEAO that was obtained during consultation with the public, government agencies, and Aboriginal groups during preparation of the EIS (see Volume 1 Section 9 Information Distribution and Consultation). The list of candidate VCs identified in step 1 is provided in Volume 2 Appendix A Project Interaction Matrix, Table 1.

10.2.2 Project Interaction Identification – Step 2

In step 2, the list of candidate VCs was screened to determine if there was a potential interaction with the Project. To determine whether there would be a potential interaction, the following steps were undertaken:

1. Project components and activities were identified
2. Project components and activities were mapped
3. Candidate VCs were located temporally and spatially
4. Potential interactions between the candidate VC and project components or activities were identified

After taking these factors into account, if a potential interaction was identified, the candidate VC was carried forward to step 3. In the absence of a potential interaction, a candidate VC was excluded from further evaluation.

In some cases, potential interactions between some candidate VCs and project components or activities have been aggregated. For example, the interaction between the Project and local government revenue is best understood by considering the interaction with the Project as a whole, rather than the interaction with separate project components or activities.

In the Project Interaction Matrix (Volume 2 Appendix A Project Interaction Matrix, Table 1), a potential interaction between the candidate VC and the Project is indicated by "✓". The absence of interaction between a candidate VC and the Project is indicated with a "0".

Candidate VCs with an interaction, indicated by "✓"were carried forward into step 3 of the VC selection process.

10.2.3 Selection of Valued Components – Step 3

Step 3 involved the determination of whether the effect of an interaction on each candidate VC carried through to this point in the selection process could be effectively assessed under a separate and related, but more appropriate, candidate VC. For all candidate VCs, the result of this determination is set out in the last column in Volume 2 Appendix A Project Interaction Matrix, Table 1.

A key consideration in determining whether a more appropriate candidate VC exists is whether, given the nature of the candidate VC, it falls within the same effects pathway as another candidate VC.

For example, air quality and human health, both of which are candidate VCs, could be affected due to the effects pathway from the combustion of project-related woody debris. The combustion may lead to an increase in airborne particulates, which may result in an adverse effect on human health. Therefore, human health, rather than air quality, was selected as the VC.

The candidate VCs that were not rejected in steps 1, 2, and 3 and that could not be assessed under another VC have been taken forward as VCs in the effects assessment. A list of VCs that were identified and carried forward is provided in Table 10.2 below.

Descriptive information and technical data collected, analyzed, and modelled for aspects of the environment that were identified as candidate VCs are presented in Volume 2 Section 11 Environmental Background. This technical data have been taken into account in the assessment of potential effects on the VCs.

10.3 Assessment Boundaries

10.3.1 Spatial Boundaries

The spatial boundaries delineate areas within which the potential effects of the Project on VCs have been assessed. Where the appropriate spatial boundary is an administrative or technical boundary, such as a management area, this is explained. The spatial boundaries are presented and described in the spatial boundary tables in the VC-specific effects assessment sections of this EIS. Each of these sections provides the scientific justification for the selection of relevant spatial boundaries.

Study boundaries have been defined taking into account as applicable the appropriate scale and spatial extent of potential changes, and as available, community and Aboriginal traditional knowledge, current land and resource use by Aboriginal groups, and ecological, technical, and social considerations.

The spatial boundaries have been defined based on applicable discipline guidance documents (BCMOE 2008, BCOGC 2009). Spatial boundary descriptors are listed in Table 10.1.

Table 10.1 Spatial Boundary Descriptors

Spatial Boundary	Details of Spatial Boundary
Technical study area	This is the physical extent of the data collection program, or the physical boundaries for the technical modelling program.
Project activity zone	This is the area within which the project components and activities will be located or will occur, but this does not include existing transportation infrastructure that will be used without modification to transport materials or personnel required for the Project[a]
Local Assessment Area	The Local Assessment Area, or LAA, is the area within which the potential adverse effects of the Project will be assessed.
Regional Assessment Area	The Regional Assessment Area, or RAA, is the area within which projects and activities, the residual effects of which may combine with residual effects of the Project, will be identified and taken into account in the cumulative effects assessment.

NOTES:

[a] Transportation infrastructure that will be used without modification to transport materials or personnel required for the Project is excluded from the Project activity zone because Project-related traffic will be within the design capacity of that infrastructure.

10.3.1.1 Local Assessment Areas

The Local Assessment Area (LAA) boundaries vary depending upon the VC. The LAA for each VC has been determined independently based on the nature or characteristics of each VC. For each VC, the LAA has been defined in consideration of the expected maximum geographic extent of the potential for the Project to cause an adverse effect on the VC. Consistent with the method employed to identify potential interactions, the LAA for each VC was identified by taking into account the following:

- The nature of the VC and its susceptibility to various influences (e.g., emissions, noise, total suspended solids, loss of habitat)
- The expected maximum range of the potential for the Project to interact with the VC (e.g., dispersion of emissions, amount and range of noise levels, clearing requirements, labour requirements)

Table 10.2 summarizes the LAA for each VC. Figures depicting the LAAs for each VC are provided in each effects assessment section (Sections 12 to 33).

Table 10.2 Local Assessment Areas

Valued Component	Local Assessment Area
Fish and Fish Habitat	The Peace River in the proposed reservoir area; tributaries entering the proposed reservoir; the Peace River downstream of the proposed Site C dam to Many Islands, Alberta; watercourses and waterbodies within the transmission line and roadway rights-of-way; watercourses and waterbodies within the Project activity zone (construction materials); riparian areas adjacent to identified watercourses and waterbodies.
Vegetation and Ecological Communities	The Project activity zone, buffered by an additional 1,000 m, including new roads, roads requiring sizable upgrades, quarries, the dam site, and the transmission line. For the proposed reservoir the Erosion Impact Line has a 1,000 m buffer. The LAA also extends downstream from the dam to the Alberta border, and includes a 1,000 m buffer on both the south and north banks of the Peace River
Wildlife Resource	Vegetation and Ecological Communities LAA, as described above.
Greenhouse Gases	A 30 m buffer zone around the maximum reservoir elevation to describe greenhouse gas emissions from land conversion, and the Project activity zone to characterize emissions associated with construction activities.
Local Government Revenue	City of Fort St. John, District of Taylor, District of Hudson's Hope, District of Chetwynd, City of Dawson Creek, and Peace River Regional District
Labour Market	Peace River Regional District, and Northern Rockies Regional Municipality
Regional Economic Development	Peace River Regional District, and Northern Rockies Regional Municipality
Current Use of Lands and Resources for Traditional Purposes	Fish and Fish Habitat LAA and Wildlife Resources LAA, as described above.

Valued Component	Local Assessment Area
Agriculture	Agricultural land and individual farm operators LAA – Project activity zone and the remainder of the farm operations that are within the Peace River valley and that overlap the Project activity zone Agricultural economy and food production and consumption LAA – Peace River Regional District and the Northern Rockies Regional Municipality, which comprise the Peace River Agricultural Region (Statistics Canada Agricultural Region 8[a])
Forestry	Project activity zone and area within 5-year Beach Line
Oil, Gas, and Energy	Project activity zone, area within 5-year Beach Line and Spectra Energy's Taylor water intake
Minerals and Aggregates	Project activity zone and area within 5-year Beach Line
Harvest of Fish and Wildlife Resources	Project activity zone, the area within reservoir impact lines, and the Peace River downstream to the Alberta border.
Outdoor Recreation and Tourism	Project activity zone, within the reservoir impact lines and downstream to Peace Island Park
Navigation	Navigation - Project activity zone, downstream to Peace Island Park, and the Shaftesbury and Tompkins Landing ice bridges Aviation – North Peace Regional Airport (Fort St John airport) and the associated obstacle limitation surfaces
Visual Resources	Site C reservoir, Site C dam site, and transmission corridor, plus an 8 km buffer as well as the sites for quarried and excavated materials and worker accommodation, plus a 1 km buffer
Population and Demographics	Peace River Regional District
Housing	Peace River Regional District
Community Infrastructure and Services	City of Fort St John, District of Taylor, District of Hudson's Hope, District of Chetwynd, City of Dawson Creek, and Peace River Regional District
Transportation	Road and rail networks within the Project activity zone and Highway 97 between Taylor and Hudson's, and the North Peace Regional airport
Heritage Resources	Project activity zone
Human Health	LAA corresponds to relevant technical study areas for air quality, noise, water quality, electric and magnetic fields, country foods, and mercury.

NOTES:

[a] Statistics Canada Census Division 55 in Agricultural Region 8 – Peace River encompasses the organized areas of Hudson's Hope, Chetwynd, Tumbler Ridge, Pouce Coupe, Dawson Creek, Fort St. John, Taylor, and the Electoral Areas D, C, B, and E in the Peace River Regional District.

10.3.2 Temporal Boundaries

Specific temporal boundaries have been set for the assessment of potential effects on each VC. The temporal boundaries span the following phases of the project: construction, operation, maintenance, and foreseeable modifications where appropriate.

Operation and maintenance are addressed under "Operations" in the EIS. There are no foreseeable modifications to the Project.

The temporal boundaries have been determined based on consideration of the following:

- Timing and duration of Project components and activities
- Natural cycles of activity of VCs (e.g., sensitive life cycle periods, such as breeding, nesting, rearing, and overwintering) and relevant human cycles (e.g., seasonal variations in economic or recreational activity), where these are relevant to the assessment of potential effects

The schedule for the Project is discussed in Volume 1 Section 4 Project Description. In summary, construction will occur over an eight-year period, and the Project is intended to be operated and maintained over the long term with no future decommissioning contemplated. As required by Section 3.3.11 of the EIS Guidelines, the following are described in this EIS:

- Off-site components of the Project to be retained and maintained as part of the ongoing maintenance of the Project
- Decommissioning of temporary construction facilities and any associated reclamation
- BC Hydro's commitment to address a plan for decommissioning and restoration in accordance with applicable regulations at that time, should a proposal be made in the future to decommission the Site C dam and generating station

10.4 Effects Assessment Methods

The potential effects of the Project on VCs have been assessed in accordance with the requirements of Section 8.5 of the EIS Guidelines.

10.4.1 Baseline Conditions

For each VC carried through the assessment, the baseline conditions are described in the EIS. For each VC:

- The relevant legal framework is described
- Methods used to collect the baseline data are explained
- Sources of baseline information are identified
-
- The extent to which Aboriginal traditional knowledge has been obtained and has been considered in the EIS is explained
- An overall baseline description is provided

10.4.2 Description of Potential Adverse Effects on Valued Components

Potential project interactions have been evaluated and ranked as follows, and are presented in Volume 2 Appendix A Project Interaction Matrix, Table 2:

- A rank of "0" was given where no interaction is predicted between a project component or activity and a VC

- A rank of "1" was given where an adverse effect may result from an interaction, but the effect is well understood and standard measures to avoid or minimize the potential effect are available and are well understood to be effective, resulting in no or negligible residual effects
- A rank of "2" was given where interactions may result in an adverse effect and the nature of the effect and/or the effectiveness of mitigation measures is uncertain

In some cases, in Table 2 described above, the potential interaction between an activity or component and a VC is marked "N/A". This indicates that the interaction was considered as an interaction with the Project component or with the Project as a whole, and was not evaluated at the activity level.

VCs subject to an interaction ranking of "2" were carried forward in the effects assessment process. Potential interactions rated "0" or "1" were not further assessed because there is no interaction or the interaction can be avoided or minimized by implementing mitigation, these industry standard mitigation measures are understood to be effective, and any residual effects are negligible. Rationale for a ranking of "0", and mitigation measures taken into account in determining a rating of "1", are summarized in the EIS and in the interaction matrix provided in Volume 2 Appendix A Project Interaction Matrix, Table 2.

In some cases, potential interactions between some VCs and project activities were aggregated. For example, interactions between the visual resources VC and separate dam and generating station construction activities (e.g., installation of temporary facilities, relocation of surplus material) were indistinguishable. Accordingly, it was more appropriate to consider the potential interaction between visual resources and the dam and generating station in aggregate. Similarly, in some cases, potential interactions with some VCs are more appropriately considered in relation to the Project in its entirety. For example, the interaction with the local government revenue VC is better understood by considering the interaction with the Project as a whole, rather than the interaction with separate project components or activities.

In this EIS, for each VC carried through the effects assessment, the potential adverse project effects are identified, described, and analyzed. The analyses conducted are described separately for each VC in Volume 2 Sections 12 to 15, Volume 3 Sections 16 to 27, and Volume 4 Sections 28 to 33, of this EIS.

10.4.2.1 Identification of Mitigation Measures

In this EIS, the terms "mitigation" and "mitigation measures" both have the meaning defined for "mitigation measures" in Section 2(1) of CEAA 2012:

> *"mitigation measures" means measures for the elimination, reduction or control of the adverse environmental effects of a designated project, and includes restitution for any damage to the environment caused by those effects through replacement, restoration, compensation or any other means.*

Technically and economically feasible mitigation measures, including compensation measures that BC Hydro is proposing to use to mitigate adverse effects of the Project are described separately for each VC in Volume 2 Sections 12 to 15, Volume 3 Sections 16 to 27 and Volume 4 Sections 28 to 33, of this EIS. The measures proposed by BC Hydro include measures that have been integrated into project planning and design, such as site and route selection, scheduling, and construction practices, as well as technological features that serve to avoid or minimize potential adverse effects.

10.4.2.2 Characterizing Residual Effects

Residual adverse effects are the effects of the Project that may remain after taking into account the implementation of mitigation measures, including compensation.

Potential residual adverse effects that may result from the Project are characterized objectively as required by Section 8.5.2.3 and Table 8.3 of the EIS Guidelines. In Volume 5 Section 38 Summary of the Potential Residual Effects of the Project, as summary of the residual effects in relation to the following, as required by Section 23 of the EIS Guidelines, is provided

- Changes to the environment
- Changes to components of the environment within federal jurisdiction
- Changes to the environment that would occur on federal or transboundary lands
- Changes to the environment that are directly linked or necessarily incidental to federal decisions
- Effects of changes to the environment on Aboriginal peoples
- Effects of changes to the environment that are directly linked or necessarily incidental to federal decisions

The criteria set out in the EIS Guidelines are shown in Table 10.3, below.

Where possible, these criteria are described quantitatively. When residual effects cannot be characterized quantitatively, they are characterized qualitatively. Definitions are provided when qualitative terms are used.

The manner in which the characterization criteria provided in Table 10.3 are applied is described separately for each VC in Volume 2 Sections 12 to 15, Volume 3 Sections 16 to 27, and Volume 4 Sections 28 to 33, of this EIS.

Table 10.3 Residual Effects Characterization

Criteria	Description
Direction	This refers to the ultimate long-term trend of the environmental, social, economic, heritage, or health effect (e.g., increase, decrease, or neutral).
Magnitude	This refers to the amount of change in a key indicator or variable relative to baseline case (e.g., low, moderate, high); consideration is given to factors such as the uniqueness of the effect, and the comparison to natural or background variation.
Geographic extent	This refers to the geographic area in which an environmental, social, economic, heritage, or health effect occurs (e.g., site-specific, local, regional, provincial, national, international).
Duration	The period of time required until the valued component returns to its baseline condition, or until the effect can no longer be measured or otherwise perceived (e.g., short term, medium term, long term, permanent).

Criteria	Description
Frequency	The number of times during a project or a specific project phase that an environmental, economic, social, heritage, or health effect may occur (e.g., once, daily, weekly, monthly, continuous).
Reversibility	This refers to the degree to which existing baseline conditions can be re-established after the factors causing the effect are removed. Effects can be reversible or irreversible.
Context	This refers to the extent to which the area within which an effect may occur has already been adversely affected by human activities and/or is ecologically fragile and has little resilience and resistance to imposed stresses.
Probability	The likelihood that an adverse effect will occur (e.g., low, high, or unknown).
Level of confidence	This is an evaluation of the scientific certainty one has in the review of project-specific data, relevant literature, and professional opinion; the EIS will include a statement on the level of confidence in the assessment of direction, magnitude, extent, duration, frequency, and reversibility.

10.4.2.3 Significance of Residual Effects

The significance determination for residual adverse effects, and its rationale, has been evaluated by taking into account the objective characterization of each criteria described above and other factors including relevant guidance published by the Agency and the BCEAO (FEARO 1994, Agency 1999, Hegmann et al. 1999, and BCEAO 2010).

The manner in which the significance of potential residual adverse effects have been assessed is described separately for each VC in Volume 2 Sections 12 to 15, Volume 3 Sections 16 to 27, and Volume 4 Sections 28 to 33, of this EIS. A summary of potential residual adverse effects is provided in table format in each section.

In addition, Volume 5 Section 38 Summary of the Potential Residual Effects of the Project summarizes the significant adverse environmental effects identified in relation to:

- Changes to the environment
- Changes to components of the environment within federal jurisdiction
- Changes to the environment that would occur on federal or transboundary lands
- Changes to the environment that are directly linked or necessarily incidental to federal decisions
- Effects of changes to the environment on Aboriginal peoples
- Effects of changes to the environment that are directly linked or necessarily incidental to federal decisions

10.4.2.4 Follow-up Programs

BC Hydro has, in accordance with Section 23.5 of the EIS Guidelines, proposed certain follow-up programs to verify the accuracy of the assessment or the effectiveness of mitigation measures. Follow-up programs are described separately, and as required, for each VC in Volume 2 Sections 12 to 15, Volume 3 Sections 16 to 27, and Volume 4 Sections 28 to 33, and summarized in Volume 5 Section 39, of this EIS.

Follow-up programs have been developed where the likelihood, nature or extent of a predicted adverse residual effect on a VC or the effectiveness of a recommended mitigation measure is uncertain. Technically feasible, cost-effective and environmentally sound measures (e.g., alternative mitigation method, adaptive management) are proposed.

10.5 Cumulative Effects Assessment

An assessment of the cumulative effects that are likely to result from the Project in combination with other projects or activities that have been or will be carried out has been conducted in accordance with Section 8.5.3 of the EIS Guidelines and is provided in this EIS. As required by Section 8.5.3, assessment of the potential cumulative effects of the Project on a VC has been conducted if a potential residual adverse effect of the Project on that VC has a spatial and temporal overlap with a residual effect of another project or activity.

10.5.1 Spatial and Temporal Boundaries

10.5.1.1 Spatial Boundaries: Regional Assessment Areas

To conduct a cumulative effects assessment, a Regional Assessment Area (RAA) has been identified for each VC. The RAA boundaries for each VC are set out in Table 10.4 and illustrated in a figure in each VC-specific effects assessment section (Sections 12 to 33). Each of the VC effects assessment sections provides the rationale for the selection of spatial boundaries.

Table 10.4 Regional Assessment Areas

Valued Component	Regional Assessment Area
Fish and Fish Habitat	Peace River from Peace Canyon Dam, B.C. to Vermilion Chutes, Alberta, which is a distance of approximately 865 km.
Vegetation and Ecological Communities	The proposed dam, reservoir, transmission line, Highway 29 realignment, temporary access roads, and quarries occur within five Wildlife Management Units - designated 7-31, 7-32, 7-33, 7-34, and 7-35, which includes most of the Peace Lowlands ecosection.
Wildlife Resource	Vegetation and Ecological Communities RAA, as described above.
Greenhouse Gases	National
Local Government Revenue	City of Fort St. John, District of Taylor, District of Hudson's Hope, District of Chetwynd, City of Dawson Creek, and Peace River Regional District
Labour Market	Peace River Regional District, Northern Rockies Regional Municipality, and Fraser-Fort George Regional District
Regional Economic Development	Peace River Regional District, Northern Rockies Regional Municipality, and Fraser-Fort George Regional District
Current Use of Lands and Resources for Traditional Purposes	Fish and Fish Habitat RAA and Wildlife Resources RAA, as described above.

Valued Component	Regional Assessment Area
Agriculture	Peace River Regional District and the Northern Rockies Regional District; Peace River Agricultural Region (Statistics Canada Agricultural Region 8[a]
Forestry	Dawson Creek Timber Supply Area, Fort St. John Timber Supply Area, Peace River supply block of Timber Forest Licence 48
Oil, Gas, and Energy	Project activity zone, area within 5-year Beach Line and Spectra Energy's Taylor water intake
Minerals and Aggregates	Fort St. John, District of Hudson's Hope, District of Taylor, Peace River Regional District, Area "C"
Harvest of Fish and Wildlife Resources	Peace River Regional District
Outdoor Recreation and Tourism	Peace River Regional District
Navigation	Navigation - Project activity zone, downstream to Peace Island Park, and the Shaftesbury and Tompkins Landing ice bridges Aviation – Area from the North Peace Regional Airport (Fort St John airport) to the crest of the potential Project construction site
Visual Resources	LAA and Visual Landscape Inventory viewpoints within or adjacent to Project activity zone
Population and Demographics	Peace River Regional District
Housing	Peace River Regional District
Community Infrastructure and Services	City of Fort St John, District of Taylor, District of Hudson's Hope, District of Chetwynd, City of Dawson Creek, and Peace River Regional District
Transportation	Peace River Regional District
Heritage Resources	Project activity zone
Human Health	Consistent with LAA. RAA corresponds to relevant technical study areas for air quality, noise, water quality, electric and magnetic fields, country foods, and mercury.

NOTES:

[a] Area C is a regional district electoral area in the Peace River Regional District. The electoral area covers the area of Fort St. John.

10.5.1.2 Temporal Boundaries: The Cases

To assess the cumulative effects that may result from the Project in combination with other future foreseeable projects or activities that have been or will be carried out, the following are presented in the EIS:

Baseline Case: The Baseline Case describes the current status of the VC. In doing so, it reflects the residual effects of projects and activities that have been and are being carried out.

Future Case without the Project: To identify the potential adverse effects of other projects and activities that will be carried out, the Future Case without the Project was developed to predict the status of the VC by taking into account the Baseline Case and projects and activities that are at least as foreseeable as the Project. This demonstrates the potential residual effects of projects and activities that have been and will be carried out.

September 5, 2012 was chosen to demarcate the Baseline Case from the future cases because 1) this was the date the EIS Guidelines were issued by the federal Minister of Environment and the Executive Director of the BCEAO, and 2) by this date, BC Hydro had already substantially developed the assessment of potential effects and cumulative effects of the Project.

Project Case: To demonstrate the cumulative effects that are likely to result from the Project, the Project Case demonstrates the predicted status of the VC, taking into account the residual effects of the Project combined with those due to other projects and activities as identified in the Future Case without the Project.

Effects from potentially overlapping projects or activities that are recently operational may not be fully reflected in baseline conditions. Those projects and activities have been evaluated in the VC cumulative effects sections to determine whether they should be included in Baseline Case or the Future Case without the Project and the Project Case.

10.5.2 Projects and activities included in the cumulative effects assessment

10.5.2.1 Sources of Information about Potential Projects and Activities

The following information sources were reviewed to identify other projects and activities located within the largest RAA to be taken into account in the Future Case without the Project and in the Project Case:

- Registered active projects listed on the BCEAO and Agency websites, including hydroelectric projects such as the Dunvegan Hydroelectric Project (Section 10.5.2.2 and 10.5.2.10)
- Registered oil and gas applications listed on the British Columbia Oil and Gas Commission or National Energy Board websites (Section 10.5.2.4)
- Registered water licence applications listed on the Ministry of Environment Water Stewardship Division website (Section 10.5.2.5)
- Projects or activities associated with existing or “accepted” applications for land tenure under the B.C. *Land Act* or the B.C. *Range Act* (e.g., range tenures, grazing licenses, wind, gravel) as provided by GeoBC (Section 10.5.2.6)
- Current harvest plans associated with tenured forest operations and timber sales (Section 10.5.2.7)
- Official Community Plans, and parks and recreation plans (Section 10.5.2.8)
- Large waste discharges into the Peace River from Peace Canyon Dam to Vermilion Chutes, Alberta (Section 10.5.2.9)

A list of these projects and activities is provided below. The locations of the other projects and activities are shown in Figure 10.3, Figure 10.4, Figure 10.5, and Figure 10.6.

10.5.2.2 Criteria for Identification of Specific Projects for Consideration in the Cumulative Effects Assessment

To determine whether specific projects or activities identified from the information sources were to be taken into account in the cumulative effects assessment, project-wide spatial and temporal criteria were developed (Table 10.5). Those criteria were used to develop a conservative list of candidate projects and activities found within the largest RAA. To assess the potential cumulative effects on particular VCs, this list of projects and activities was reviewed to identify specific projects and activities to be taken into account.

Table 10.5 Screening Criteria Used to Identify Other Projects and Activities for Consideration in the Cumulative Effects Assessment

Type of Overlap	Excluded	Included
Spatial	– Project or activity is outside the largest RAA. By using a conservatively large RAA, all potential cumulative effects for VCs were captured. – Project or activity is located in Alberta beyond 100 m of the Peace River high water mark or further downstream than Fort Vermilion (i.e., downstream of the RAA boundary of the Fish and Fish Habitat VC).	– Project or activity is within the largest RAA. – Project or activity is located in Alberta within 100 m of Peace River high water mark and as far downstream as Fort Vermilion.
Temporal	– Project was in operation or activity was occurring prior to September 5, 2012; therefore, associated residual effects may be reflected in baseline case conditions.[a] – Project or activity is not reasonably foreseeable (i.e., not as likely to proceed as Site C Clean Energy Project).	– Active projects in federal or provincial environmental assessment or other regulatory process. – Approved projects and activities that are: o not constructed o under construction or o constructed, but not operational – Project or activity is reasonably foreseeable (i.e., at least as likely to proceed as the Site C Clean Energy Project).

NOTES:

[a] Effects from potentially overlapping projects or activities that are recently operational may or may not be fully reflected in baseline conditions. Those projects and activities have been evaluated in the VC cumulative effects sections to determine whether they should be included in Baseline Case or the Future Case without the Project and the Project Case.

The process of identification of projects and activities from the various sources is discussed in the sections that follow.

10.5.2.3 Active Projects on Registry Websites

Potential projects located in northeast B.C. and northwest Alberta were identified based on an initial search of federal and provincial online databases and registries, which was conducted up to and including September 5, 2012, the date of the issuance of the EIS Guidelines. The information gathered during this search was compiled and sorted by project name, approval agency, proponent name, location, regulatory status, Internet source, and brief project description.

Publicly accessible information was reviewed, and the spatial and temporal screening criteria identified in Table 10.5 were applied to each project. Spatially, all projects and activities located within the largest RAA, which had been identified as of September 5, 2012, that is, the RAAs for the Labour Market VC and Regional Economic Development VC, were selected. This area consists of the Peace River Regional District, the Northern Rockies Regional Municipality, and the Fraser-Fort George Regional District. In addition, because the RAA for Fish and Fish Habitat extends downstream along the Peace River to Fort Vermilion, Alberta, projects and activities that satisfied the spatial criteria shown in Table 10.5 with respect to that unique RAA were also selected. The area described above is the area considered in the cumulative effects assessment, where there are potential cumulative effects for some VCs.

Location co-ordinates for each project were input to a GIS database and plotted or manually digitized on a map with the boundary of the cumulative effects assessment area of interest. The temporal criteria shown in Table 10.5 were applied to identify those projects located within the cumulative effects assessment area of interest that are currently in or have recently completed an environmental assessment; therefore, they are at least as likely to proceed as the proposed Project. Projects and activities that met both the spatial and temporal criteria described in Table 10.5 were selected for consideration in the cumulative effects assessment.

10.5.2.4 Registered Oil and Gas Project and Applications

Information regarding registered oil and gas projects and activities in northeastern British Columbia was compiled based on a review of the following sources:

- BC Oil and Gas Commission database for pipelines, facility sites, and access roads, as well as individual proponent websites
- National Energy Board Regulatory Document Index

Relevant Alberta oil and gas projects were captured by the process described in Sections 10.5.2.2 and 10.5.2.10.

The methods used to extract information from each of these sources, including summaries and recommendations for further investigation, are described below.

British Columbia Oil and Gas Commission Database

BC Hydro extracted GIS data layers from the British Columbia Oil and Gas Commission website for applications for pipelines, facilities sites, and roads associated with oil and gas projects as well as activities proposed for Crown land within the largest RAA. Facilities include battery sites, cathodic or anode sites, compressor stations, dehydrator sites, flaresites, and meter sites.

The locations of pipelines, facilities, and roads included in the British Columbia Oil and Gas Commission data were plotted with respect to the area considered in the cumulative effects assessment.

National Energy Board Website and Regulatory Document Index

Project applications in the National Energy Board's Regulatory Document Index were searched for projects not already captured by the review of the Agency and BCEAO project registries. Some projects were included on both the Agency website and the National Energy Board's Regulatory Document Index. It was noted that relevant documents are included in the National Energy Board registry that may not be included in the Agency registry; therefore, these documents were provided for consideration in the cumulative effects assessment.

10.5.2.5 Registered British Columbia Water Licences and Applications

The British Columbia database of registered water licences and applications was reviewed to identify the nature and volume of current and proposed domestic and industrial water use or water withdrawals from the area considered in the cumulative effects assessment. This list of applications was sorted by applicant and watershed, plotted in a GIS layer (Figure 10.6), and vetted for inclusion or exclusion in the Future Case scenarios (Table 10.7). Water licence applications that fall within the Peace River watershed within the cumulative effects area of interest were considered in the cumulative effects assessment.

10.5.2.6 British Columbia Land Tenure Applications

A Geo BC (Geo BC 2012) land tenure dataset dated soon after the issuance of the EIS Guidelines (September 18, 2012) was searched for applications for tenure under the B.C. *Land Act* and the B.C. *Range Act* located within the area considered in the cumulative effects assessment. From this list, a sub-list was compiled consisting only of those tenure applications included in the "accepted" or "offered" category, meaning those that are active in the application process. Applications that were categorized as temporary, for investigative use, renewals of existing tenures, or expressions of interest in land were not considered further in the cumulative effects assessment because the use of the land or resource would be short term, low effect, reflected in baseline conditions, or is associated with projects that are less certain than the Project.

Land uses or tenure purposes that were already captured through the screening process outlined in Sections 10.5.2.2 and 10.5.2.4 were filtered from the list of land and range tenure applications. Low-effect to zero-effect land uses were filtered from the list of tenure applications (e.g., environmental protection, fish and wildlife management, greenbelt, land claim settlement). Applications that are related to the feasibility stage of projects were excluded because these were considered less certain than the Project.

For consideration in the cumulative effects assessment, a total of 699 land tenure applications were included, comprising 236,794.34 ha and 14 land use purposes as defined by the Province of British Columbia (Table 10.6). From Table 10.6, over 86% of the tenure application area consists of land earmarked for commercial recreation, while the smallest area contributions are from commercial, communication, and community land use purposes defined categories.

Table 10.6 Summary of Considered Land Tenure Applications, Land Use Purposes, and Area under Application

Land Use Purpose	Land Use Sub-purpose	Number of Applications	Total ha in Land Tenure Application	% of Total ha
Agriculture	Extensive, grazing	33	3,196.26	1.35%
Alpine skiing	General, lifts, miscellaneous	3	648.13	0.27%
Commercial	General, miscellaneous, commercial 'a', commercial wharf	8	25.00	0.01%
Commercial/ recreational	Cat skiing, fishing camps, guided nature viewing, heli-hiking, hunting camps, multiple use, private camps, trail riding	148	204,873.44	86.52%
Communication	Communication sites, combined sites	12	24.06	0.01%
Community	Trail maintenance, community facility, miscellaneous	8	13.05	0.01%
Energy production	Campsite, general, inlet site, land farms	49	106.66	0.05%
Industrial	General, heavy industrial, industrial camp, light industrial, log handling/storage, miscellaneous	201	11,241.56	4.75%
Institutional	Miscellaneous, waste disposal site	2	1.77	0.00%
Miscellaneous land uses	Other	2	274.23	0.12%
Quarrying	Pozzolan, clay, diatoms; sand and gravel; miscellaneous; rock for crushing	86	12,347.28	5.21%
Residential	Miscellaneous, private moorage, recreational residential, remote residential, rural residential, urban residential	23	375.80	0.16%
Transportation	Airport/airstrip, railway, roadway	15	2,742.33	1.16%
Utility	Electric power line, miscellaneous, telecommunication line, water line	109	924.79	0.39%
Total		**699**	**236,794.34**	**100.00%**

All established tenures overlapping the Project RAAs are included in the baseline conditions. Active tenures that are associated with non-operating project that may potentially operate in the future are captured through the evaluation process outlined in Section 10.5.2.2.

10.5.2.7 Current Harvest Plans Associated With British Columbia Tenured Forest Operations And Timber Sales

Timber harvest in northeast B.C. is conducted pursuant to various types of forest licences, including:

- Replaceable forest licences
- Non-replaceable forest licences
- Tree farm licences
- Pulpwood agreements
- Woodlot licences
- Community forests

A timber supply review is pending for the Peace Forest District, the results of which will not be available prior to the submission of the EIS. Timber harvest plans are developed by timber harvesting companies every five years and they are based on the province's timber supply review, and thus the volume of timber available in a given area. Because this information will not be available, the characterization of future timber harvest activities and potential interactions is based on publicly available tenure and licence information, which is summarized in Figure 10.6.

10.5.2.8 British Columbia Official Community Plans, and Parks and Recreation Plans

The cumulative effects assessment considered Official Community Plans for the following communities, rural areas, and districts located within the cumulative effects area of consideration (year of plan shown in brackets):

- District of Chetywnd (2010)
- City of Dawson Creek (2009)
- City of Fort St. John (2011)
- District of Hudson's Hope (2011)
- District of Mackenzie (1996 - 2010)
- Northern Rockies Regional Municipality (2011)
- South Peace Fringe Area, Peace River Regional District (2009 - 2012)
- Dawson Creek Rural Area (1986)
- Rural Area, PRRD (2011)
- North Peace Fringe Area (2009)
- West Peace (1997)

- Village of Pouce Coup (2010)
- District of Taylor (1995)
- District of Tumbler Ridge (2005)

In assessing potential cumulative effects, the Official Community Plans for communities located in the particular RAA for each VC were considered.

An online search was also conducted to identify proposed parks and recreation plans in the RAAs. The proposed Peace Boudreau Park is considered in the cumulative effects assessment, as its long-standing status as a proposed protected area has long influenced local land use decisions. Consequently, the proposed park is considered as an existing activity for the purpose of assessing the potential cumulative effects of the Project.

No other new or proposed parks or park extensions or modifications were identified during the course of this review.

10.5.2.9 Large Waste Discharges into Peace River Watershed

Based on a database search of Geo BC (Geo BC 2012) conducted by BC Hydro, no new proposed large waste discharges were identified in the RAA of interest. The existing discharges identified are:

- Outfall from Peace River Regional District
- Outfall from Fort St. John
- Outfall from Spectra Gas Inc. in Taylor
- Outfall from town of Peace River, Alberta

As these are all existing discharges, they are considered in the Baseline Case.

10.5.2.10 Alberta Projects and Activities

As previously noted, the Fish and Fish Habitat RAA extends into Alberta because the residual effects of projects within this RAA may overlap spatially and temporally with potential residual adverse effects of the Project on Fish and Fish Habitat. Thus, Alberta environment and land tenures were searched for projects and activities located between the Peace Canyon Dam and Vermilion Chutes, Alberta, and those situated within 100 m of the Peace River high water mark. Projects and activities identified within this area of potential residual effect overlap were considered in the cumulative effects assessment.

The 2012 Major Project Inventory prepared by Alberta Enterprise and Advanced Education, Alberta's Oil Sands Projects and Upgraders prepared by Alberta Energy, the National Energy Board's website, the Agency's online public project registry, and individual proponent websites were all reviewed to assemble information regarding the scope, likelihood, timing, and environmental issues associated with existing and future foreseeable projects and activities within this RAA. Following the review of these sources, five projects were identified, two of which are existing and three of which have been included in the inclusion list for consideration in the assessment of potential cumulative effects of the Project on Fish and Fish Habitat.

10.5.3 Projects and Activities for Consideration in the Cumulative Effects Assessment

An overall list of projects and activities for consideration in the assessment of the potential cumulative effects of the Project on VCs (Table 10.7) was compiled based on a review of the seven types of projects and activities listed in Section 10.5.2. The list was used during preparation of the discipline-specific cumulative effects assessments. For each VC, only those other projects and activities whose residual effects are considered likely to interact cumulatively with the residual effects of the Project are included in the VC-specific cumulative effects assessment.

Table 10.7 List of other Projects and Activities for Consideration in the Cumulative Effects Assessments

Project Name	
Alliance Pipeline Sunrise Meter Station Relocation*	Moberly River Pipeline Replacement Project*
Babkirk Secure Landfill Project	Montney Gas Play
Project Name	
Cabin Gas Plant Project*	Mount George Wind Park
Carbon Creek Coal Mine	Mt. Milligan Gold-Copper Project (Town of Mackenzie Rail Loadout Facility Options)
Dawson Creek-Chetwynd Area Transmission	Murray River Coal Project
Dawson Creek Processing Plant*	Northern Gateway Pipeline Project
Dokie Wind Project Phases I* and II	Northern Rockies Secure Landfill*
Dunvegan Hydroelectric Project	Ojay Pipeline Project*
Farrell Creek 88-I South Gas Plant	Provident Beatton River Replacement *
Fort Nelson Processing Plant*	Pacific Trail Pipeline Project
Fortune Creek Gas	Quality Wind Project
Gething Coal Project	Quintette Coal Project
Giscome Quarry and Lime Project	Rocky Creek Energy Project
Groundbirch East Receipt Meter Station*	Roman Coal Mine
Groundbirch Mainline Project*	Septimus Pipeline Project*
Hackney Hills Wind Project	Thunder Mountain Wind Project
Heritage Secure Landfill Project	Transmission North 2011 Pipeline Project*
Hermann Mine Project	Transmission North 2012 Pipeline Project
Horizon Mine Coal Project	Tumbler Ridge Wind Energy Project
Horn River Basin Gas Play	Wartenbe Wind Energy Project
Komie North Extension Pipeline Project	Wildmare Wind Energy Project
McGregor/Herrick Hydroelectric Project	Wolverine Secure Landfill Project
Meikle Wind Energy Project	
*These projects have been in operation since 2010, 2011, or 2012, so residual effects on VCs may be reflected in baseline conditions. However, the determination of whether these projects were included in the baseline conditions or future case scenarios and the supporting rationale will vary for VCs, and is described in Sections 12 to 33.	

BC hydro FOR GENERATIONS

Administrative Plans	
City of Dawson Creek Official Community Plan (2009)	North Peace Fringe Area Bylaw No. 1870 (2009)
District of Chetwynd Official Community Plan Bylaw No. 919 (2010) and Amendments	Peace River Regional District, Dawson Creek Rural Area Official Community Plan Bylaw No. 477 (1986)
District of Hudson’s Hope Official Community Plan Amendment Bylaw No. 804 (2011)	Peace River Regional District, Rural Area Official Community Plan Bylaw No. 1940 (2011)
District of Mackenzie Official Community Plan and Amendments (1996 - 2010)	Peace River Regional District, West Peace Official Community Plan Bylaw No. 1986 (1997)
District of Taylor Official Community Plan Bylaw No. 509 (1995)	Peace River Boudreau Protected Area
District of Tumbler Ridge Official Community Plan Bylaw No. 498 (2005)	South Peace Fringe Area Official Community Plan (2009 - 2012)
Fort St. John Official Community Plan Bylaw No. 2076 (2011)	Village of Pouce Coupe Official Community Plan Bylaw No. 930 (2010)
Northern Rockies Regional Municipality, Fort Nelson, Official Community Plan	
Water Licences	
Crew Energy Oilfield Injection, Pine River, 25 km west of Septimus pipeline	Refer to Figure 10.6 Forestry and Water Use Tenure Applications Considered in the Cumulative Effects Assessment
Tenure Applications	
Refer to Figure 10.5 British Columbia Land Tenure Applications Considered in the Cumulative Effects Assessment	Refer to Figure 10.6 Forestry and Water Use Tenure Applications Considered in the Cumulative Effects Assessment
Timber Harvesting	
Refer to Figure 10.6 Forestry and Water Use Tenure Applications Considered in the Cumulative Effects Assessment	
Spatially Relevant Existing Waste Discharges	
Fort St. John’s treated sewage outfall	Spectra Gas Inc. refinery outfall in Taylor
Peace River Regional District’s outfall	Town of Peace River, Alberta treated sewage outfall

10.5.4 Identification and Description of Cumulative Effects

For each VC for which for which residual adverse effects are predicted, the potential cumulative effects of the Project on that VC have been assessed taking into account the following information:

- other project(s) or activity(ies) found with the RAA for each VC, the residual effects of which may interact cumulatively with the residual effects of the Project
- status of the other project(s) or activity(ies)

- the potential residual effects of the other project(s) or activity(ies)

In order to identify the other projects and activities for consideration in assessing the potential cumulative effects of the Project on a VC, each discipline-specific environmental assessment team has reviewed the overall list of other projects and activities, and has identified a subset of projects and activities found within the RAA and which may result in adverse residual effects which may overlap temporally and spatially with residual adverse effects of the Project. The potential cumulative effects of the Project on various VCs that have been predicted are described in the respective VC cumulative effects assessment sections.

10.5.5 Identification of Cumulative Effects Mitigation Measures

BC Hydro has recommended a number of possible regional approaches to mitigation. These mitigation measures may involve government departments and/or third parties in independent and/or collaborative initiatives. The potential adverse cumulative effects and possible regional approaches to mitigation are discussed in the respective sections of this EIS where the potential effects of the Project on those VCs are discussed.

10.5.6 Characterizing Residual Cumulative Effects

Residual cumulative effects have been characterized using the approach outlined for the Project-specific effects assessment described in Section 10.4.2.2 and the criteria provided in Table 10.3. The potential residual adverse cumulative effects are discussed in the respective VC cumulative effects assessment sections.

10.5.7 Significance of Residual Cumulative Effects

A determination of the significance of the potential residual adverse cumulative effects that may result from the Project, in combination with other projects and activities, and its rationale for the determination is provided in the respective VC cumulative effects assessment sections.

References

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Agency (Canadian Environmental Assessment Agency). 1999. *Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects* (Reference Guide for Responsible Authorities).

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11 ENVIRONMENTAL BACKGROUND

This section of the EIS provides a description of the environment in the vicinity of the Project. It begins with a summary of previous hydroelectric development on the Peace River. Baseline conditions on land, in the water and air are described and predicted changes in the following technical areas are presented:

- Geology, Terrain, and Soils
- Land Status, Tenure, and Project Requirements
- Surface Water Regime
- Water Quality
- Groundwater Regime
- Thermal and Ice Regime
- Fluvial Geomorphology and Sediment Transport Regime
- Methylmercury
- Microclimate
- Air Quality
- Noise and Vibration
- Electric and Magnetic Fields

The baseline information and predicted changes described in this section were used in the effects assessment on VCs, as relevant.

11.1 Previous Developments

The environmental conditions in the Peace River watershed have been influenced by a range of ongoing anthropogenic developments and environmental factors, both prior to and following the development of upstream hydroelectric facilities. Understanding environmental changes, in particular those associated with previous hydroelectric development, provides context for the environmental assessment of the Project. The following sections describe the existing hydroelectric facilities in the Peace River watershed, the environmental changes that are understood to be caused by these hydroelectric developments, and the key follow-up programs that have been initiated to manage those environmental changes due to hydroelectric development.

11.1.1 Existing Hydroelectric Generation Projects on the Peace River

BC Hydro owns and operates two hydroelectric generation facilities on the Peace River. The facilities play an important role in the BC Hydro system and together account for greater than 30% of the capacity of the electrical power generation facilities in B.C. The existing facilities are operated as part of a coordinated system to allow BC Hydro to respond to seasonal and hourly changes in electricity demand.

W.A.C. Bennett Dam was completed in 1968 and is located 168 km upstream of the Alberta border. The 183-m-high earthfill dam is located at a natural outlet of the northern portion of the Rocky Mountain trench, and impounds the Williston Reservoir. The reservoir provides capacity for the multi-year storage of seasonal runoff from tributary sources upstream of the W.A.C. Bennett Dam. The G.M. Shrum Generating Station, which is located at the W.A.C. Bennett Dam, has 10 generating units with a total installed capacity of 2,730 MW. The maximum total discharge capacity from the facility is approximately 11,200 m^3/s (1,968 m^3/s for power generation and 9,200 m^3/s for spillway).

The Peace Canyon Dam was constructed in 1976 approximately 23 km downstream of the W.A.C. Bennett Dam near the town of Hudson's Hope. The 61-m-high concrete dam impounds the Peace River to form Dinosaur Reservoir within the steep walls of the Peace Canyon, located in the eastern foothills of the Rocky Mountains. Dinosaur Reservoir is smaller than Williston Reservoir, with a width of approximately 1 km at its widest point, an operating range of approximately 3 m, and active storage of approximately 0.1% of the active storage of Williston Reservoir. Water discharged from the G.M. Shrum Generating Station or released from discharge facilities (spillways, low level outlets) at W.A.C. Bennett Dam flows directly into the Dinosaur Reservoir. The Peace Canyon Generating Station, which is integrated into the dam, has four generating units with a total installed capacity of 694 MW. Operations of the generating station are generally matched to be in balance with upstream operations such that the flow through both generating stations is approximately equal at any given time. Total maximum discharge capacity from Peace Canyon Dam is approximately 12,250 m^3/s (1,982 m^3/s for power generation, and 10,280 m^3/s for spillway releases).

11.1.2 Environmental Changes Resulting From Previous Developments

11.1.2.1 Physical Conditions

Upstream of Peace Canyon Dam

Dam construction resulted in conversion of a river valley environment upstream of Peace Canyon Dam to one composed of two separated water bodies. The construction of W.A.C. Bennett Dam resulted in the inundation of approximately 360 km of the Findlay, Parsnip, and Peace rivers, and lower portions of smaller tributaries flowing into them on the west side of the Rocky Mountains. The interconnected river valley system was transformed into a single water body with a surface area of approximately 1,773 km^2. Williston Reservoir is deep (maximum depth 166 m), with an average water surface elevation that is, on average, more than 40 m higher than river levels during pre-regulation conditions (Stockner et al. 2005). The reservoir volume and surface area extent vary on a seasonal basis. In general, reservoir levels are higher in the late summer and early fall following the capture of seasonal inflows, and lower in the early spring after water is withdrawn from storage to generate electricity through the winter. The licensed range of reservoir levels in the Williston Reservoir is 30 m; however, annual operations within this range typically vary by less than 18 m.

The construction of Peace Canyon Dam created the smaller Dinosaur Reservoir immediately downstream of the Williston Reservoir. The extent of inundation was limited by the distance between the two dams and the steepness of the canyon in which the reservoir is located. Dinosaur Reservoir levels are managed to fluctuate over a smaller range than those observed in Williston Reservoir (i.e., normal operating range of approximately 3 m).

The construction of reservoirs resulted in flooding of the valley bottom and upland areas, and increased the potential for the methylation of mercury. Inundation of the river valley bottom was more extensive in the case of the Williston Reservoir than Dinosaur Reservoir. Assessment of methylmercury concentrations in environmental receptors was first conducted in the Peace River system in 1980, following the development of existing hydroelectric facilities. Methylmercury levels in key environmental receptors (i.e., water, sediment, invertebrates, fish) were observed to be elevated above that expected in lakes in the region; and, in some species of fish, methylmercury levels exceeded some Health Canada guidelines for consumption. However, follow-up assessments have demonstrated that, as expected, the increase in methylmercury levels in environmental receptors following reservoir development was not permanent. Concentrations have declined and are expected to continue to decline to levels reflective of expected pre-regulation conditions (EVS Environment Consultants 1999). Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report provides more detailed information on the effects of previous hydroelectric developments on methylmercury in the Peace system.

As water is withdrawn from Williston Reservoir, the drawdown zone is progressively exposed around the shoreline of the reservoir. Depending on the pattern of reservoir operation, littoral zones can be exposed for periods of several weeks to several months each year. During drawdown, wind storms can pick up fine particles of silts and clays ("dust") from certain beaches in the northern end of the reservoir in the exposed drawdown zone. Reservoir water levels are typically at their lowest in April, and the majority of the drawdown zone where dust is generated is flooded again by June. The primary concern regarding dust generation is air quality and community health (BC Hydro 2003). As a result of the limited drawdown and topography of Dinosaur Reservoir, there has been no reported incidence of concerns about air quality resulting from dust generation.

Downstream of Peace Canyon Dam

Prior to development of the existing facilities, the seasonal flow pattern of the Peace was similar to that observed in other large northern rivers. Flows in the Peace River were dominated by snowmelt runoff and rainfall that produced high spring and summer flows; low flows were typical in late fall and winter. With the exception of the filling period of Williston Reservoir, long-term average flows have not been altered due to regulation; however, there have been changes on an annual basis, and more noticeable changes in the seasonal and daily pattern of flows. The nature and extent of the changes to the surface water regime due to regulation depend on: 1) time of year, and 2) distance downstream from the point of regulation (i.e., Peace Canyon Dam). Average monthly flows released from Peace Canyon Dam are between 18% (June) and 590% (February) of flows observed before regulation. In addition, generating station flow releases vary on a daily basis, generally higher flow releases during the day than at night. Changes in river flow and water levels resulting from flow regulation are most pronounced immediately downstream of Peace Canyon Dam, and attenuate with increasing distance downstream. Several unregulated tributaries (e.g., Halfway, Pine, Beatton, Kiskatinaw, Smoky, and Wabasca Rivers) join the Peace River downstream of the existing dams and dampen the changes resulting from flow regulation. However, during the fall and winter when natural tributary flows are low compared to the spring and summer, regulated releases from upstream facilities have a greater influence on downstream flows. Changes to the surface water regime of the Peace River resulting from the existing hydroelectric developments are described in greater detail in Section 11.4.2.3 below.

The Peace-Athabasca Delta (PAD) is designated a wetland of international importance under the Ramsar Convention, and it is the location of Wood Buffalo National Park, which is a UNESCO World Heritage site. Since the construction of the W.A.C. Bennett Dam, the question of whether flow regulation has caused changes to the PAD has been raised. On the basis of historical data, some authors (e.g., Peters and Buttle 2009; Beltaos et al. 2006) have concluded that there have been hydrologic changes in the PAD that are related to the operation of the existing facilities on the Peace River in British Columbia. Investigations by other authors indicate that other factors (e.g., climate change/variation, flow control weir installation, dredging, geomorphic succession of the delta) have affected the hydrology of the PAD (Timoney 2002; Wolfe et al. 2012). These other factors have acted concurrently with the hydroelectric facilities, and have confounded the assessment of hydrologic changes that have been observed on the PAD since construction of the W.A.C. Bennett Dam. The influence of flow regulation on the hydrology of the PAD has been examined for decades, yet there remains an ongoing debate amongst the scientific community about the overall contribution of hydroelectric development to observed hydrological changes in the PAD. Since flow regulation, the observed changes within the PAD lie within the range of natural variation in the system (Timoney 2006).

Limited pre-regulation information is available to precisely quantify the influence of previous hydroelectric development on the water temperature regime of the Peace

River. However, the influence of hydroelectric reservoirs on downstream water temperature can be described based on first principles. A flowing river responds more quickly to changes in atmospheric conditions than a reservoir does. This is due to the greater proportion of the total flow that is exposed (at the surface) to the meteorological conditions of the atmosphere, as well as the relatively small depths and high degree of mixing of the water in a river compared to a reservoir. Once a river reach is transformed into a reservoir with greater depths and lower velocities, water temperatures do not respond as rapidly to changes in meteorological conditions. Compared to a flowing river reach, it takes longer to warm the water in a reservoir in the spring/summer, and it takes longer to cool that water in the fall/early winter. Hence, water temperatures at the outlet of a reservoir would be expected to be cooler in the spring/summer, and warmer in the fall/winter compared to conditions prior to the creation of the reservoir. Also, the variability of water temperatures at the outlet of a reservoir would be smaller compared to a river reach, again due to the reduction in exposure to the atmospheric conditions and the larger mass of water to heat or cool. Observed temperatures of water released from the existing facilities range between approximately 0.5˚C and 14˚C.

Changes in the thermal regime resulting from construction of the existing facilities have affected the ice regime of the Peace River. The two primary changes to the ice regime are: 1) modification of the seasonal timing, duration, and location of the annual ice front progression up the river, and 2) alteration of the freeze-up and breakup conditions. Prior to hydroelectric development, ice front development progressed upstream of the location of existing hydroelectric facilities. However, after that, in all but extreme years, the ice front has not been observed in the reach of river immediately downstream of the Peace Canyon Dam (Keenhan et al. 1982). Further downstream, near the Town of Peace River in Alberta, ice cover still develops each year; however, the timing of freeze-up and ice front progression is delayed in comparison to that occurring prior to hydroelectric development. Flow regulation has not appeared to have affected timing or duration of the ice cover on the river downstream of the Town of Peace River; however, increased regulated river flows have altered the ice freeze-up levels both at the Town of Peace River and farther downstream to Peace Point, Alberta (Ashton 2003).

Prior to hydroelectric development, fluvial geomorphology and sediment transport regime in the Peace River were naturally dynamic due to the localized nature of sediment inputs from tributaries and valley-wall landslides, and due to a seasonal range in flows. The influence of hydroelectric development on fluvial geomorphology and sediment transport in the Peace River has been studied extensively (Church 1995; Church et al. 1997). The primary changes include:

- Suspended sediment generated in the Peace River watershed upstream of the two dams is trapped in the two reservoirs; this has a reduced suspended sediment load in the river downstream of the dams
- Moderation of flows in the Peace River downstream of the Peace Canyon Dam has resulted in reduced bed material mobility. This in turn has resulted in the accumulation of bedload from tributaries, which is expressed in the form of expanded alluvial fans at tributary confluences and increased bed elevation in the Peace River downstream from confluences.
- Vegetation encroachment onto gravel bars and side channels along the Peace River, and an overall reduction in active channel width of the Peace River

These changes are most pronounced in the proximal reaches downstream of the Peace Canyon Dam, and diminish in the downstream direction due to water and sediment inflows from tributaries. The largest accumulation of tributary bedload has occurred at the Halfway, Moberly, and Pine river confluences, which are the largest gravel-transporting tributaries closest to the Peace Canyon Dam. Immediately downstream from each confluence, tributary bedload inputs have accumulated in the Peace River channel, causing the bed elevation to rise over time. Vegetation encroachment and channel width reduction are most pronounced between the Peace Canyon Dam and the Smoky River confluence. Fluvial geomorphology and sediment transport regime in the Peace River have been, and will continue to be, in a state of adjustment to the regulated flow conditions for decades to come (Church 1995). For more detailed information on the effect of flow regulation on geomorphology and sediment transport on the Peace River refer to Volume 2 Section 11.8. Fluvial Geomorphology and Sediment Transport Regime.

As a result of the development of Williston and Dinosaur Reservoirs and the regulation of the flow of the Peace River, the seasonal and spatial variability of specific water quality characteristics has been dampened (Alberta/British Columbia Instream Flow Needs Sub-Committee 1991). The river now tends to have lower and more consistent concentration of dissolved components (Shaw et al. 1990). This is believed to be caused by 1) interception of dissolved constituents from tributaries flowing into the two reservoirs, and 2) reduced seasonal variability of river flow released from the two dams. Flow regulation does not appear to have affected the river's dilution capacity for the various industrial and municipal discharges currently entering the river (Shaw et al. 1990).

The operation of the existing hydroelectric power generation facilities in the Peace watershed has been observed to periodically alter dissolved gas concentrations in the Peace River. Elevated levels of total dissolved gases are directly associated with 1) operations of spillways, and 2) specific non-routine low flow operations of the generation stations (i.e., synchronous-condense cycles or air injection during turbine operations in 'rough' load zones; Millar and Wilby 1999). Tributary inflows below Peace Canyon Dam that flow into Peace River have been documented to reduce elevated gas concentration.

11.1.2.2 Biological Conditions

The construction and operation of the hydroelectric facilities have resulted in some changes to biological conditions in the Peace River relative to that which occurred prior to hydroelectric developments. Information on the current status of aquatic, vegetation, and wildlife resources is available for the geographic area affected by the existing facilities. However, there is limited information that describes biological conditions prior to the construction of the W.A.C. Bennett dam. Therefore, it is not possible to describe species composition, distribution, and productivity in biological resources that existed in the time prior to construction of W.A.C. Bennett dam from recorded observations. This makes it impossible to measure directly any change to those factors resulting from development of the hydroelectric facilities. Furthermore, other anthropogenic changes to the Peace River system have occurred that are unrelated to hydroelectric development (e.g., forestry, agriculture, oil and gas), resulting in biological changes and further confounding any effort to quantify any changes that may be attributable to the existing hydroelectric facilities. Furthermore, other anthropogenic changes to the Peace River system have occurred that are unrelated to hydroelectric development (e.g., forestry, agriculture, oil and gas), resulting in biological changes and confounding understanding of changes that may be attributable to the existing hydroelectric facilities. Below is a summary description of general changes to aquatic, vegetation, and wildlife resources.

Aquatic Resources

Upstream of Peace Canyon Dam

The impoundment of Williston and Dinosaur Reservoirs resulted in the transformation of flowing river sections of the Peace River, Findlay, and Parsnip rivers into two physically separated, adjacent lake-like water bodies. This conversion resulted in changes to the physical nature of the habitat conditions available for aquatic resources, and resulted in a change in the structure and productivity of aquatic communities. The major physical changes to aquatic habitats include:

- Increased habitat volume
- Reduction in diversity of the types of habitat available for fish and aquatic organisms
- Alteration of hydraulic conditions (e.g., depth, velocity) and seasonal patterns of water level
- Changes to thermal and ice regimes
- Changes to water quality

Changes in physical characteristics of habitats resulting from reservoir creation resulted in changes in the composition and productivity of aquatic communities. Replacement of flowing river habitats with the reservoirs resulted in a shift of the trophic structure of aquatic food webs from predominantly benthic to pelagic-based food webs. Similarly, replacement of riverine habitats with pelagic habitats and lower suitability littoral habitats (due to seasonal drawdown) supported a shift in the fish community to species that can exploit pelagic habitats for food resources and still meet life history requirements in unaffected portion of reservoir tributaries. In Williston Reservoir, the development of littoral trophic and fish communities is also currently limited by seasonal drawdowns.

W.A.C. Bennett and Peace Canyon dams affect survival and limit movement of fish populations that have successfully colonized the reservoirs. The dams initially interrupted established patterns of upstream and downstream movement of fish in mainstem habitats in the Peace River. Peace Canyon was believed to be a natural barrier to the upstream movement of fish; however, downstream movements would have been unimpeded to allow dispersal and genetic interchange among upstream and downstream populations of riverine species. Upstream movements are currently completely blocked, and the dams now interfere with dispersal of fish to downstream environments, which may have consequence for genetic diversity. Passage of reservoir fish through discharge structures of the dams still occurs but also causes injury or mortality to some fish and, in general, reduces the potential productivity of upstream fish populations.

Downstream of Peace Canyon Dam

The regulation of flow at Peace Canyon Dam has altered characteristics of aquatic habitats for fish and other aquatic organisms in the Peace River. Changes to fish habitat result mainly from changes to surface water flow regime and channel morphology. These include:

- Loss of side-channel habitat, due to river channel changes
- Reduced suitability of side channel habitats, due to reduced inundation frequency
- Reduced suitability of near-shore mainstem shallow water habitat, due to fluctuating water levels
- Increased risk of fish stranding and fish egg dewatering, due to increased daily and seasonal variation in flow levels
- Changes to the accessibility of tributaries, resulting from changes to tributary fan morphology and seasonal changes in river flow
- Reduced productivity of benthic communities, due to seasonal and daily flow fluctuations
- Periodic production of elevated levels of total dissolved gas effects

Physical changes resulting from the flow regulation and channel changes are most apparent immediately downstream of Peace Canyon Dam and diminish downstream, to where they are negligible at the Town of Peace River, AB (Hildebrand 1990). Information is available to describe the composition and relative productivity of benthic and fish communities downstream of the dams as well as certain physical changes that occurred as a result of hydroelectric development. However, there is no information about the structure and productivity of aquatic communities located in the Peace River as it existed prior to the construction of the W.A.C. Bennett Dam.

<u>Vegetation Communities</u>

Upstream of Peace Canyon Dam

Upstream of the W.A.C. Bennett Dam, the formation of the reservoir inundated river valley bottoms in portions of the Peace, Findlay and Parsnip rivers, as well as lower reaches of tributary confluences to these rivers. Flooding in the Williston Reservoir resulted in some loss of vegetation communities occupying river floodplains, and riparian features such as wetlands. To a lesser extent, upland areas within these valleys were also flooded up to the maximum reservoir elevation. Seasonal variation in storage of water and consequent variation in the reservoir surface area have created an extensive drawdown zone around the 1,770 km perimeter of Williston Reservoir. The composition and productivity of riparian communities colonizing this drawdown zone is now regulated by patterns of reservoir level variation. More limited valley bottom flooding occurred during the flooding of Peace Canyon to form Dinosaur Reservoir. Topography and physiography of the canyon, and the operational strategy of limited variation in surface water levels (3 m) limited the extent to which riparian vegetation communities were changed.

Downstream of Peace Canyon Dam

Downstream of the W.A.C. Bennett and Peace Canyon Dams, seasonal changes to the surface water regime have altered the structure of riparian vegetation communities (Church et al. 1997). Reduced annual flood flows and increased winter flows have modified the extent and seasonal timing of floodplain inundation. At upper elevations of the river floodplain, colonizing herb and shrub communities have encroached on exposed river bars due to reduced flood flows, and have progressed to early riparian forest stands. At lower floodplain elevations, successional processes have been delayed due to inundation during elevated spring and winter flows. Much farther downstream, where an annual ice cover forms, ice still plays a primary role in regulating vegetation succession by influence on water levels and through scour damage from ice jamming (Uunila 1997).

<u>Wildlife Resources</u>

Upstream of Peace Canyon Dam

The flooding of river valleys upstream of the existing hydroelectric developments transformed the terrestrial ecosystem. This transformation has resulted in loss of river valley bottom habitats used by wildlife, and displacement of wildlife to upland habitats or to adjacent unaffected river valleys. The types of changes that would have been expected due to formation of the reservoir include:

- Loss of productivity area for wildlife including semi-aquatic and riparian habitat
- Loss of wetlands
- Reduced functionality/productivity of remaining habitats located in drawdown zones surrounding the reservoir
- Loss of animals unable to escape flooding
- Fragmentation home ranges, territories, and migration corridors

Downstream of Peace Canyon Dam

Flow regulation has altered the quality and quantity of habitat conditions for wildlife resources downstream of Peace Canyon Dam. The primary change to wildlife habitat along the Peace River resulted from changes to the physical structure and vegetation communities inhabiting floodplain habitats (Blood 1979; Simpson 1991). The quality of riparian and semiaquatic habitats has been affected by 1) modification of the composition of vegetation communities in riparian habitats, and 2) alteration of the timing, extent, and frequency of floodplain inundation. Changes in the quality of riparian and semiaquatic habitats can reduce productivity of riparian or semiaquatic species groups by reduced food availability, reduced reproductive success, or reduced cover for avoiding predation, which affects local areas used for movement or migration. The quantity and distribution of riparian habitats has also been modified. Channel downsizing processes result in the modification of tributary fan areas and the abandonment of side channels and back channels, resulting in a reduction in the areal extent of river floodplain habitats. Also, changes to the river ice regime may have impeded movements of ungulates and other species groups between habitats during winter.

11.1.3 Follow-Up Programs

For all of its hydroelectric generation developments, BC Hydro undertakes a range of activities to avoid and manage the environmental effects of construction, operation, and maintenance of its facilities. The four primary activities that form the overarching strategic approach for environmental management include:

- Integration of environmental considerations into planning of maintenance and operations of hydroelectric facilities
- Development and implementation of site-specific follow-up programs to manage identified individual environmental issues arising from construction and operating of hydroelectric facilities
- Implementation of system-wide programs to develop broadly accepted and regulatory sanctioned operating regimes for each hydroelectric facility in the BC Hydro system
- Implementation of long-term programs of environmental restoration and enhancement activities to compensate where mitigation options are not available, are uncertain, or are not effective for managing environmental effects

For the existing hydroelectric facilities on the Peace River, operational management programs are undertaken to avoid and mitigate normal activities associated with the maintenance and operation of the dams, reservoir, and generating facilities. Environmental management involves the systematic integration of consideration into planning, and the application of accepted best management practices for avoidance and minimization of potential environmental effects of routine and non-routine activities. Four additional follow-up programs, which are ongoing today, have been implemented to address effects of the construction and operation of the existing hydroelectric facilities on Peace River. The primary objectives of these programs are 1) to address ongoing environmental effects of operations of the W.A.C. Bennett and Peace Canyon facilities, and 2) to address footprint effects associated with construction of the existing facilities. Brief summaries of these programs are presented below.

Alberta-British Columbia Joint Task Force on Peace River Ice

In 1975 the Alberta-British Columbia Joint Task Force on Peace River Ice was formed in to coordinate the management of effects of existing hydroelectric facilities on the Peace River ice regime in the provinces of British Columbia and Alberta. Since its inception, the Joint Task Force has conducted annual monitoring of ice front progression in the Peace River. This information has been used to inform decisions about management of flow regulation during ice front development and progression, and to develop operating procedures related to BC Hydro operations to reduce the ice jam flooding hazard at the Town of Peace River. For full details related to the mandate and mitigation efforts of the Joint Task Force, refer to Volume 2 Appendix G Downstream Ice Regime Technical Data Report.

Peace Fish and Wildlife Compensation Program

The Peace Fish and Wildlife Compensation Program was initiated in 1988 to compensate for environmental footprint effects associated with the development of the Peace River facilities. The program is a joint initiative of BC Hydro, the B.C. Ministry of

Environment and Fisheries, and Oceans Canada. The primary activities of the program are 1) planning, inventory, and research, and 2) habitat restoration and enhancement. The spatial scope of the program is limited to those areas affected upstream of Peace Canyon Dam. Additional information on the objectives, scope and programs undertaken by Peace Fish and Wildlife Compensation Program since 1988 can be found at http://www.bchydro.com/pwcp/.

Williston Reservoir Dust Management

The Williston Reservoir Dust Management Strategy was developed in 1996 in response to concerns expressed by members of the public about the potential for risk to human health from the generation of dust along the northern drawdown zone of Williston Reservoir. The strategy involved the implementation of a sequential program with the goal of controlling dust generation in Williston Reservoir. The key components of program included 1) monitoring and research to understand dust generation processes and human health effects, 2) investigate alternative means for dust control, and 3) working with the community in the development of a long-term control program and provision of employment opportunities. The implementation of the dust control program is has been ongoing since 1996, and is now managed under the auspices of the Peace Water Use Plan, which is described below. More detailed information on the Williston dust control program can be found at http://www.bchydro.com/about/sustainability/conservation/water_use_planning /northern_interior/peace_river.html.

Peace Water Use Plan

The Peace Water Use Planning process was initiated in 2001, completed May 2003, and approved by the Cabinet of the Province of British Columbia in 2007. In developing the plan, a consultative process was initiated by the Province of British Columbia, in cooperation with BC Hydro. A complete description of the consultation process, analysis of operating alternatives, and description of Information and Management Plans are found in the Consultative Committee Report: Peace Water Use Plan (BC Hydro 2003). For more detailed information on the Water Use Planning process, see http://www.env.gov.bc.ca/wsd/plan_protect_sustain/water_use_planning/index.html

To develop the Water Use Plan, information was assembled to evaluate the effects of current operating procedures over a range of non-power interests identified in the Peace River system (BC Hydro 2007). Operating constraints and procedures for the facilities were reviewed by a Consultative Committee that involved licensees, government agencies, First Nations, key stakeholders, industry representatives, and key environmental and recreation interest groups. The key interest categories identified during the process were: air quality and community health (dust); erosion and land stability; First Nations heritage and traditional use; industrial water use and effluent; power generation; public safety, flooding and ice management; recreation and tourism; transportation; water supply and quality; and fish and wildlife. Fifteen operating scenarios were developed to address power and non-power interests. In each case, detailed operational constraints on the hydroelectric facilities intended to meet certain objectives were specified. In addition, a full range of physical works alternatives to mitigate effects were developed for management of operational effects on key interests in lieu of operating changes (BC Hydro 2003).

During the process of evaluating the operating scenarios, gaps in technical understanding that interfered with the ability to make informed decisions about water use became apparent. Key uncertainties were with respect to 1) baseline status of environmental conditions, 2) effects of operations on key non-power objectives or interests, and 3) potential effectiveness of operational or alternative physical work based mitigation programs (BC Hydro 2003; BC Hydro 2007). In response to these uncertainties, the Water Use Plan adopted an adaptive approach. Where the benefits of specific alternative operations were believed to be more certain, they were recommended for immediate implementation. These were 1) downstream minimum flow release of 283 m^3/s from Peace Canyon Dam for environmental protection, 2) continuation of special operating procedures to manage downstream flow releases for ice formation and breakup; 3) implementation of a Williston Reservoir variable minimum elevation rule to allow more effective use of reservoir storage for power generation, and 4) implementation of protocol for managing environmental effects of spillway releases into the Peace River. Where benefits were less certain, the Water Use Plan directed BC Hydro to undertake coordinated Information and Management Plans to address uncertainties and to guide further decisions about implementation of mitigation options in the future. Information Plans are detailed plans to collect sufficient information needed to assist in future decisions about mitigation measure implementation. Management Plans included studies and trial application programs to guide development of full scale non-operational mitigation measures and monitoring programs to audit their effectiveness (BC Hydro 2007).

A review of the Peace Water Use Plan was proposed to be conducted after 10 years. The review will be undertaken to interpret the results of Information and Management Plans. The results of that review can in turn be taken into account in determining effectiveness of follow-up actions, and whether there is any need to reconsider operational constraints or apply other mitigation measures in lieu of operating changes.

11.1.4 Historic Grievances regarding Existing Facilities

Since the development of the existing hydroelectric facilities on the Peace River, some Aboriginal groups have asserted claims or raised concerns, through the commencement of litigation or otherwise, that the creation and operation of the dams and associated reservoirs has created impacts to their communities, and the exercise of their Aboriginal or treaty rights. BC Hydro has a group within its Aboriginal Relations and Negotiations department that is tasked with addressing, reviewing and resolving, if appropriate, these historic grievances.

To date, BC Hydro has resolved historic grievances associated with the existing facilities with three First Nations in B.C. and Alberta. These include the Athabasca Chipewyan First Nation, the Kwadacha First Nation and Tsay Keh Dene. BC Hydro's historic grievances group is currently addressing other outstanding claims and concerns from Aboriginal groups regarding the existing hydroelectric facilities.

Issues or concerns with respect to historic grievances raised during the consultation process on the Project are set out in Volume 1 Appendix H Aboriginal Information Distribution and Consultation Supporting Documentation. During the consultations carried out to date on the Project, as grievances respecting the existing hydroelectric facilities are identified by Aboriginal groups, the Site C team advises the Aboriginal group raising the grievance of the existence of BC Hydro's historical grievances group, and advises BC Hydro's historical grievance group of the Aboriginal group's grievance or concern so that it can engage directly with the Aboriginal group with respect to those concerns.

11.2 Geology, Terrain, and Soils

The geology, terrain stability, and geotechnical soil conditions within the Project activity zone are outlined in the subsections that follow. Both current conditions and potential changes as a result of the proposed project activities are described.

Details of the geology, terrain stability, and geotechnical analyses are presented in supplementary technical data reports that are contained in Volume 2 Appendix B Geology, Terrain Stability and Soil Reports. Volume 2 Appendix B, Part 1 Terrain Stability Mapping describes the results of terrain stability mapping within the Project activity zone, and the potential changes to terrain stability resulting from activities such as removal of vegetation and access road construction. Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines describes the bedrock and surficial geology within the proposed reservoir shoreline technical study area in greater detail. Predicted changes to erosion and slope stability as a result of the creation and operation of the proposed reservoir are described. Reservoir impact lines delineating zones of potential flood, erosion, landslide, and landslide-generated wave hazards are provided.

11.2.1 Physiography and Topography

The western boundary of the Project activity zone lies in the Rocky Mountain foothills, while the eastern boundary lies in the boreal plains. A shaded relief image is shown on Figure 11.2.1. The Peace River area to the east of the Rocky Mountains is characterized by forested and rolling uplands cut by deep river valleys, including the Peace River valley. The valleys and uplands are connected by benches that typically slope downward less than 2° to the east.

Within the Project activity zone, the Peace River valley is broad and flat-floored, occupying a trench approximately 3.5 km wide and 200 m deep. The river typically ranges from 0.5 to 1 km wide. Wide fluvial terraces are common between the floodplain and the broader valley walls, and are typically elevated less than 75 m above river level. At locations where the river is adjacent to such terraces, the slopes are referred to as low banks. Elsewhere, where the river is in direct contact with the deep valley walls, the slopes are referred to as high banks.

Downstream of Peace Canyon Dam, the Peace River flows to the northeast and then turns east, flowing past the city of Fort St. John. The average gradient of the river in the Project activity zone is 0.6 m/km or 0.03°. The major tributaries of Peace River within the Project activity zone are Halfway River and Moberly River, as well as Pine River, which joins Peace River about 20 km downstream of Site C.

The plains surrounding the Peace River valley are part of the Alberta Plateau. The Alberta Plateau and its subdivision, the Fort Nelson Lowland, comprise approximately 10% of the land area of British Columbia. The region is underlain by sedimentary rocks that are flat-lying and gently dipping.

The Alberta Plateau is the product of numerous cycles of broad subsidence, marine and freshwater sedimentation, and emergence and erosion cycles. The initial pattern of topography was developed during the Tertiary period by mass wasting and fluvial action. The repeated advance and wasting of glacial ice during the Pleistocene period further modified these landforms and are responsible for the majority of the unconsolidated deposits found in the area today.

11.2.2 Geology

11.2.2.1 Regional Bedrock Geology

Marine and non-marine sedimentation in northeastern British Columbia and northwestern Alberta lasted from Jurassic to Upper Cretaceous time (i.e., from approximately 200 million years ago to 70 million years ago). In the Project activity zone, the regional geology consists of flat to gently dipping sedimentary rocks of Cretaceous age. Rocks of the Lower and Upper Cretaceous Fort St. John Group are exposed along the Peace River valley and include the Moosebar, Gates, Hulcross, Boulder Creek, and Shaftesbury formations (Figure 11.2.2 and Figure 11.2.3). Upper Cretaceous rocks of the Dunvegan formation are also exposed on parts of the valley rim and in the plateau. Other rocks of importance in the Project activity zone are the limestone in the Rocky Mountains to the southwest and the Gething sandstone to the west, where potential rock quarries are located.

The Moosebar Formation is composed of marine shale and siltstone, and underlies the Gates Formation. The Gates Formation is a marine succession of near flat-lying sandstone, shale, and conglomerate. The Gates and Moosebar formations are typically found below elevation 500 m in the western part of the proposed Site C reservoir. The Hulcross Formation consists of marine shales overlying the Gates Formation, and is overlain by the Boulder Creek Formation, which comprises sandstone and conglomerate beds. The Hulcross and Boulder Creek formations are found along Peace River near Lynx Creek.

Rocks of the Shaftesbury Formation are dark grey, rusty, and fissile marine shale to mudstone with lesser sandstone. This formation dips gently northeast and appears gradationally conformable with the overlying Dunvegan Formation. The Shaftesbury formation is exposed in the river banks along Highway 29 and Peace River as far east as the Alberta border.

Rocks of the Dunvegan Formation are medium- to fine-textured, evenly bedded siltstone and carbonaceous shale with lesser interbedded ironstone, coal, coarse sandstone, and conglomerate. This formation is found primarily in the eastern part of the Project activity zone.

Past regional tectonic activity has had little effect on the rocks of the proposed reservoir area. The most easterly major thrust structures related to development of the Rocky Mountains occur immediately downstream of Peace Canyon between Hudson's Hope and Farrell Creek and consist of a series of broad northeast-trending folds and low angle thrusts.

Geologic structures near the proposed dam site, including shear zones and jointing, are described in Section 11.2.2.4.

11.2.2.2 Regional Glacial History

In the latter part of the Quaternary, the Project activity zone experienced at least three major advances of Laurentide and Cordilleran ice. The Laurentide (or Continental) ice sheets dominated the plains region during the Pleistocene. The greatest extent of Cordilleran ice occurred about 15,000 years ago, when it overrode the foothills and, extending eastward, probably abutted the Laurentide ice sheet occupying the plains region. Much of the plains region experienced cyclical glacial and interglacial deposition sequences: fluvial gravels during interglacial periods; glaciolacustrine sands, silts and clays resulting from aggradation and ponding of Peace River by advancing Laurentide ice; till deposition by the ice itself; and then sands, silts and clays deposited in a series of ice dammed lakes during the retreat stages of Laurentide glaciation.

As the eastern front of the Cordilleran ice retreated from the plains, back to the foothills and the Rocky Mountains, it was responsible for the deposition of tills, glacial fluvial sands and gravels, and glaciolacustrine sediments in numerous localities throughout the plains/foothills region.

Throughout the area, many glacial deposits were removed by the fluvial action of modern streams and rivers. With a few exceptions, the courses of streams and rivers fall within the boundaries of older river valleys that formed during interglacial periods.

The formation of the modern Peace River valley began 14,000 years before present (BP), with the retreat of the Laurentide ice sheet and the formation of glacial lakes behind it. By 10,500 BP, the glacial lakes had drained and Peace River had begun incising the modern valley. The formation of the modern Peace River valley is shown schematically on Figure 11.2.4 and Figure 11.2.5.

11.2.2.3 Regional Surficial Geology and Terrain Stability

Terrain stability mapping involves the subdivision of landscape into geomorphic units (i.e., terrain polygons), based on criteria established for a particular study. Terrain mapping, and the various standards that are involved in it, form a British Columbia-wide standard practice requested by regulators for proposed resource road construction and other development activity. Where activity is proposed within unstable or potentially unstable terrain polygons, additional field investigation is usually undertaken and, if required, measures to reduce the potential for landslides are prescribed.

Standard terrain mapping techniques were used to delineate areas with distinct surficial geology and terrain stability for the Project activity zone. The terrain mapping results are presented in drawings contained in Volume 2 Appendix B, Part 1 Terrain Stability Mapping.

Much of the proposed reservoir shoreline is flanked by steep valley walls underlain by fine-textured material composed of glaciolacustrine sands, silts and clays, silty colluvium, or shale bedrock. Most of these slopes have been mapped as unstable (Class V) or potentially unstable (Class IV). Large flood plains are common at river level and large glaciofluvial terraces are common above the riverside scarps. The terrace surface is mapped as stable (Class I), while the steep scarp slopes are usually mapped as Class III to V. Thick colluvial deposits are present on gentle to moderate slopes where they have been deposited by slumps or slides from higher elevations. These deposits are usually mapped as moderately stable (Class II or III).

The proposed transmission line and many of the proposed construction access roads cross a gentle plateau underlain by glaciolacustrine sands, silts and clays, or glacial till. Bogs are scattered throughout this area. Much of the plateau area is very gently sloping, and no landslides are present. These areas are mapped as stable (Class I). Steeper slopes are present where the transmission line or access roads cross streams. These slopes have been mapped as Class III to V based on their steepness and the presence of landslides.

Proposed quarry development sites at Portage Mountain and West Pine are located in rocky areas to the west and southwest of the proposed reservoir. In both areas, rock ridges are partially covered by till or colluvial material. Based largely on slope steepness and morphology, most polygons in these areas have been mapped as Class II to III. A few steeper slopes overlain by shallow colluvium have been assigned Class IV.

The results of the terrain stability mapping are intended to support planning for activities such as access road construction and reservoir clearing. In some locations, such as at the proposed dam site and reservoir, the results of the terrain stability mapping have been superseded by more detailed geotechnical investigation and analysis.

11.2.2.4 Dam Site Geology

The dam site is located in a section of the valley where the postglacial Peace River has cut down from the general level of the Alberta Plateau near Fort St. John, at about elevation 630 m, through the overburden filling the interglacial valley and into bedrock.

The north (left) bank of Peace River at the proposed dam site is about 180 m high, slopes at about 1.8H:1V and consists of glacial and interglacial deposits of clay, silt, sand, and gravel between about elevation 580 m and bedrock at about elevation 470 m. Colluvial deposits, derived from sliding and sloughing of overburden and shale slopes above, skirt the toe of the bank and in places extend for a considerable distance from the toe of the slope.

The present-day river flows in a wide channel mainly infilled with up to 10 m of medium dense to dense alluvial sands and gravels overlying bedrock. In some areas adjacent to the north bank, clayey colluvium occurs above bedrock and is interlayered with the granular materials. The overburden bedrock interface is smooth in some areas and irregular in others. The bedrock at the interface is slightly weathered, very weak rock to a depth of 1 to 3 m, below which it is fresh, weak to medium strong rock.

The south (right) bank of Peace River at the proposed dam site is composed of broad terraces at about elevation 415 m and elevation 470 m. Bedrock is near elevation 405 m beneath the lowest terrace and near elevation 455 m beneath the upper terrace. Alluvial silts, sands and gravels overlie bedrock in the terraces. Behind the second terrace, the slope rises to the plateau at about elevation 630 m, with bedrock generally at about elevation 455 m. A thick deposit of clay, silt, and sand overlies a layer of sand and gravel about 10 m thick on top of the bedrock.

A buried valley is located to the south and west of the dam site that passes from a point about 2 km upstream of the mouth of the Moberly River to the Pine River. The base of the buried valley is between elevation 440 m and elevation 460 m but is at about elevation 455 m near the dam site.

Rock exposed at the site is part of the Shaftesbury Formation and consists of weak to medium strong, flaky to fissile, silty shale interbedded with siltstone, sandstone, and shale. The “Fish Scale Marker Bed”, commonly used to define the boundary between the Upper and Lower Cretaceous in northwestern B.C., is found in the rock of the upper north abutment. Thus, most of the rock at the site is Lower Cretaceous in age. The rock is of marine origin and is in an intermediate stage of diagenesis. The stratigraphy is uniform throughout the site. Numerous marker beds, as little as a few millimetres in thickness, can be traced throughout the site. The bedding has a regional dip of about 1° northeast, although local variations of 1° to 2° from this regional dip are common. As a result, the beds on the south bank are about 10 m higher than equivalent beds on the north bank. The bedrock has been divided into a number of units based on lithology, as shown in Figure 11.2.6. For example, the lowest bedrock unit that has been designated is a silty shale designated Unit 1 and shown on Figure 11.2.6 as SSH 1.

The bedrock is cut by three sets of fractures (Figure 11.2.7), which are characteristic of valleys eroded in flat-lying, weak, sedimentary rocks, namely:

- Fractures or softened zones parallel to bedding
- Steep relaxation fractures parallel to valley slopes
- Low angle shear zones of limited displacement

These structural features are explained by general rebound effects of valley erosion in reducing the horizontal and vertical stresses. These stress changes have resulted in:

- Inward movements of the valley walls
- Sprung bedding planes
- Shear zones formed due to displacements along the weaker beds
- Local thrust faults in the abutments

Although many discontinuities along the bedding have been recognized, only seven bedding planes are considered in design. Four of these – Bedding Plane 8 (the white clay), Bedding Plane 12 (the Marl), Bedding Plane 18, and Bedding Plane 25 – are important because of their low frictional resistance and because they are considered to be continuous throughout the site, although they are located above the rock surface in the valley floor. The fifth, Bedding Plane 28, is important because it might be continuous beneath the earthfill dam. The remaining two, Bedding Plane 31 and Bedding Plane 33, are important because they will be present in the deeper excavations for the buttress on the south bank.

Bedding Planes 8, 12, and 18 are continuous, but will not influence the structures. They are, however, important to the stability of the upper north bank and to the stability of excavations on the south bank. Bedding Plane 8 is continuous on the north bank, but not continuous on the south bank. It comprises 0.5 to 10 mm of light grey clay and shale breccia. Bedding Plane 12 underlies the Marl marker bed, and is continuous within the north and south banks. It comprises 1 to 4 mm of grey clay. Bedding Plane 18 is continuous on the north and south banks. In some areas, it is a tight discontinuity with rock-to-rock contact, and in others, comprises up to 50 mm of broken shale.

Bedding Plane 25 underlies the area of the proposed concrete structures on the south bank and occurs about 10 m below river level on the north bank. It is notable because of its relatively low peak and residual shear strength and its continuity throughout the site. Where exposed in exploratory Adits 3 and 5, this bedding plane is a discrete but tight discontinuity, very planar and apparently continuous. Clay-size material is almost always found at Bedding Plane 25, formed either as gouge from shearing movements or from softening of the shale by groundwater circulation. Although this clay material is generally observed, there are locations where it is not present and rock-to-rock contact occurs.

Under the riverbed, sprung (rebound) bedding planes exist in the upper 6 to 8 m of rock. Because of the difficulties of drilling in the river, it has not been possible to confirm the absence or presence of continuous open bedding planes beneath the river. There is some evidence to suggest that Bedding Plane 28 is reasonably continuous about 2 m below bedrock surface in the river channel.

Bedding Plane 28 has been observed in five out of seven large diameter drill holes in the riverbed and in two large-diameter drill holes on the south bank of the Peace River. On the south bank, it is a tight to slightly separated bedding plane within a 20 to 50 mm thick fracture zone with 1 mm of clay gouge seen in one of the holes. Beneath the riverbed, this bedding plane is similar, except that the fracture zone is up to 100 mm thick and sometimes contains shale fragments and silty alluvial infill.

Bedding Planes 31 and 33 have not been shown to be continuous and have only been observed in a few large diameter drill holes in the riverbed and south bank. They are typically hairline discontinuities with little to no infill.

Steep relaxation fractures in the bedrock striking approximately parallel to the valley have been observed in exploratory trenches and in the exploratory adits. On the north bank, the steeply dipping fractures are open greater than 1 mm for a horizontal distance of about 20 m into the bedrock and, on the south bank, for a horizontal distance of about 35 m (Figure 11.2.7). These fractures are typically truncated by bedding surface discontinuities, particularly Bedding Plane 8, Bedding Plane 12, and Bedding Plane 25.

A zone of open relaxation fractures is also found within the top 8 m of rock in the riverbed. These fractures are along the bedding as well as across it.

Cross-cutting shears have been observed in most areas of the proposed dam site. These shears are characterized by distorted bedding and a few centimeters to a few metres of gouge and breccia. The major shears can consist of over 3 m of gouge and breccia with pods of intact rock and distorted bedding. Shearing on the north bank is not as intense as on the south bank. Offsets are less and shears do not appear to be as continuous as on the south bank. The orientations of the shears are such that they are not critical to the stability of the planned excavations on the south bank.

The shears are generally more permeable than the bedding plane fractures and are thought to be one of the main features controlling groundwater movement within the rock mass. In the adits or large-diameter drill holes, shears were often observed to be moist or dripping water.

Mapping of the large-diameter drill holes revealed that two sets of joints occur on the south bank; these are more commonly found above the Marl layer near elevation 435 m. On the south bank above elevation 430 m, more relaxation of the bedrock has occurred. Evidence for this is relatively closely spaced joints seen in large-diameter holes and seismic survey results. Similarly, on the north bank, joints are more closely spaced at higher elevations, especially above Bedding Plane 8, which is near elevation 432 m.

The permeability of the rock mass, based on extensive packer tests and response tests of piezometers, ranges from more than 10^{-6} m/s in the relaxed surface rock to less than

10^{-9} m/s in the relatively undisturbed bedrock (i.e., deeper than 30 m below the bedrock surface).

On the north bank, the piezometers (mainly standpipes) indicate that the elevation of the piezometric surface on individual bedding planes decreases with depth. The piezometric pressure seldom exceeds 10 m above any given bedding plane discontinuity. However, the piezometric pressures have not been found to be higher than the top surface of the bedrock.

On the south bank, the piezometric surfaces have a gradient toward the river of about 25H:1V. Since the horizontal permeability is probably several orders of magnitude greater than the vertical permeability, the water probably flows near horizontally. An exception is near the valley walls, where steeply dipping relaxation joints are present.

Piezometric levels existing in the rock immediately below the river are generally near river level. At depth in the rock, piezometric levels are lower than river level.

11.2.3 Reservoir Impact Lines

11.2.3.1 Background

The proposed Site C reservoir will result in changes to erosion and slope stability at some locations within the reservoir shoreline technical study area. The location and nature of these changes have been predicted through a detailed characterization of the reservoir shoreline geology, inventory and characterization of existing slopes and landslides, groundwater monitoring and modelling, shoreline erosion modelling, and slope stability analyses. Preliminary reservoir impact lines have been prepared to characterize the following hazards around the proposed reservoir:

- Potential floods – the Flood Impact Line
- Potential erosion – the Erosion Impact Line
- Potential landslides – the Stability Impact Line
- Potential landslide-generated waves – the Landslide Generated Wave Impact Line

11.2.3.2 Simplified Geological Mapping Units

The geology of the proposed reservoir shoreline is described in detail in Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines and was summarized in Section 11.2.2.

The proposed reservoir area is underlain by gently northeast-dipping Upper and Lower Cretaceous sedimentary rocks. Due to the regional northeasterly dip of the beds, younger rocks are progressively exposed at river level along Peace River between Hudson’s Hope and the proposed dam site.

For the purposes of groundwater, erosion, and stability analyses, bedrock exposed at the maximum normal reservoir level has been divided into three main groups on the basis of general decreasing grain size and age, and increasing susceptibility to erosion and landslides with distance downstream:

- Siltstone upstream of Gates Island

- Silty shale between Gates Island and Cache Creek
- Shale downstream of Cache Creek

Sandstone bedrock exposed in the Dunvegan Escarpment above the proposed reservoir level between Cache Creek and Wilder Creek has been grouped as a separate sandstone unit.

The Cretaceous bedrock in the technical study area is overlain by a Quaternary sequence of overburden comprising fluvial, glacial, and interglacial deposits up to 400 m thick.

For the purposes of groundwater, erosion, and stability analyses, the overburden units have been grouped based on dominant grain size, age, and susceptibility to erosion and landslides. The simplified overburden mapping groups include:

- Interbedded sand, silt and clay
- Overburden colluvium
- Bedrock colluvium
- Sand and gravel
- Till
- Tufa

All glaciolacustrine units in the technical study area, including Glacial Lake Peace, Glacial Lake Mathews and Cordilleran Basin glaciolacustrine deposits, have been grouped together as interbedded sand, silt, and clay, while all fluvial and glaciofluvial units have been grouped together as sand and gravel. Man-made fills and the large diamicton exposure across from Lynx Creek have also been included in the sand and gravel group.

Sand, silt and clay materials are interpreted to be most susceptible to shoreline erosion and potential changes in slope stability caused by reservoir operations. The Cordilleran Basin glaciolacustrine deposit (interbedded sand, silt, and clay) is present along approximately 8% of the proposed reservoir shoreline at the maximum normal reservoir level. An additional 15% of the shoreline comprises sand, silt, and clay landslide debris (overburden colluvium), which, in most locations, is of limited thickness and overlies sand and gravel or bedrock. The remainder of the proposed reservoir shoreline comprises sand and gravel and fill (37%), bedrock colluvium (10%), and bedrock (30%). The approximate distribution of the materials present at the proposed maximum normal reservoir level is shown on Figure 11.2.8.

Around the majority of the proposed reservoir, one or more sand and gravel units separate the materials present at maximum normal reservoir level from overlying interbedded sand, silt, and clay units. As discussed further below, the presence of the sand and gravel limits the potential for the proposed reservoir to influence groundwater flow and slope stability in the overlying Glacial Lake Mathews and Glacial Lake Peace interbedded sand, silt and clay units.

Interpreted geological conditions along the proposed reservoir shoreline are presented in Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines by way of geological fence diagrams (which illustrate the position of the main geological units in profile along the river valley) and cross-sections located approximately every kilometer along the north and south bank of the river valley. Figure 11.2.8 shows the locations of the geological cross-sections.

11.2.3.3 Landslide Inventory

Post-glacial downcutting of the modern Peace River during the Late Pleistocene and Holocene formed steep slopes in Cretaceous bedrock and Quaternary fluvial, glacial, and interglacial deposits. The bedrock topography and the occurrence of Quaternary soils in the area are controlled by the presence of buried interglacial valleys (paleovalleys), which have been re-excavated by the modern valley. Landslides most commonly occur within the Cretaceous Shaftesbury Formation, and within glaciolacustrine deposits of laminated silt and clay. In some cases, the modern river valley intersects paleovalleys in which landslides were present, potentially facilitating the reactivation of paleo-landslide surfaces.

Landslides in shale bedrock and glaciolacustrine overburden share some similarities. Most have the character of compound slides, exploiting weak near-horizontal clay layers found at multiple levels in both materials. Typically, a basal sliding surface first develops along a bedding plane pre-sheared to a residual friction angle and then connects to a steep main scarp by cross-cutting the layers of soil or bedrock. Frequently, this mechanism repeats successively at multiple levels if multiple weak bedding planes are present.

Bedrock landslides from low bank slopes typically comprise rock falls, toppling, and shallow slumping along steep valley relaxation joints. Overburden landslides from low bank slopes typically comprise shallow translational and rotational landslides and earth flows.

The four dominant types of landslides from high bank slopes in the Peace River valley are:

- Compound bedrock slides (typically associated with failures in Shaftesbury shale)
- Compound soil slides (typically associated with failures in Glacial Lake Mathews, Cordilleran Basin glaciolacustrine and Upper Paleovalley glaciolacustrine sediments)
- Flow slides (typically associated with failures in Glacial Lake Peace sediments)
- Earth flows (typically associated with remobilization of bedrock and overburden colluvium)

A comprehensive inventory of landslides that have occurred in the modern Peace River valley was completed for the proposed reservoir area based primarily on identification and interpretation of geomorphological features evident in a high-resolution digital elevation model generated from light detection and ranging (LiDAR) imagery. The LiDAR analysis was supplemented by an examination of 1:20,000 and 1:40,000 scale orthorectified aerial photographs (orthophotos) that were taken in 2007. Additional historical airphotos dating back to 1945 were also examined, and extensive reference was made to an existing regional airphoto-based landslide inventory. Additional ground-truthing was carried out during site investigation work in 2010 and 2011 (see Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines). Historical and recent drilling and test pitting results were also studied, including laboratory tests on samples taken from the 1973 Attachie Slide and adjacent slopes.

Two of the most significant landslide complexes in the landslide inventory are the Cache Creek Slide and the Attachie Slide.

The Cache Creek Slide is a bedrock landslide located on the north bank of Peace River downstream of the confluence with Cache Creek. The landslide complex is defined by a prominent head scarp approximately 1500 m long and 150 m high. It is the largest known landslide complex in the Peace River valley with an estimated volume of 82 million m^3. The age of the landslide complex is unknown; however, anecdotal evidence suggests that reactivation of a part of the landslide may have occurred in the late 1700s. Geotechnical investigations indicate that sliding occurred along a weak, pre-sheared, sub-horizontal bedding plane within the Shaftesbury shale approximately 100 m below the shale-sandstone contact and approximately 140 m above the proposed maximum normal reservoir level. While future movement of the Cache Creek Slide is possible, movement rates within flat-lying shale bedrock landslides like the Cache Creek Slide are expected to be slow to moderate.

The Attachie Slide is located on the south bank of Peace River opposite the Halfway River confluence. The slide occurred on May 26, 1973, and has an estimated volume of 14.7 million m^3. Debris traveled across the river and up the opposite bank, damming the river for approximately 12 hours. Geotechnical investigations suggest that the basal failure surface was coincident with a pre-sheared layer located near the base of the Glacial Lake Mathews interbedded sand, silt and clay deposits. The Attachie Slide exhibited two main phases of movement: an initial phase of slope deformation over a period of several decades resulting in a slope marked by scarps and open tension cracks, followed by a rapid to extremely rapid compound slide that transitioned to an extremely rapid flow slide. The Attachie Slide was unusual in that it is the only confirmed extremely rapid landslide of this size that has occurred within over-consolidated glaciolacustrine sediments in the Peace River valley.

A total of 1,834 landslide complexes comprising 4,010 individual landslides were identified. Of the individual landslides in the inventory:

- 6% were classified as compound rock slides in Shaftesbury shale; 40% were classified as compound earth slides in Glacial Lake Mathews, Cordilleran Basin glaciolacustrine, and Upper Paleovalley glaciolacustrine sediments; 52% were classified as flow slides in Glacial Lake Peace sediments; and 2% were classified as earth flows in overburden and/or bedrock colluvium
- 19% were classified as having experienced a significant episode of movement affecting all or part of the landslide within the last 100 years, while 81% of the landslides were classified as greater than 100 years old
- The debris from 71% of the landslides did not extend to the proposed maximum normal reservoir level elevation of 461.8 m, while debris from 29% of the landslides did
- Estimated deposit volumes ranged between 1,100 m^3 and 44 million m^3, with a mean value of 320,000 m^3 and a median value of 90,000 m^3

Of particular interest is the number and percentage of existing landslides with a basal failure surface situated below the maximum normal reservoir level, as these landslides have a greater likelihood of being affected by reservoir operations. Eighty-nine (approximately 2%) of the landslides identified around the perimeter of the proposed reservoir appear to have a basal failure surface elevation that would be below the proposed maximum normal reservoir level. Fifty-eight of these landslides are in shale bedrock slopes situated downstream of Cache Creek, where potential landslide movement rates are expected to be low.

Further details on the landslide inventory, along with more detailed descriptions of the Cache Creek, Attachie, and other large landslides are provided in Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines.

11.2.3.4 Slope Angle Inventory

Representative cross-sections were generated to create an inventory of the slope angles that have formed in the different geological materials around the proposed reservoir.

Within each geological unit, the steepest slopes observed are typically slopes that are subject to active river or gully erosion at the base of the slope. The steepest slopes provide an indication of the range of slope angles likely to form over the short term as a result of wind-generated shoreline erosion, and are referred to as 'eroded slope angles'.

The flattest slopes observed within each geological unit are typically not subject to active toe erosion. In most cases, these slopes have been modified by surface erosion and landslides that have contributed to the gradual flattening of the slopes over the past several hundred to several thousand years. The flattest slopes provide an indication of ultimately stable slope angles within each of the geological units, and are referred to as 'ultimate slope angles'.

The results of the slope angle inventory, combined with results from the geotechnical site investigations and slope stability analyses, were used to establish predicted eroded and ultimate slope angles for each of the geological units around the proposed reservoir. These values are summarized in Table 11.2.1.

Table 11.2.1 Predicted Slope Angles by Geological Unit

Geological Unit	Eroded Slope Angle	Ultimate Slope Angle
Sandstone	N/A	1H:1V (45 degrees)
Siltstone	vertical	1H:1V (45 degrees)
Silty Shale	1H:1V (45 degrees)	1.5H:1V (34 degrees)
Shale (low bank)	1H:1V (45 degrees)	1.5H:1V (34 degrees)
Shale (high bank)	1H:1V (45 degrees)	3H:1V (18 degrees)
Bedrock Colluvium	1.3H:1V (38 degrees)	3H:1V (18 degrees)
Sand and Gravel	1.3H:1V (38 degrees)	2H:1V (27 degrees)
Interbedded Sand, Silt, and Clay (low bank)	1.3H:1V (38 degrees)	2H:1V (27 degrees)
Interbedded Sand, Silt, and Clay (high bank)	1.3H:1V (38 degrees)	4H:1V (14 degrees)
Overburden Colluvium	1.3H:1V (38 degrees)	4H:1V (14 degrees)

NOTE:
N/A = not applicable

11.2.3.5 Groundwater Flow

Predicted changes in groundwater flow that might affect slope stability as a result of proposed reservoir operations were characterized using a series of two-dimensional geological cross-sections located at key locations perpendicular to the river valley (Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines). The cross-sections illustrate the subsurface geology, hydrostratigraphy, and water table positions for unconfined and confined aquifers. Two-dimensional numerical groundwater flow models (seepage models) were developed to simulate baseline groundwater flow under current conditions and to predict potential changes to groundwater flow as a result of reservoir operations at the locations of the key cross-sections. The reservoir shoreline geological models were used to extend the results of the groundwater monitoring and seepage analyses to the other slopes around the proposed reservoir. Results of the analyses of current and predicted conditions are presented in contained in Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines.

The groundwater regime within the slopes adjacent to the proposed reservoir typically consists of water tables perched on lower permeability silt and clay or bedrock units, with the sandier interbeds providing drainage to the slope face, resulting in groundwater exiting as springs. Springs from some of these groundwater bearing zones form a calcium carbonate (tufa) deposit at the ground surface. Deeper lying bedrock aquifers consist of sandstone, siltstone, and shale bedrock units that generally dip at less than 3° to the northeast.

Recharge to the system is typically from percolation into and through gravel aquifers present at either the ground surface and/or at depths corresponding to relict fluvial drainage systems. Locally, this may be supplemented by groundwater from a deeper buried, glacially-carved basin that passes beneath the project area in the vicinity of Hudson's Hope, Lynx Creek, and Farrell Creek.

In the uppermost unconfined aquifer in the unconsolidated sediments, the water levels fluctuate with seasons and climatic variability, as the recharge areas tend to be dependent on precipitation and snow melt. The regional recharge area is located upland and groundwater flow is generally towards the Peace River.

Predicted average and above-average groundwater recharge rates were estimated by applying a baseflow separation technique to historical streamflow data collected from two hydrometric stations located on the Halfway River near Attachie, B.C. The groundwater seepage modelling and subsequent slope stability analyses considered both average and above-average recharge rates and explored the potential changes of up to a 67% increase in long-term groundwater recharge rates over average conditions on groundwater levels. The above-average recharge conditions used in the seepage analyses are expected to be greater than those predicted by BC Hydro (2012a) under a range of potential long-term climate change scenarios.

The widespread presence of sand and gravel units within the valley slopes limits the potential for the proposed reservoir to influence groundwater flow and slope stability in the upper Glacial Lake Peace and Glacial Lake Mathews interbedded sand, silt, and clay units. Groundwater flow and slope stability within these upper units are dominated by seasonal and annual variability in recharge rates and by the presence of sub-horizontal clay layers that tend to control stability and promote the formation of perched water tables.

The largest changes in groundwater flow potentially affecting slope stability, as predicted by seepage modelling, occur within the glacially-carved buried valley that extends below the riverbed in the Hudson's Hope to Farrell Creek stretch of the Peace River. At these locations, the amount of groundwater rise is directly correlated to the proposed increase in water levels associated with reservoir filling, and the lateral extent of predicted changes in groundwater levels are based on the predicted widths of the glacially-carved buried valley.

Groundwater levels are also expected to increase near the valley bottom as a result of reservoir operations at most other slopes around the proposed reservoir. At these locations, however, current regional groundwater levels are typically higher than the proposed maximum normal reservoir level. Consequently, the predicted lateral extent of changes in groundwater flow is less than for the glacially-carved buried valley sections.

11.2.3.6 Floods and Wind-Generated Waves

Flood discharges from Peace Canyon Dam upstream of the proposed reservoir, and from tributary valleys within the proposed reservoir, combined with wind-generated waves, have the potential to temporarily inundate lands above the maximum normal reservoir level. Conditions that result in operation of the auxiliary spillway could also surcharge the reservoir.

As described in Section 4 Project Description, the Project would be designed for the probable maximum flood. As described in effects of the environment on the Project in Volume 5 Section 37 Requirements for the Federal Environmental Assessment, the methodology used to determine the probable maximum flood does not define an annual exceedance frequency; however, the governing storm combination has an annual exceedance frequency of less than 1/10,000. More likely events with higher annual exceedance frequencies were analyzed for determining the reservoir impact line for potential floods and wind generated waves.

An analysis of the potential floods on the proposed reservoir is summarized in Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines, along with an analysis of potential wind-generated wave runup at selected locations along the proposed reservoir shoreline.

Three flood and wind-generated wave scenarios were analyzed to help understand the potential range of reservoir levels. The events analyzed included:

- 1000-year release from Peace Canyon Dam (7,000 m^3/s) combined with waves from the 200-year wind storm
- 1000-year return period flood from Halfway River (4,250 m^3/s) and powerhouse flows from Peace Canyon Dam (2,000 m^3/s), combined with waves from the 200-year wind storm
- Passage of upstream powerhouse flows from Peace Canyon Dam (2,000 m^3/s) with the Site C generating facilities offline and all spillway gates inoperable and in the closed position

MIKE-11 and HEC-RAS flood modelling were carried out to estimate potential reservoir water levels for each of the flood scenarios. Wave runup estimates were combined with wind setup (storm surge) estimates to determine total wind effects.

For the 1000-year Peace Canyon Dam release (7,000 m^3/s), the modelled reservoir surface profile was higher than elevation 465 m near Peace Canyon Dam; but declined exponentially downstream (to below elevation 462 m downstream of Farrell Creek). Similarly, for the 1000-year Halfway River flood (4,250 m^3/s), the modelled reservoir surface profile was higher than elevation 465 m near the upstream end of the Halfway River arm of the proposed reservoir, but declined exponentially downstream (to below elevation 462 m at the confluence of the Halfway River arm and the main Peace River reach).

As described in Volume 5 Section 37 Requirements for the Federal Environmental Assessment, in the unlikely event that the powerhouse was inoperative and all spillway gates failed to open, the auxiliary spillway could pass 2,000 m^3/s powerhouse flows from Peace Canyon Dam, with the reservoir at elevation of 465 m.

The estimated wave runups for the 200-year return period wind storm vary around the proposed reservoir and ranged from 0.5 m to 4.2 m.

11.2.3.7 Reservoir Shoreline Erosion

Wind-generated waves would have the potential to cause shoreline erosion around the proposed Site C reservoir. The potential erosion volumes are a function of the potential wave energy and the erodibility of the geological materials present at the reservoir shoreline. The amount of bank recession for a given erosion volume is a function of the bank height and the inclination of the eroded slopes that are predicted to form above the shoreline.

The shoreline materials were classified based on field mapping, drilling, and interpretation of the LiDAR digital elevation model (Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines). Erodibility coefficients assigned to each of the classified material types were established based on a review of case studies and on historical erosion observed along the shores of Williston Reservoir and Dinosaur Reservoir.

Average shoreline recession distances were predicted for vertical banks at five and 100 years after reservoir filling, as described in Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines. The results are shown in Table 11.2.2.

Table 11.2.2 Summary of Average Predicted Shoreline Erosion Distances

Years of Operation	Predicted Erosion Distance (in metres) by Shoreline Material Type (percentage of shoreline length is shown in brackets)						
	ISC (8%)	OC (15%)	BC (10%)	SG (36%)	SST (11%)	SSH (11%)	SH (8%)
5	24	18-43	2-5	1-6	<1	<1	1
100	47	30-80	5-23	4-18	<1	2	3

NOTES:

ISC = interbedded sand, silt, and clay; OC = overburden colluvium; BC = bedrock colluvium; SG = sand and gravel; SST = siltstone bedrock; SSH = silty shale bedrock; SH = shale bedrock

An additional 1% of the reservoir shoreline would comprise fill that would be designed to prevent erosion.

As shown in Table 11.2.2, the shoreline materials with the greatest predicted recession distances are the interbedded sand, silt, and clay materials and overburden colluvium.

Within these material types, approximately half of the predicted shoreline erosion would be expected to occur during the first five years of reservoir operation.

11.2.3.8 Slope Stability

Potential groundwater changes and shoreline erosion would affect the stability of slopes around the proposed Site C reservoir.

Two-dimensional limit equilibrium slope stability analyses were carried out to refine an understanding of the mechanisms controlling slope stability, and to help quantify the potential changes of the proposed Site C reservoir on the stability of the reservoir slopes (Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines). The purposes of the analyses were to: calibrate shear strength parameter values; analyze the relative change in slope stability upon reservoir filling; analyze the relative change in slope stability due to predicted shoreline erosion over time; analyze the sensitivity of the slopes to potential earthquakes, rapid drawdown scenarios, and ranges in groundwater recharge rates; and to confirm that the ultimate slope angles used to determine the location of the preliminary Stability Impact Line are appropriate.

Twenty-one representative cross-sections along the proposed reservoir shoreline were analyzed, including 12 low bank and 9 high bank cross-sections where subsurface information was available nearby. In addition, a back-analysis of the pre-failure conditions at the 1973 Attachie Slide was carried out. All of the low bank cross-sections were located where existing residences may be impacted by the proposed reservoir or in the vicinity of propose shoreline protection measures at Hudson’s Hope. The high bank cross-sections were located at well-documented landslides and/or where there is a possibility of landslides that could generate waves that could impact low-lying properties or sections of Highway 29.

Each cross-section was assessed at three stages: existing conditions, Year 1 conditions during operations, and Year 100 conditions during operations. Reservoir Year 1 analyses were conducted using the present slope geometry and a reservoir at maximum normal reservoir level. For reservoir Year 100 analyses, slope geometry was adjusted to account for a conservative prediction of 100 years of shoreline erosion.

The analyses indicate that the creation of the proposed reservoir would have limited impact on the overall stability of the high bank slopes. This is because the critical failure surface for most potential landslides typically daylights above maximum normal reservoir level, and because sand and gravel units within the high bank slopes generally prevent a rise in the groundwater table, as a result of reservoir impoundment, into overlying Glacial Lake Mathews sediments, which tend to be more prone to landslides. Exceptions include the slopes opposite Lynx Creek and Farrell Creek, where interbedded sand, silt, and clay sediments extend below current river level, and where current groundwater levels are low. At these locations, the seepage and stability analyses, combined with predictions of shoreline erosion, indicate a decrease in stability. Shoreline erosion could also reduce the stability of high bank slopes where the maximum normal reservoir level would be located in the sand and gravel units. A decrease in stability is also predicted in the high bank bedrock slopes downstream of Wilder Creek (including Moberly River), where weak bedding planes would be located below maximum normal reservoir level. Some remobilization of overburden and bedrock colluvium at the toe of high bank slopes throughout the proposed reservoir area could also be expected.

Very small changes in stability are predicted for the low bank slopes in bedrock located upstream of Hudson's Hope, with predicted changes in stability ranging from a 5% decrease to a 2% increase.

In general, creation of the reservoir would have a higher impact on the low bank slopes in overburden. The results of the analyses indicate up to a 7% decrease in stability at some of these locations. However, shoreline erosion would likely dominate the observed changes.

The seepage and slope stability analyses indicate that potential rapid drawdown of the proposed reservoir would have limited impact on the overall stability of most high bank and low bank slopes. The slopes that potentially benefit from a buttressing effect from the proposed reservoir under normal operating conditions would experience the greatest decrease in stability under rapid drawdown conditions.

The computed static factor of safety at the position of the preliminary Stability Impact Line was equal to or greater than 1.5 in every case. Under 2,475 year earthquake loading, the factor of safety was greater than 1.0 in every case. These results satisfy typical slope stability guidelines for new residential development in B.C.

At several cross-sections, including the low bank bedrock slopes upstream of Hudson's Hope and most of the high bank slopes, the computed critical factor of safety at the position of the preliminary Stability Impact Line was higher than 2.0 under both static and seismic loading conditions. These results reflect a general conservative positioning of the line in terms of deep-seated sliding potential. However, other failure mechanisms are also covered by the Stability Impact Line. Upstream of Hudson's Hope, the dominant failure mechanisms are toppling of bedrock and sloughing of sand and gravel near the slope crest, which can cause 5-10 m of slope retrogression in a single event. Likewise, the ultimate slope angles in high bank glaciolacustrine materials are governed by failures in Lake Peace deposits on top of the plateau, which can extend hundreds of metres back from the slope crest.

Further details on slope stability are provided in Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines.

11.2.3.9 Landslide-Generated Waves

Landslides with the capability of achieving extremely rapid velocities (greater than 5 m/s) have the potential to generate impulse waves if they enter the reservoir. Six areas were identified for detailed study, including the slopes opposite Lynx Creek, the slopes opposite Farrell Creek, the slopes opposite Halfway River (near the 1973 Attachie Slide), the slopes between Halfway River and Cache Creek, the slopes opposite Cache Creek (Bear Flat), and the slopes opposite Wilder Creek.

These six study sites were selected because they involve high bank slopes with a history of large landslides in the Glacial Lake Mathews and/or Cordilleran Basin glaciolacustrine deposits and are situated across the reservoir from low bank slopes where the potential consequences of inundation could be high. The Landslide-Generated Wave Impact Line assessment was focused on these types of slopes because of the potential for Lake Mathews and Cordilleran Basin glaciolacustrine failures to travel extremely rapidly, similar to the 1973 Attachie Slide, and therefore generate large waves upon impact with the proposed reservoir.

Although large overburden landslides can also originate from the Glacial Lake Peace deposits near the top of the valley slopes, these types of landslides occur progressively in a fluid-like manner and have limited potential for generating large waves by the time they reach reservoir level. Similarly, landslides in the flat-lying bedrock of the reservoir area are not expected to fail rapidly and generate large waves.

The results of the landslide inventory, geotechnical site investigations, and slope stability analyses were used to establish a design landslide volume and velocity for each area in order to assess the landslide-generated wave hazard.

Three stages of landslide-generated wave development can be distinguished: 1) wave generation, 2) wave propagation, and 3) wave runup. The first phase involves the displacement of water by the landslide mass at the impact site, the collapse of the initial turbulent splash, and the development of a well-defined wave, referred to as a gravity wave. The second phase involves the propagation and transformation of the gravity wave across the water body, including attenuation with distance from the source and refraction and shoaling as it enters shallower water near the shoreline. The third phase involves the impact of the wave against the shoreline and its runup onto dry land.

A hybrid modelling approach was adopted that combined empirical wave generation estimates with numerical wave propagation and runup modelling. The results of this modelling methodology were compared with historical physical model tests. Both the physical and numerical modelling methods produced consistent results.

Based on the methods outlined above, it was determined there would be some potential for landslide-generated wave impacts at elevations above the Flood Impact Line east of Lynx Creek and Farrell Creek, and on either side of Halfway River. While there is some potential for landslide-generated waves at the other three study sites, because of the greater reservoir width and/or smaller predicted landslide source volumes, the predicted wave runups do not exceed the Flood Impact Line elevation.

11.2.3.10 Reservoir Impact Lines

Preliminary impact lines have been determined around the proposed Site C reservoir based on information gathered as part of historical and recent geotechnical investigations, and analyses of erosion, seepage, slope stability, and landslide-generated wave potential, as described in the preceding subsections. Four preliminary impact lines are briefly described below, and in detail in Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines. Schematic illustrations of the Flood, Erosion, and Stability Impact Lines at low bank and high bank slopes are shown in Figure 11.2.9.

An overview map showing the location of the impact lines around the proposed reservoir is shown in Figure 11.2.10. A full set of maps and map sheet descriptions showing the impact lines is appended to Volume 2 Appendix B, Part 2 Preliminary Reservoir Impact Lines, and is also available online at www.bchydro.com/sitec.

The impact lines are considered ‘preliminary’ because they currently do not take into account the potential benefits associated with erosion protection and/or slope stabilization measures that could be incorporated into the final designs for the proposed Highway 29 realignment sections. Additionally, small changes to the position of the impact lines could be made based on information that becomes available through additional geotechnical investigations carried out to support the final design of the Project.

11.2.3.10.1 Flood Impact Line

The Flood Impact Line is the boundary beyond which land would not be expected to be affected by floods, wind-generated waves, the operation of the Site C auxiliary spillway, or waves caused by boats and small landslides (Figure 11.2.9). Based on flood and wind-generated wave modelling results described above, the selected Flood Impact Line elevation is 466 m, or approximately 4 m above the maximum normal reservoir level. Because and the Flood Impact Line would typically be located on the reservoir side of the Erosion Impact Line, its position in plan view would change over time as shoreline erosion occurs.

11.2.3.10.2 Erosion Impact Line

The Erosion Impact Line is the boundary beyond which the top of the slope would not be expected to regress due to erosion caused by the creation and operation of the reservoir over a period of 100 years. It considers both predicted shoreline erosion and the formation of a slope above the reservoir shoreline using the eroded slope angles corresponding to the geological units present around the shoreline (Figure 11.2.9). The most active period of erosion would be expected to occur during the first five years of reservoir operation.

11.2.3.10.3 Stability Impact Line

The Stability Impact Line is the boundary beyond which land would not be expected to be affected by landslide events caused by the creation and operation of the reservoir. The position of this line considers extremely unlikely landslide events. It accounts for the predicted amount of shoreline erosion over a 100-year period of reservoir operation, potential changes in groundwater levels, and gradual flattening of slopes above the reservoir shoreline using the ultimate slope angles corresponding to the geological units present around the shoreline (Figure 11.2.9).

11.2.3.10.4 Landslide-Generated Wave Impact Line

The Landslide-Generated Wave Impact Line is a boundary applied to three areas on the north bank of the proposed reservoir (Lynx Creek, Farrell Creek and Halfway River), where landslide-generated waves could temporarily inundate elevations higher than the Flood Impact Line. The position of this line is based on combinations of landslide volumes and velocities that are considered extremely unlikely to occur.

11.2.3.11 Shoreline Classification

The total area contained between the proposed maximum normal reservoir level and the outermost preliminary impact line is 9,648 ha. The areas between the maximum normal reservoir level and the individual impact lines area as follows:

- Flood Impact Line = 648 ha
- Erosion Impact Line = 1,464 ha
- Stability Impact Line = 9,190 ha

The area between the Flood Impact Line and Landslide-Generated Wave Impact Line is 210 ha.

Of the land area encompassed by the impact lines, approximately 70% is steeper than 17°. Terrain steeper than 17° in the Peace River valley is prone to erosion and landslides under natural conditions, and is typically not considered suitable for residential use. Consequently, on their own, the impact lines do not facilitate a direct quantification of the predicted changes to slope stability or potential land use caused by the reservoir. The potential changes to slope stability are quantified based on the results of a shoreline erosion and stability classification before and after reservoir filling.

Shoreline segments were assigned to one or more shoreline erodibility classes based on the material type at the maximum normal reservoir level. Shoreline segments were also assigned to one or more landslide hazard classes as shown in Table 11.2.3. Only landslides capable of moving faster than 1.6 m/s were considered in defining the hazard classes.

Table 11.2.3 Landslide Hazard Class Definitions

Landslide Hazard Class	Applicable To	Definition	Additional Notes
A	Low bank slopes (10–75 m high)	Potential for landslides in bedrock with volumes >10,000 m^3 and generally limited velocities	Total landslide volume may include overlying overburden Peak landslide velocities would typically be less than 13 m/month and are unlikely to exceed 1.8 m/hr, but could exceed 5 m/s where rock falls initiate on near-vertical slopes
B	Low bank slopes (10–75 m high)	Potential for landslides in overburden with volumes >10,000 m^3 and possible extremely rapid velocities	Peak landslide velocities would typically be less than 13 m/month but could exceed 5 m/s where flow slides are generated
C	High bank slopes (>75 m high)	Potential for landslides in bedrock with volumes >100,000 m^3 and generally limited velocities	Total landslide volume may include overlying overburden Peak landslide velocities would typically be less than 13 m/month and are unlikely to exceed 1.8 m/hr
D	High bank slopes (>75 m high)	Potential for landslides in overburden with volumes >100,000 m^3 and possible extremely rapid velocities	Includes potential remobilization of bedrock and overburden colluvium Peak landslide velocities would typically be less than 13 m/month but could exceed 5 m/s where flow slides are generated

Bedrock landslides from low bank slopes associated with Landslide Hazard Class A are rare and typically comprise rock falls, toppling, and shallow slumping along steep valley relaxation joints. Overburden landslides from low bank slopes associated with Landslide Hazard Class B typically comprise shallow translational and rotational landslides and earth flows.

The four dominant types of landslides from high bank slopes are compound bedrock slides, compound soil slides, flow slides, and earth flows. Compound bedrock slides are associated with Landslide Hazard Class C, while Landslide Hazard Class D includes compound soil slides, flow slides, and earth flows.

One of three landslide likelihood classes was assigned to each landslide hazard class for each shoreline segment, as defined in Table 11.2.4.

Table 11.2.4 Landslide Likelihood Class Definitions

Landslide Likelihood Class	Annual Probability	Additional Notes
Two star (**)	>1:100	Likely to occur over 100 years of reservoir operation
One star (*)	1:100 to 1:1,000	Possible over 100 years of reservoir operation
No star	<1:1,000	Unlikely to occur over 100 years of reservoir operation

For current conditions, the landslide likelihood classes were assigned primarily based on interpretation of the landslide inventory. For reservoir conditions, the landslide likelihood classes also consider the influence of predicted shoreline erosion and groundwater changes on slope stability, as determined by slope stability analyses on typical cross-sections.

The resulting shoreline stability classification indicates that the likelihood of Class A landslides in low bank bedrock slopes would not generally be expected to increase under proposed reservoir conditions. The likelihood of Class B landslides in low bank overburden slopes would be expected to increase over a length of approximately 27.9 km of reservoir shoreline, primarily at locations where interbedded sand, silt, and clay would be present at or below the maximum normal reservoir level, and erosion and groundwater changes could affect slope stability.

The likelihood of Class C landslides in high bank bedrock slopes would be expected to increase over a length of approximately 48.7 km of reservoir shoreline, primarily downstream of Wilder Creek, where weak bedding planes associated with previous landslides, including the Tea Creek Slide, would be subject to pore water pressure changes during reservoir impoundment and operation. The likelihood of Class D landslides in high bank overburden slopes would be expected to increase over a length of approximately 66.5 km of reservoir shoreline, primarily at locations where sand and gravel and interbedded sand, silt, and clay would be present at or below the maximum normal reservoir level, and erosion and groundwater changes could affect slope stability.

11.2.3.12 Consideration for Land Use and Public Safety within the Impact Lines

11.2.3.12.1 Land Use

BC Hydro has developed an approach to land use on private property within the impact lines. The approach focuses on public safety, maximizing flexibility for land owners, and minimizing the amount of land required by the project.

No new residential structures would be permitted within the impact lines. Non-residential structures could remain within the impact lines, pending site-specific geotechnical assessment. Existing residential structures within the Flood, Erosion, and Wave Impact Lines would not be permitted to remain, to protect public safety.

Within the Stability Impact Line, and outside the Flood, Erosion, and Wave Impact Lines, existing residential structures could remain for a period of time, at the owner's request and provided a site-specific geotechnical assessment determines that it is safe to do so.

The approach outlined above is consistent with criteria that have been developed and used elsewhere in British Columbia for managing new and existing residential development in landslide-prone areas.

11.2.3.13 Hudson's Hope Shoreline Protection

Shoreline protection adjacent to the community of Hudson's Hope would be constructed prior to filling the reservoir. The proposed shoreline protection includes a combination of a granular berm and slope flattening to prevent shoreline erosion and to offset effects of the reservoir on slope stability (Figure 11.2.11). The shoreline protection would extend from a location where the proposed reservoir shoreline transitions from bedrock to interbedded sand, silt, and clay materials at the upstream end, downstream to beyond the current location of the municipal sewage treatment facility, for a total length of about 2,650 m. As the proposed shoreline protection offsets the predicted effects of the reservoir on erosion and slope stability, an Erosion and Stability Impact Line have not been established through this section. BC Hydro would not acquire rights to restrict land use at the top of this section of slope, but it is anticipated that the District of Hudson's Hope would continue to enforce setback guidelines for new development to address natural erosion and slope stability hazards that would not be mitigated by the shoreline protection.

11.2.3.13.1 Highway 29

Proposed realigned segments of Highway 29 have been located outside of the preliminary impact lines, where practical. The proposed highway realignment at the Halfway River crossing is situated inside the Landslide-Generated Wave Impact Line. The potential for landslide-generated waves has been considered in determining the highway embankment elevation, bridge elevation, and bridge design parameters. The proposed highway and bridge design at Halfway River has been reviewed by the Ministry of Transportation and Infrastructure.

Some existing segments of Highway 29 are currently situated on marginally stable slopes and are located within the Stability Impact Line. Each of these segments has been reviewed by BC Hydro and the Ministry of Transportation and Infrastructure. It has been determined by BC Hydro that the potential changes to the stability of these highway segments as a result of the impoundment and operation of the reservoir are small, and an approach to ongoing highway monitoring and maintenance has been established in collaboration with the Ministry of Transportation and Infrastructure to manage the residual risks.

11.2.3.14 Shoreline Monitoring and Impact Line Updates

An operational monitoring plan will be developed for the Project. As part of this plan, BC Hydro will commit to regular monitoring of shoreline conditions, including groundwater levels, shoreline erosion rates, and landslide activity. An update of the preliminary impact lines will take place following the first five years of reservoir operations based on observations made during and following reservoir filling.

11.2.4 Geochemistry

11.2.4.1 Geochemical Characterization Program

11.2.4.1.1 Overview

A comprehensive geochemical characterization program was developed for the Project consistent with the following regulatory policy for British Columbia and guidance documents:

- Policy for Metal Leaching and Acid Rock Drainage at Minesites in British Columbia, Ministry of Energy and Mines and Ministry of Environment, Lands and Parks, July 1998
- Guidelines for Metal Leaching and Acid Rock Drainage at Minesite in British Columbia, Ministry of Energy and Mines, August 1998
- DRAFT Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Minesites in British Columbia, Ministry of Employment and Investment, April 1997
- List of Potential Information Requirements in Metal Leaching/Acid Rock Drainage Assessment and Mitigation, MEND Report 5.10E, January 2005
- Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials, MEND Report 1.20.1, December 2009
- The Global Acid Rock Drainage Guide, http://www.gardguide.com/index.php/Main_Page, International Network for Acid Prevention INAP, 2012

Since 2008, a geochemical characterization program has been underway to evaluate the acid rock drainage and metal leaching potential of the material that would be excavated, exposed or disturbed by construction activities for the Project, and to develop strategies for the management of potential acid rock drainage and metal leaching issues. The program is at an advanced stage, where there is sufficient understanding of the geochemical behaviour of the materials, that any uncertainties and risks can be addressed by conservative assumptions and estimates, and prevention and mitigation strategies have taken these into account. Volume 2 Appendix B, Part 4 Acid Rock Drainage and Metal Leaching Management Plan describes the prevention and mitigation strategies that have been developed based on the test results obtained to date.

The geochemical characterization program includes static, leachate extraction, and laboratory and field kinetic testing, and takes into account the proposed construction and excavation schedule and volumes. The geochemical characterization program would continue through detail design and procurement, and the results will be used to validate and, if necessary, refine the material management plans for the Project.

Figure 11.2.12 shows schematically the steps used for determining the acid rock drainage and metal leaching potential of the materials that would be excavated, exposed or disturbed by construction activities for the Project. The tests shown on the Figure are described in Section 11.2.4.1.2. No further testing is required if a material is classified as not potentially acid generating in Step 1. The additional tests listed under Steps 2 through 4 are undertaken on materials identified as uncertain or potentially acid generating in Step 1.

The current and planned temporal phases of the geochemical characterization program are:

- Phase 1 – 2008: Preliminary geochemical characterization of dam site south bank bedrock and overburden, including static, leachate, and laboratory kinetic tests
- Phase 2 – 2010: Preliminary geochemical characterization of dam site north bank overburden, including static and leachate tests
- Phase 3 – 2011: Additional geochemical characterization of dam site south bank bedrock and overburden, consisting of field leach barrel construction
- Phase 4 – 2011: Preliminary geochemical characterizations of off-site borrow and road realignment materials, including static and leachate extraction tests
- Phase 5 – 2012: Construction and monitoring of additional field leach barrels and field leach pads at the dam site; and further sampling and testing of samples from the West Pine Quarry and the Portage Mountain Quarry
- Phase 6 – 2012 and 2013 ongoing monitoring of field leach barrels and the field leach pad to provide additional information on the predicted lag times, leachate and water quality under site-specific field conditions

The results of the above testing to the end of 2012 are presented in KCB & SLI 2012.

11.2.4.1.2 Tests for Determining Acid Rock Drainage and Metal Leaching Potential

Static acid-base accounting tests are one-time screening tests to determine the balance of acid-generating versus acid-neutralizing components in a geologic unit, and non site-specific screening criteria are used to classify the acid rock drainage and metal leaching potential of each geologic unit. Whole rock and trace elemental analyses are screening tests to determine which concentrations are elevated in the solid-phase that may be released during acid rock drainage and metal leaching potential processes. Mineralogical analyses are used to identify and estimate the abundance of the specific minerals that occur in each geologic unit. The static test results also provide information that is used to guide sample selection for leachate extraction and kinetic tests.

Leachate extraction tests are short-term tests (i.e., hours to days) and provide preliminary analyses of water quality. Shake flask extraction leachate tests are short-term leaching tests to determine the concentrations of readily soluble constituents (e.g., sulphate, acidity, and major and trace elements) typically under near-neutral to alkaline pH conditions for geologic materials. The standard test procedure uses a 3:1 water to solids ratio by weight on material 6.35 mm or smaller, and the sample is gently agitated to provide continuous exposure of particle during the 24-hour test period. These test conditions are considered to be more aggressive than would occur under site-specific field conditions; therefore, the results are considered to represent a more conservative case than the expected water quality under site-specific conditions. The net acid generation tests are aggressive short-term leachate extraction tests that are designed to fully oxidize the sulphide minerals within a sample using hydrogen peroxide. The net acid generation tests are used to confirm acid-base accounting test results and to determine if a sample is likely to generate acid rock drainage in the future, and provide a conservative assessment of leachate quality under acidic pH conditions (e.g., sulphate, acidity, and major and trace elements) for each geologic material tested.

Kinetic tests are performed on sample materials that the static tests indicate are either potentially acid generating or metal leaching or have an uncertain potential. Laboratory humidity cell kinetic tests are temporal tests (i.e., weeks to months) designed to determine the primary rates of acid generation, acid neutralization, and the time to the onset of acid rock drainage. Field kinetic tests are also temporal tests designed to determine overall rates of acid generation, acid neutralization, and the time to onset of acid rock drainage under site-specific field conditions. Additionally, the field kinetic tests allow for the accumulation, storage, and release of secondary weathering products to occur, which the humidity cell is designed to minimize. The leachate generate from field kinetic tests is also considered to be the most representative site-specific concentrations of constituents (e.g., sulphate, acidity, and major and trace elements) for each geologic material. Larger-scale field kinetic tests are also used to evaluate the potential effectiveness of proposed material management strategies.

11.2.4.1.3 Phases 1 through 4

In Phases 1 through 4, a suite of static, leachate extraction, and laboratory kinetic tests were completed on samples of the various geologic units that would be excavated, exposed, or disturbed during Project construction. The extent of testing completed on the samples varied depending on the nature, purpose, and location of the geological materials, and the results of preliminary geochemical testing. Based on the results of Phases 1 through 4, the preliminary geochemical characterizations of the materials that would be excavated are summarized in Sections 11.2.4.2 through 11.2.4.4.

The laboratory kinetic tests undertaken in Phases 1 through 4 were humidity cell tests that accelerate the natural weathering rate of samples so that key indicator secondary weathering products can be used to determine the primary acid-generating and acid-neutralizing reaction rates. The laboratory humidity cell operating conditions can be considerably more aggressive than the site-specific field conditions at the dam site that excavated materials will be exposed to because:

- Laboratory testing is usually conducted at room temperature (~20°C), which is greater than the atmospheric temperature to which the excavated materials will be exposed to for most of each year. Lower temperatures slow both chemical and biological reaction rates involved in acid generation.
- Laboratory testing ensures a rigorous dry air/moist air/water rinse cycle to accelerate sulphide oxidation and to maximize oxidation product flushing. Most sites experience neither the regularity of the dry air/moist air cycle nor the regularity and intensity of wet precipitation corresponding to the water rinse cycle in the humidity cell.
- The water rinse cycle of the humidity cell is conducted to ensure the wetting and rinsing of the entire sample is as complete as possible. Precipitation infiltration into and flow through placed excavated materials is non-uniform due to heterogeneity of

the material, and channelling and complete wetting and rinsing is typically not achieved. Thus, the reactive fraction of sulphide minerals exposed to oxygen and water is typically much lower than in a humidity cell.

The primary acid generation and acid neutralization rates determined from a humidity cell test are used determine if a given sample will become acid generating; however, the estimated lag-time the sample will take to become acid generating is typically conservatively underestimated since the humidity cell operation accelerates sulphide mineral oxidation. The accelerated sulphide oxidation rate also results in accelerated production rates of secondary oxidation products such as acidity, sulphate, and major and trace elements. The major and trace element concentrations in the weekly rinse leachate are likely to be higher than those generated under site-specific field conditions. Therefore, the time periods for excavated materials to become acid generating would be longer than indicated by the humidity cell tests. Nevertheless, the humidity cell tests are useful in determining primary acid-generating and acid-neutralizing rates, and estimating a conservative laboratory-based lag time for materials to become acid generating. Typically humidity cell results are scaled or adjusted to account for these differences between the laboratory operating conditions of the humidity cells and site-specific field conditions. The field kinetic testing described below provides information under site-specific field conditions that assist and provide increased confidence in expected geochemical behavior under site-specific field conditions and the selection of appropriate scaling factors for humidity cell results.

11.2.4.1.4 Phases 5 and 6

Based on the results of the preliminary geochemical characterization program, additional testing has been done in 2012 and will be done in 2013 to provide additional certainty in the geochemical variability and/or acid rock drainage and metal leaching classification of geological units that would be excavated, exposed, or disturbed. The goal is to increase certainty in acid rock drainage and metal leaching predictions that will lead to material management plans for construction that prevent or mitigate acid rock drainage and metal leaching and protect the receiving environment. The following testing will be incorporated into Phases 5 and 6:

- Additional sample collection and static, leachate extraction, and kinetic testing of dam site bedrock units
- Ongoing field leach barrel testing of dam site bedrock units
- Construction and monitoring of a field leach pad using excavated rock from the exploratory adit constructed in 2012
- Ongoing field leach barrel testing of unconsolidated overburden units
- Additional geochemical (static, leachate extraction, and kinetic) testing of off-site materials

The kinetic tests to be undertaken in Phases 5 and 6 are field scale tests that will provide more definitive information on the likely potential of the excavated materials to produce acid rock drainage and metal leaching under site-specific field conditions. The field leach barrel tests consist of 115 l barrels containing bedrock drill core or overburden from different geologic units. The field leach barrels are located at the dam site and exposed to the weather conditions at the dam site. The field leach pad is located in an open area lined with a membrane. Excavated material is placed in the field leach pad by trucks, which emulates how surplus excavated materials would be placed on-site during full-scale dam construction. Leachate from the field leach barrels and field leach pad is sampled periodically for laboratory analysis to provide:

- An assessment of expected aqueous concentrations under site-specific field conditions
- An estimate of production rates of sulphide oxidation from bedrock geologic units under site-specific field conditions
- An estimate the lag time to onset of acid rock drainage under site-specific field conditions
- An estimate of metal leaching production rates from unconsolidated overburden units under site-specific field conditions

11.2.4.2 Dam Site

11.2.4.2.1 Bedrock

A total of 61 bedrock samples were collected from bedrock Unit 1 (lowest) through Unit 9 (highest) and submitted for geochemical characterization (see Figure 11.2.6 for bedrock units). These samples were taken from drill holes on the south bank of the dam site.

Based on the results of the geochemical characterization program to date, the following preliminary material management units have been defined for the bedrock units at the dam site:

- Material management unit 1: bedrock Units 9, 8, 7, 4, 2 and 1 – These bedrock units are acid generating or potentially acid generating. The humidity cell tests indicate a short estimated lag time of one year or less before the onset of acid rock drainage and metal leaching, with an estimated time to exhaustion of sulphide mineral oxidation of five years or less and therefore within the Project construction period.
- Material management unit 2: bedrock Units 6 and 5 – These bedrock units are potentially acid generating. The humidity cell tests indicated a longer estimated lag time before the onset of acid rock drainage and metal leaching of approximately seven to eigth years, and a longer estimated time once acid rock drainage and metal leaching commences. The humidity cell indicated that Uni 6 is estimated to be acid generating for approximately 16 years and Uni 5 for approximately 23 years. Therefore, the estimated time to complete exhaustion of sulphide-sulphur oxidation and acid rock drainage and metal leaching is well beyond Project construction.
- Material management unit 3: Unit 3 is potentially acid generating and is unique since the humidity cell indicated an estimated lag time of one year before the onset of acid rock drainage and metal leaching, but with an estimated time of acid generation of 12 years. Therefore, the estimated time to complete exhaustion of sulphide mineral oxidation and acid rock drainage and metal leaching is well beyond Project construction.

11.2.4.2.2 Overburden

A total of 30 unconsolidated overburden samples were selected from two sonic drill holes on the north bank of the dam site. The unconsolidated overburden units that have been sampled and tested for the dam site have no potential to generate acid. This conclusion is based on a very low to low sulphide mineral content and variable carbonate content, ranging from low to high.

The results of the shake flask extraction tests, however, do indicate a potential for metal leaching. Trace elements readily soluble from the unconsolidated overburden materials at concentrations above the British Columbia Ministry of Environment Approved and Working Water Quality Guidelines are aluminum (Al), arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), selenium (Se) and silver (Ag). Sulphate (SO4) was also elevated in several unconsolidated overburden units. Based on the common presence of elevated selenium in leachate from the majority of the unconsolidated overburden units, no specific material management units are defined at this time, and all units require that selenium leaching as well as leaching of other readily soluble trace elements be prevented or mitigated applying the same mitigation strategies.

11.2.4.2.3 Material Management

Figures 4.37, 4.38, and 4.39 in Volume 1 Section 4 Project Description show the areas that have been designated for the relocation of surplus excavated materials at the dam site. Table 4.16 in Volume 1 Section 4 Project Description summarizes the sources of the excavated materials, disposal area and approximate embankment volumes.

Based on the preliminary geochemical characterization of the dam site materials, the main acid rock drainage and metal leaching mitigation strategies for the design of the material relocation areas are:

- Preventing or minimizing water contact with the relocated material, by limiting the infiltration of surface runoff, precipitation, snow melt, or groundwater into the material
- Preventing or minimizing air (oxygen) ingress into the relocated material

More details of the material management are provided in Volume 2 Appendix B, Part 4 Acid Rock Drainage and Metal Leachate Management Plan.

11.2.4.3 Off-Site Construction Materials

Geochemical samples were collected from the following sources of off-site construction materials:

- West Pine Quarry, which would be the source for permanent riprap for the dam, generating station, and spillways
- Wuthrich Quarry, which would be the source of temporary riprap for construction of the dam generating station and spillways
- Portage Mountain Quarry, which would be the source of riprap for the Highway 29 relocations and the Hudson’s Hope shoreline protection

Based on the results of the geochemical characterization undertaken in Phases 1 through 4, the following sites contain material that is not potentially acid generating:

- West Pine Quarry
- Wuthrich Quarry

The tests indicated that the metal leaching potential from these quarry materials is low, with the exception of the potential for elevated selenium from the rock from the West Pine Quarry. Additional static, leachate, and kinetic testing would be carried out in 2013 on the West Pine Quarry material to determine the variability in selenium content in the limestone from this quarry site and to undertake a more detailed investigation and assessment of its mobility under the expected site-specific field conditions and intended construction uses. Following the completion of the additional leachate and kinetic testing, an appropriate material management plan will be prepared for the West Pine Quarry.

For the Portage Mountain Quarry site, the testing to date indicates that this material may contain potentially acid-generating lenses or pockets. However, the sulphide mineral content of this material is very low and the likelihood of this material being acid generating is also very low. Confirmation testing will be carried out in 2013 to support that there are no significant acid rock drainage and metal leaching issues for this quarry material.

11.2.4.4 Highway 29 Materials

Geochemical characterization was carried out on 31 samples collected from eight drill holes along the Peace River between Farrell Creek and Hudson's Hope at location of Highway 29 realignment segments and reservoir slope stabilization near Hudson's Hope.

The testing on unconsolidated overburden samples collected from the Lynx Creek and Farrell Creek Highway 29 realignment areas indicate that the materials are not potentially acid generating. Additional tests will be carried out on this material to confirm that there are no significant metal leaching issues.

Both unconsolidated overburden and bedrock samples were collected and tested from the Hudson's Hope reservoir bank stabilization area. The overburden samples were classified as not potentially acid generating.

The bedrock samples yielded acid rock drainage and metal leaching classification ranging from potentially acid generating to not potentially acid generating, with 14 of 17 samples classified as not potentially acid generating. Since the bedrock will not be disturbed during berm construction no management measures will be required.

11.2.4.5 Monitoring

During dam construction, an on-site geochemical characterization program would be implemented for the bedrock units to improve the understanding of the spatial variability of geochemical properties of the bedrock units and make adjustments to the materials management plans as necessary.

More details of the monitoring are provided in Volume 2 Appendix B, Part 4 Acid Rock Drainage and Metal Leachate Management Plan.

11.2.5 Regional Seismicity and Seismic Hazard

As described in Volume 1 Section 4 Project Description, the earthquake design ground motion adopted for the Project has a mean annual exceedance frequency of 1 in 10,000 in accordance with the Canadian Dam Association Dam Safety Guidelines.

This section describes:

- The seismicity of the region of western North America bounded by longitudes 110°W to 140°W and latitudes 45°N to 65°N
- The site-specific seismic hazard assessments undertaken for the Project
- The potential for seismicity induced by reservoir filling
- The potential for seismic seiches and tsunamis
- The current understanding of how petroleum-related activities may affect seismicity
- Ongoing seismic monitoring during operations

11.2.5.1 Regional Seismicity

British Columbia is located along the western margin of the North America tectonic plate (Figure 11.2.13).

The boundary between the North America and Pacific plates lies off the west coast of British Columbia and is a complex seismically active region. On a global scale, the Pacific plate is moving northward relative to the North America plate at a rate in the order of 50 mm/year, along the Queen Charlotte fault. South of the Queen Charlotte fault is the 1100-km-long Cascadia subduction zone that extends from northern Vancouver Island to northern California, in-between the Pacific and North America plates. From north to south, the Cascadia subduction zone consists of the Explorer, Juan de Fuca and Gorda tectonic plates. Along the western edge of these plates, new oceanic crust is being created along spreading ridges and pushed outwards. Along their eastern edge, these plates are being pushed under the North America plate in a process referred to as subduction, at a rate in the order of 40 to 45 mm/year.

As a result of these ongoing active tectonic movements, the plate boundary region dominates the seismicity of B.C. (Figure 11.2.13). The Queen Charlotte fault has produced earthquakes as large as moment magnitude M_W8.1, including the October 29, 2012 Mw 7.7 Haida Gwaii earthquake. Based on palaeoseismic investigations, the Cascadia subduction zone is known to have produced earthquakes as large as about M_W9. Although very large in magnitude, earthquakes such as these occur at too great a distance to be of concern to the Project. However, the cumulative tectonic movements along the plate boundary have strongly influenced the tectonic conditions and stresses that cause earthquakes within the adjoining continental North America plate.

Much of the continental plate is underlain by the North America craton, which comprises geologically ancient and massive rocks, such as those exposed in the Canadian Shield. The craton is generally stable, with little internal deformation and relatively low seismic activity. However, the craton includes some ancient rift fault zones where deformation may still occur, sometimes producing infrequent large magnitude earthquakes. One example is the New Madrid, Missouri area in the central US, where three major earthquakes in 1811-12, estimated to be up to magnitude M_W8 or larger, are attributed to displacements along a reactivated rift structure.

Within the region of North America referred to as the Interior Plains, the craton is overlain by up to several kilometres of sedimentary rocks that were deposited in an inland sea that existed from Jurassic to Cretaceous time. These rocks are now the source of extensive and economically important petroleum deposits.

For purposes of seismic ground motion modelling, and seismic hazard analysis, the eastern edge of the Rocky Mountains is considered to be approximately the western edge of the craton. The northeast corner of B.C. east of the Rocky Mountains is considered to be part of the Interior Plains, while the rest of B.C. consists of a series of northwesterly trending geological belts (Figure 11.2.13) that are defined on the basis of their characteristics and origins. All of these belts include numerous geologically significant faults (Figure 11.2.14) along which past displacements have occurred, in some cases up to tens or even hundreds of kilometres over millions of years.

Inland from the plate boundary region, seismic activity occurs at low to moderate rates across B.C. (Figure 11.2.15). Although various trends and concentrations can be interpreted in the locations of recorded earthquakes, it has generally not been possible to correlate these inland earthquakes with specific fault sources. There are only a small number of faults in southern B.C. that are considered active or potentially active; all of these faults are more than 600 km away and are of no concern to seismic hazard at the Project.

The Project would be physically situated on sedimentary rocks overlying the western margin of the North America craton. The sedimentary rocks are flat-lying and relatively undeformed. Along the Peace River upstream of the Project site several low angle thrust faults are exposed in the near-surface bedrock. These faults are related to the major deformations and major thrust faults associated with the development of the Rocky Mountains and there is no evidence that they are active now. At the proposed dam site, several local shear zones have been mapped in the foundation bedrock. These features are not of tectonic origin and are interpreted to be related to valley rebound resulting from the formation of the modern Peace River valley.

The Project would be located above the Peace River Arch, a feature that developed along the western edge of the North America craton, bordering the early Paleozoic passive margin. The Peace River Arch was the site of recurrent uplift and deformation periodically through the late Mesozoic or early Cenozoic. The western portion of the initial uplift subsequently failed and became a depositional basin, referred to as the Peace River Embayment, through the early Cenozoic. Repeated faulting of the embayment left a series of northeast and northwest-striking faults that bound grabens along the former arch. None of these faults are reported to extend into the middle or upper Cenozoic deposits of the Peace River Embayment.

Earthquakes less than about magnitude M_W5 are too small to cause damage to well-engineered structures. A large region around the Project has a low level of historic seismicity, and within a distance of 200 km there has been one recorded earthquake larger than M_W5, a $M_W5.4$ event near Dawson Creek in 2001.

11.2.5.2 Site-Specific Seismic Hazard Assessments

The damage potential of an earthquake is determined by how the ground moves and how structures respond to those ground movements.

Expected ground motions can be calculated on the basis of probability and are referred to as seismic hazard. The seismic hazard is described by peak spectral accelerations over a range of vibration periods. The period is the time required for the passage of one full cycle of an earthquake wave of a given frequency. Peak spectral acceleration is a measure of ground motion that takes into account the sustained shaking energy at a particular period. It is a better measure of potential damage than the peak ground acceleration, which is often used as an indication of the strength of the ground motion from an earthquake. Peak ground acceleration and peak spectral accelerations are given in terms of a percentage or decimal fraction of the acceleration due to gravity, e.g., 5.4%g or 0.054g.

The response of a structure to earthquake ground motion depends on the natural frequency or period of the structure. For example, the periods of interest for buildings are typically in the range of 0.2 second to 5.0 seconds depending on the height of the building, with higher buildings having longer periods. The periods of interest for the principal structures of the Project are in the range of 0.3 second to 1.0 second.

In the National Building Code of Canada, earthquake ground motion values are provided in terms of probable exceedance, that is the likelihood of given peak horizontal spectral accelerations or peak horizontal acceleration being exceeded during a particular period of time. The probability used in the National Building Code is a median 0.000404 per annum, which is numerically equivalent to an annual probability of exceedance of 1/2475 or a 2% probability of exceedance over 50 years. This means that, over a 50-year period, there is a 2% chance of an earthquake causing ground motions greater than the given expected value.

The earthquake ground motions provided by the National Building Code of Canada are calculated by probabilistic seismic hazard analyses based on the Cornell-McGuire method. Site-specific analyses based on this method have also been performed for the Project.

The major components of this method are:

- Based on the current understanding of the regional seismicity:
  - Defining seismic sources, either areal sources or linear faults
  - Defining the earthquake recurrence rates within each seismic source
  - Defining the maximum magnitude considered possible in each seismic source
- Defining the attenuation of ground-shaking relationship for earthquakes in the area
- Numerical summation of the contributions of all earthquake magnitudes at all distances from the site from each source

A probabilistic seismic hazard analysis evaluates all possible earthquake magnitude and distance scenarios and provides results that can be summarized in the form of:

- Seismic hazard curves, which plot peak accelerations versus annual frequencies of exceedance

- Uniform hazard response spectra for the range of periods of interest for a range of annual frequencies of exceedance

Uncertainty is taken into account by using alternative weighted model parameters as inputs. For purposes of organizing the inputs in a structured manner, and to visually portray the alternatives and their weightings, these details are summarized in logic trees. As a result, a probabilistic seismic hazard analysis provides mean ground motion hazards and their uncertainties. The Canadian Dam Association recommends the use of mean seismic hazards for design of dams. In comparison, the National Building Code of Canada adopts median seismic hazards, which are typically lower than mean hazards.

The following subsections describe two separate site-specific probabilistic seismic hazard analyses that were undertaken for the Project. These two assessments gave very similar results and, as described below, the slightly higher values are used for the design of the Project.

11.2.5.2.1 2009 Seismic Hazard Analysis

A site-specific seismic hazard analysis was undertaken in 2009 by the Site C engineering team, with specialist input and review by a consulting seismologist with substantial experience in seismic hazard analysis (Klohn Crippen Berger and SNC Lavalin Inc. 2009).

Several alternative seismic source models were developed, in which seismic sources were all defined as area sources in various configurations. The alternative source models included maximum possible magnitudes of up to M_W7 to M_W7.2, albeit at very low rates of occurrence. Contributions from potential seismic sources up to 400 km from the site were included in the analyses.

At the western edge of the North America craton, seismic ground motions attenuate more rapidly with distance in the folded and faulted rocks to the west as compared to attenuation in the more massive rocks to the east. Consequently, different sets of ground motion prediction models have been developed for the regions west and east of the craton margin. Three western ground motion prediction models and one eastern model were included as weighted alternatives in the analyses, since the Project could experience ground motions from earthquakes occurring in either region.

Peak ground accelerations and uniform hazard response spectra for several annual exceedance frequencies down to 1/10,000 were computed. At a mean 1/10,000 annual exceedance frequency, the computed peak ground acceleration was 0.23g.

The analysis concluded that for the mean 1/10,000 annual exceedance frequency seismic hazard:

- The mean magnitudes for the earthquakes giving the peak ground acceleration were M_W5.8 to 5.9 at mean distances of 10 km to 50 km
- The range of magnitudes for the 0.2 second period motions was similar and the range of magnitudes for the 0.7 second period motions was slightly higher but still less than M_W6.3
- The seismic hazard is dominated by magnitudes in the range M_W5.8 to 5.9

11.2.5.2.2 2012 Seismic Hazard Assessment

In 2012, BC Hydro completed a system-wide probabilistic seismic hazard analysis as a Level 3 analysis, in accordance with the guidance provided by the Senior Seismic Hazard Analysis Committee (SSHAC, 1997). The SSHAC guidance originated in the nuclear industry in the 1990s and is now starting to be applied on probabilistic seismic hazard analyses for other types of critical facilities such as dams.

The SSHAC process includes a number of specific roles for suitably qualified participants, including:

- Resource experts – members of the scientific community with specific knowledge and expertise relevant to the probabilistic seismic hazard analysis inputs. These individuals may be consulted by the project team and/or may participate in project meetings and workshops.
- Evaluators – individuals who are responsible for reviewing and evaluating the scientific merit of information and alternative interpretations to be considered in developing inputs to the probabilistic seismic hazard analysis
- Analysts – individuals who are responsible for analyzing scientific data and developing appropriate models to represent those data, or for computing seismic hazard estimates
- Technical Integrators – individuals who are responsible for integrating the alternative interpretations into a composite distribution of models and parameter estimates that represent the opinions of the informed technical community. Technical integrators may also be evaluators.
- Peer Review Panel – a group of senior experts charged with review and validation of the SSHAC process as it is implemented and its viability with respect to achieving the SSHAC goal. The peer review panel is similar to an advisory board on a major engineering project.

These participants are typically earth scientists, seismologists, and engineers with strong expertise in their respective disciplines and in seismic hazard analysis. The SSHAC guidance includes advice on selection of such participants.

The project team for the BC Hydro system-wide probabilistic seismic hazard analysis was composed of over 20 earth scientists, engineers, and seismologists who served as evaluators, analysts, or technical integrators. This team was drawn from several major consulting companies, universities, individual consultants, and BC Hydro. A three-person participatory Peer Review Panel was involved throughout the project, in particular through attendance and feedback at major project workshops and through review of draft and final project reports. During the project, over 25 resource experts formally participated in some manner, and numerous other members of the scientific community were contacted to provide specific information, for example in relation to published technical papers. Resource experts were largely drawn from the Canadian and US Geological Surveys and universities, along with some independent consultants.

The seismic source characterization model started with development of a conceptual tectonic framework for the study region, which provided a foundation for subsequent development of seismic sources. Seismic sources included both faults and area sources.

An important part of the seismic source characterization work was the compilation of a catalogue of historical earthquakes in B.C. and adjacent regions, including removal of duplicates, selection of best epicentral locations and depths, conversion to a common magnitude scale (i.e. M_W), and quantification of uncertainties. This catalogue provided the basis for defining the historical seismicity associated with each seismic source and for developing earthquake recurrence models for each source.

Uncertainties exist for many of the seismic source characterization model parameters, resulting in numerous alternatives being defined for parameters such as source zone boundaries, recurrence models and maximum magnitudes. Different sets of alternative ground motion prediction models were selected for western and eastern attenuation regions.

In terms of the seismic source model, the proposed Project is located within the Peace River Arch areal source zone (labelled PRA on Figure 11.2.15). The Peace River Arch source zone includes the location of the 2001 M_W5.4 Dawson Creek earthquake, which has not been correlated with any specific geologic feature. The Peace River Arch zone is defined by and delineated around a distinctive group of faults in the underlying craton. Although these faults are not known to be active, they are favourably oriented for reactivation relative to the present crustal stress regime. Therefore, as an alternative to the areal source zone, an alternative source model for the Peace River Arch used in the seismic hazard analysis included this set of faults as “embedded faults” that were considered to have some potential to be the location of future earthquakes in the present tectonic environment. As such, these faults provided an alternative model for the spatial distribution of future earthquake occurrences within the Peace River Arch source zone without adding to the overall estimated rate of earthquake occurrences.

Surrounding the Peace River Arch zone to the north, east and south is the Interior Plains zone, an extensive region of very sparse seismicity (labelled IP on Figure 11.2.15). The largest recorded earthquake in this region is less than magnitude M_W5. To the west is the Northern Foreland Belt zone (labelled NFB on Figure 11.2.15), which comprises a large portion of the northern Canadian Cordillera, a region with extensive deformation and faulting, and low seismic activity. Although the largest earthquake of record in the Northern Foreland Belt zone is only about M_W4, the Cordilleran region north of the Northern Foreland Belt has experienced earthquakes as large as the Nahanni M_W6.8 event in 1985. Recognizing that the period of seismic recording for the region around the Project location is relatively short and that large magnitude earthquakes are quite infrequent, comparisons were made with other similar regions in the world. As a result, the seismic source model allows for maximum magnitudes of up to M_W7.6 in the Peace River Arch, Interior Plains, and Northern Foreland Belt zones, though at very low rates and with low weightings.

The BC Hydro probabilistic seismic hazard analysis computed peak ground accelerations and uniform hazard response spectra for a range of annual exceedance frequencies. At a mean 1/10,000 annual exceedance frequency, the computed peak ground acceleration is 0.25g, slightly higher than computed in the 2009 site-specific seismic hazard analysis (BC Hydro 2012b). There is good agreement between the response spectra from both analyses. The results of this 2012 probabilistic seismic hazard analysis will be used for the final design of the Project.

Table 11.2.5 shows the results of the probabilistic seismic hazard analysis for a range of annual exceedance frequencies. There is a range of possible earthquake magnitudes and distances that contribute to the seismic hazard for the Project. For dynamic analysis, time histories meeting the following criteria and scaled to the response spectrum would be representative of the seismic hazard:

- Fault mechanisms: strike-slip, reverse, and reverse-oblique
- Magnitude target: M_W6.6
- Magnitude range; M_W5.5 to 7.5 excluding aftershocks
- Distance target: 50 km
- Distance range: 0 km to 200 km

For a discussion on dynamic analyses using time histories, see the effects of the environment on the Project in Volume 5 Section 37 Requirements for the Federal Environmental Assessment.

Table 11.2.5 Peak Horizontal Ground Accelerations

Annual Exceedance Frequency	Horizontal Peak Ground Acceleration (%g)
1/10,000	0.250
1/2475	0.087
1/1000	0.041
1/475	0.022
1/100	0.005

11.2.5.3 Potential for Seismicity Induced by Reservoir Filling

The state of knowledge about reservoir-triggered seismic phenomena, sometimes referred to as reservoir-induced seismicity, has been documented in Bulletin 137 published by the International Committee on Large Dams (ICOLD, 2011). Bulletin 137 includes a table that lists 66 known cases of reservoir-triggered seismicity. Of the cases listed in Bulletin 137:

- Five earthquakes with magnitudes in the range of 5.7 to 6.3 (ICOLD does not specify any particular magnitude scale in Bulletin 137) were triggered by impounding reservoirs with a depth of 100 m or more. The World Register of Dams lists 793 dams with heights over 100 m, giving a frequency rate of about 0.6%, i.e., reservoir triggered seismicity occurred with 0.6% of dams 100 m or more high.
- Three earthquakes with magnitudes in the range 4.1 to 5.75 were triggered by impounding reservoirs with a depth of 60 m or less. The World Register of Dams lists 34,471 dams with heights 60 m or less, giving a frequency rate of about 0.01%, i.e. reservoir-triggered seismicity occurred with 0.01% of dams 60 m or less high.

The above precedents indicate that the probability of reservoir triggered seismicity at the Project, which has a reservoir depth of 52 m at the dam, is very low.

Impounding a new reservoir may trigger an earthquake under the following conditions:

- Pre-existing tectonic stresses have already created conditions near to failure on nearby active faults
- The weight of the water locally increases the stresses on an area of the Earth's crust
- Water seeping from the reservoir increases water pressures in the bedrock at depth, reducing the resistance to fault rupture

These conditions do not exist at the Project:

- There are no known active faults in the vicinity of the reservoir capable of producing a large earthquake
- As described in Section 11.2.2.1, the rocks of the Peace River valley were subjected to several periods of glaciation:
    - Advance and retreat of the ice would have subjected the rock to loads many times greater than the weight of water in the reservoir
    - Glacial lakes were many times greater in size than the Project reservoir
- The unloading due to downcutting of the river valley was several times greater than the weight of the reservoir

There is also no history of reservoir-triggered seismicity at the upstream dams and reservoirs on the Peace River, which are located in the Northern Foreland Belt (Figure 11.2.15). In particular, the nearby Williston Reservoir is about three times deeper than the Project reservoir and has a volume and weight about 30 times greater than the Project reservoir. There is no history of reservoir-triggered seismicity by the Williston Reservoir.

Even in the remote event that reservoir-triggered seismicity did occur, the resulting earthquakes cannot be larger than would have occurred without the reservoir. ICOLD Bulletin 137 states that the largest reservoir-triggered earthquake on record anywhere in the world is magnitude M6.3. As described above, the seismic hazard analysis for the Project has already accounted for the possibility of larger earthquakes close to the site.

11.2.5.4 Potential for Seismic Seiches and Tsunamis

Seismic seiches are standing waves set up on enclosed or partially enclosed bodies of water such as reservoirs, ponds, lakes, rivers, and harbours when seismic waves from an earthquake pass through the area. In contrast, tsunamis are large waves created by abrupt movement of the floor of an ocean or large lake. Tsunamis can travel long distances across the bodies of water in which they originate, whereas seiches can be created in bodies of water at long distances from the earthquake that generated the seismic waves.

11.2.5.4.1 Seismic Seiches

Seismic seiches are typically associated with large magnitude earthquakes, and can occur both in the epicentral area or at long distances from the epicentre. Some historical examples (USGS, 2012) include:

- The 1959 M7.3 Montana earthquake created a seiche in nearby Hebgen Lake, as well as smaller seiches in other bodies of water up to 545 km away
- Seiches were caused in several Scottish lakes and English harbours and ponds by the 1755 M8.7 earthquake that severely damaged Lisbon, Portugal
- Seiches were caused in fiords and lakes in Norway and England by the 1950 M8.6 Assam (Tibet) earthquake
- The 1964 Mw9.2 Alaska earthquake caused hundreds of seiches across North America and as far away as Australia

A study of the 1964 Alaska earthquake (McGarr and Vorhis, 1968) found that 859 seismic seiches were observed on water bodies after the earthquake but only about 10% of the surface water gauges that could have recorded a seiche did so. In Canada, seiches were measured as far east as Ontario. Seiches measured on rivers and lakes in British Columbia were in the range of 0.01 m to 0.2 m above still water level, the one exception being Seton Lake in British Columbia, which had a height of about 0.45 m above the still water level, which was the maximum observed seiche from all 859 records.

More recently, the 2002 Mw 7.9 Denali Alaska earthquake caused low amplitude seismic seiches at 14 BC Hydro reservoirs located 1500 km to 2400 km from the epicentre (Little and Scott, 2004). The maximum recorded amplitude (0.18 m peak-to-peak, or about 0.09 m above still water level) was again recorded at Seton Lake. No known analysis has been performed to evaluate if Seton Lake has specific characteristics that cause it to experience seismic seiches larger than those at other sites.

The prediction of seismic seiches in the epicentral region near an earthquake is difficult because of the numerous factors that may influence their occurrence, such as the level of shaking, surface tilting, geology, topography, and directional effects. At long distances, most of these factors have no influence, and seismic seiches are considered to be generated solely by seismic surface waves. Theoretical analysis (McGarr and Vorhis, 1968) indicates that the height of a seiche is directly proportional to the horizontal acceleration provided by the surface waves and the predominant periods are five to 15 seconds. The seismic surface waves can excite response in deep, regular bodies of water that have low order modes with periods of five to 15 seconds.

Seismic hazard analyses, including those performed for the Project, do not typically compute spectral accelerations for periods longer than five seconds, as accelerations at those periods do not cause shaking damage to most engineered structures and there are no available ground motion prediction models for those periods. Therefore it is not possible to directly use the results of the seismic hazard analyses to estimate potential seismic seiche effects for the Project.

As noted in Section 11.1.1.2.2, the seismic source model for the seismic hazard analysis includes potential earthquakes as large as Mw7.6, at very low probabilities. Based on the limited historical experience, a local earthquake would have to be close to this magnitude in size to potentially cause a seismic seiche in the epicentral area. The more likely potential causes of seismic seiches in the area of the Project would be large magnitude events at long distances from the Project, such as the 1964 and 2002 Alaska earthquakes. The Project reservoir would have a period of about 12 seconds for the first mode and therefore could theoretically respond to seismic surface waves and produce a seismic seiche from such earthquakes. However, based on the foregoing, it is considered that seismic seiches on the project reservoir would be less than 0.45 m, the largest seiche caused by the 1964 Alaska earthquake.

11.2.5.4.2 Tsunamis

Tsunamis are series of waves created by an abrupt underwater disturbance such as a submarine landslide or a surface displacement caused by an earthquake. A tsunami has a very long wavelength and travels at high velocity in the open ocean, slowing down and increasing in height as it approaches the shore and the water depth decreases.

Landslide-generated waves are discussed in Section 11.2.3.9.

Most destructive tsunamis are caused by surface fault rupture of the ocean floor during major earthquakes. There are no active faults in the reservoir area that could cause movements of the reservoir floor and create conditions similar to an ocean tsunami.

11.2.5.5 Current Understanding of How Petroleum Industry-Related Activities May Affect Seismicity

It has been known for many years that extraction or injection of fluids into the subsurface can induce earthquakes. For example, from 1984 to 1994, small magnitude earthquakes were induced by fluid injection to enhance recovery in conventional petroleum fields near Fort St. John (Horner et al, 1994). Elsewhere, seismic activity has also been associated with geothermal energy projects and more recently, seismic activity associated with hydraulic fracturing to extract shale gas (shale fracking) has been experienced at various locations in the US and other parts of the world.

The process of hydraulic fracturing causes shear movements or creates localized tensile fractures in the host rock, and the energy released by such movements creates very small magnitude earthquakes referred to as “microseismicity”. Such earthquakes are typically less than magnitude M2, and are too small to be felt at surface by humans. Sensitive instruments are used to detect this microseismicity during the fracking process in order to assess its effectiveness.

Recently the US National Research Council (NRC) investigated the scale, scope, and consequences of seismicity induced during fluid injection and withdrawal activities related to geothermal energy development and oil and gas development, including shale gas recovery and carbon capture and storage (National Research Council, 2012). It was found that only a very small fraction of injection and extraction activities at hundreds of thousands of energy development sites in the United States have induced seismicity at levels that are noticeable to the public. With respect to shale gas, it was found that:

- The process of hydraulic fracturing a well as presently implemented for shale gas recovery does not pose a high risk for inducing felt seismic events (only one confirmed case in the world)
- Injection for disposal of waste water derived from energy technologies into the subsurface does pose some risk for induced seismicity, although very few events have been documented over the past several decades relative to the large number of disposal wells in operation

With the expanding shale gas industry in northeastern B.C., the BC Oil & Gas Commission has also investigated the potential for induced earthquakes related to that activity (BC Oil & Gas Commission, 2012) That investigation found that 38 earthquakes from magnitude $M_L2.2$ to $M_L3.8$ that occurred in two areas of the Horn River Basin in 2011 were induced by movements on pre-existing faults due to fluid injection during hydraulic fracturing. Only one of these earthquakes was physically felt at surface and there were no reports of injury or property damage.

The Oil & Gas Commission is now establishing procedures and requirements for monitoring and reporting of induced seismicity. Each case of induced seismicity will be evaluated on the basis of its unique site-specific characteristics, but it is proposed that hydraulic fracturing would be suspended upon detection of an earthquake of magnitude M4 or larger. It should be noted that earthquakes less than about magnitude M5 do not release enough energy to cause damage to engineered structures.

11.2.5.6 Ongoing Seismic Monitoring During Operation

The Geological Survey of Canada (GSC) operates a national network of seismographs that is capable of recording and accurately locating earthquakes down to magnitude M3 or smaller. The data collected provides a national earthquake catalogue that is important for seismic hazard analyses and also provides other scientific information that improves scientific understanding of seismotectonic processes.

For several decades, BC Hydro has cooperated with the GSC in operating additional seismographs in the regions around its largest dams in order to improve the recording capability down to magnitude M2 or smaller. One of those seismographs is located on Bullhead Mountain near the W.A.C. Bennett Dam, and that seismograph already provides good recording coverage for the Project.

The BC Oil & Gas Commission is also planning the installation of a network of about six seismographs in northeastern B.C. in late 2012 or early 2013. The purpose of the network will be to investigate the potential causes of earthquakes that occur in the region where substantial shale gas activity is taking place. This network will also contribute to an improved seismic monitoring capability for the entire northeastern B.C. region.

In addition to monitoring seismic activity, BC Hydro also installs strong motion accelerographs (SMAs) at its major dams to record any seismic shaking and the response of the dam and other structures to that shaking. There are several SMAs installed at each of the existing upstream Peace River dams, and several SMAs will be installed as part of the permanent dam safety instrumentation for the Project.

11.3 Land Status, Tenure, and Project Requirements

11.3.1 Overview

BC Hydro's approach to determining land requirements for the Project is to strive to minimize the amount of land acquired for the Project while maximizing land use flexibility.

BC Hydro would acquire permanent or temporary land tenure, as required, from the provincial Crown and private landowners for the construction, operation, and mitigation of the Project. BC Hydro's approach to acquire land tenure is to compensate based on the fair market value of the land or right being acquired, in addition to compensating owners for disturbance damages and reimbursing costs related to the acquisition. The fair market value of the land is determined by qualified independent appraisers.

BC Hydro would acquire limited land tenure – where possible – by way of permanent and temporary statutory rights-of-way, leases, licences of occupation on provincial Crown land, licences on private land, and through land access permits. Where required, BC Hydro would acquire some lands in fee simple. Maps outlining the type of tenure required in the Project activity zone can be found in Volume 2 Appendix C Land Status, Tenure, and Project Requirements Maps, Figure 1 Current ownership overview and Figure 2 (Maps 1 to 9) Current ownership.

The provincial ministries associated with managing tenure over Crown land include the Ministry of Forests, Lands and Natural Resource Operations; the Ministry of Transportation and Infrastructure; and the Ministry of Energy, Mines and Natural Gas.

BC Hydro owns much, but not all, of the land, for which BC Hydro requires fee simple ownership. BC Hydro acquired these lands between 1977 and 1981, when the previous Site C hydroelectric project was put forward for regulatory review by the British Columbia Utilities Commission at the time, and later under BC Hydro's Voluntary Passive Land Acquisition Program. The voluntary program was established in the 1970s and reinstituted following a recommendation from the British Columbia Utilities Commission in 1983 which stated, *"…the Commission recommends that Hydro reinstitute its passive land acquisition program until an energy project certificate is issued.*" Under this program, BC Hydro may purchase property if it is required for the construction, operation, or mitigation of the Project, and if the property owner wishes to sell their property. The program is entirely voluntary.

Wherever possible, farmland, and ranchland acquired by BC Hydro is being maintained in a productive state, either by leasing back the property to the original owner or to another tenant.

While there are privately owned parcels throughout the Project activity zone, the majority of privately owned sites are on the north side of the Peace River. Through the project's Property Owner Liaison program, public consultation program (Volume 1 Section 9.1 Public Information Distribution and Consultation) and one-on-one meetings, BC Hydro continues to be in direct contact with owners whose land is in the Project activity zone.

BC Hydro continues to consult with property owners, as well as provide information and answer questions about the Project, to discuss the Project's land requirements as required, and to answer questions about the process for acquisition of land or rights.

11.3.1.1 Fee Simple Tenure

BC Hydro would acquire land in fee simple for portions of the dam site area, reservoir inundation, Old Fort Road realignment, and Highway 29 realignments. Fee simple tenure can be described as full ownership in land. An estimated total of 58 private land holdings, comprising 102 separate parcels of land, would be affected by inundation, Highway 29 realignments, Old Fort Road realignment, or dam site permanent structures. Land holdings are defined as common ownership over either individual or several parcels of land. For example, a farm may consist of five separate parcels of land where the land is contiguous or in the same general area, but as it is commonly owned by one or more individuals or a company, it is considered one land holding. Table 11.3.1 below identifies the fee simple tenure required.

Table 11.3.1 Estimated Fee Simple Tenure Required

Project Component	Area of Private Land (ha)	Area of BC Hydro Land (ha)	Area of Crown Land (ha)	Total (ha)
Inundation	367	667	4,523	5,557
Highway 29 realignments	125	30	91	247
Old Fort Road realignment	3.5	0	0	3.5
Dam site permanent structures Include: dam, warehouse, switchyard/substation, roads, communications tower	0	4	135	139

NOTES:

Due to rounding of the individual areas, the individual areas may not add up to the total area shown; however, the total area is correct.

This table reflects information as of November 15, 2012, and is subject to:

- Changes in property ownership
- Areas required for inundation may be reduced as a result of the construction of the Hudson's Hope shoreline protection, as well as any berms created as a result of the Highway 29 realignments
- Additional Crown or private lands may be purchased in fee simple for sources of construction materials or mitigation. The construction material lands may be available for redevelopment post-Project.

11.3.1.2 Dam Site Area – Permanent Structures

BC Hydro would acquire fee simple title for the dam site structures, including the earthfill dam, generating station, and ancillary structures, as well as internal access roads on Crown land. One hundred and thirty-five hectares of Crown land would be required, but no additional private land.

11.3.1.3 Reservoir – Inundation

In 1957, a reserve under the *Land Act* was put in place by Order-in-Council 2452. Please refer to Section 6.2 for details of the Order-in-Council and the subsequent amendments. The Order-in-Council reserve prevents the alienation of an area of Crown land under the *Land Act*.

Rights to the underlying Crown land for the reservoir would be acquired through the issuance of a *Water Act* permit from the Province.

With respect to privately owned land, BC Hydro proposes to acquire, in fee simple, land between the current river shoreline and the area required for the Site C reservoir, up to the Maximum Normal Reservoir Level, which is 461.8 m above sea level.

Approximately 81% of the lands affected by inundation are Crown lands, 12% are owned by BC Hydro, while the remaining 7% of lands are owned by private companies, private individuals, or government agencies and would be purchased in fee simple.

11.3.1.4 Highway 29 Realignments

To accommodate the Project, BC Hydro would be realigning up to 30 km of the existing Highway 29 in six separate sections. BC Hydro would acquire the private lands required for the realigned highway. Both private and Crown land required by the Project to realign the highway would be dedicated provincial highway.

11.3.1.5 Old Fort Road Realignment

BC Hydro would realign one section of the existing Old Fort Road. BC Hydro would acquire the private lands required for the realigned road and dedicate the land as road.

11.3.2 Permanent Statutory Rights-of-Way Required

Permanent statutory rights-of-way would be required for the flood impact line, erosion and landslide-generated wave impact lines, stability impact line, the transmission line widening, the tie-in locations at both the Peace Canyon Dam and the proposed dam site, the Project access road, north and south bank dam site connecting roads, and the Hudson’s Hope shoreline protection. A permanent statutory right-of-way is similar to an easement, in that it grants the right or privilege, acquired through contract, for a specific purpose or purposes. A permanent statutory right-of-way is registered on the title to the property and is perpetual in nature. BC Hydro provides compensation to land owners to acquire a permanent statutory right-of-way.

An estimated total of 106 private land holdings comprising 178 separate parcels of land would be affected by permanent statutory rights-of-way. Note that, of these totals, 52 private land holdings and 79 separate parcels would also be affected by a required fee simple tenure as described above. Table 11.3.2 below identifies the estimated permanent statutory rights-of-way required for the Project.

Table 11.3.2 Estimated Permanent Statutory Rights-of-way Required

Project Component/Activities	Area of Private Land (ha)	Area of BC Hydro Land (ha)	Area of Crown Land (ha)	Total (ha)
Impact lines: flood, erosion, and landslide-generated wave impact lines	190	322	1,377	1,889
Stability impact line	940	398	6,268	7,606
Existing transmission line (118 m)	0	0	0	0
Project access road	12	0	99	111
North and south bank dam site connecting roads	0	3	10	12
Transmission line tie-in at Peace Canyon Dam site	0	12	20	32
Transmission line tie-in at Site C dam site	0	0	51	51
Proposed transmission line widening (34 m)	29	0	222	251
Hudson's Hope shoreline protection	4	1	7	12

NOTES:

The project access road would be 21 m wide and would be partially included within the existing transmission line statutory right-of-way and proposed transmission line widening; therefore, there is some duplication in areas.

Due to rounding of the individual areas, the individual areas may not add up to the total area shown; however, the total area is correct.

This table reflects information as of November 15, 2012, and is subject to change due to changes in property ownership.

11.3.2.1 Reservoir Impact Lines

BC Hydro has developed an approach to land use on private property within the impact lines. The approach focuses on limiting risks to the public, maximizing land use flexibility, and minimizing the amount of land required by the Project. The reservoir impact lines are more fully described in Volume 2 Appendix B Geology, Terrain Stability, and Soil Report, Part 2 Preliminary Reservoir Impact Lines.

BC Hydro would purchase the property rights required within the impact lines by way of a statutory right-of-way and would compensate landowners for the restricted use of their land. A statutory right-of-way would enable title to remain with the private individual or entity, and would allow for most activities that occurred on the land prior to the Project, with some restrictions that would be specified in the statutory right-of-way document.

The statutory right-of-way would specify that no new residential structures would be permitted within impact lines. Non-residential structures could remain, pending site-specific geotechnical assessment. Other activities such as agriculture, grazing, and trapping could continue within the impact lines.

Specifically, within the stability impact zone, existing residential structures could remain, at the owner's request and provided that a site-specific geotechnical assessment conducted by BC Hydro determines that it is safe to do so. Within the flood, erosion, or wave impact lines, however, existing residential structures would not be permitted to remain.

There are currently approximately 30 residential dwellings within: the reservoir inundation area; the flood, erosion, or wave impact lines; the stability impact line; or highway realignment area. BC Hydro is in contact with the property owners to determine how many of these buildings are in use for residential purposes. There is a possibility that some of these residential dwellings could potentially be moved to another area of the existing property, or remain where they are today, pending further site-specific analysis. BC Hydro would continue discussions with property owners and, where appropriate, based on further geotechnical investigations, enter into agreements to address the removal or relocation of these buildings, or outline the conditions upon which the buildings could remain. BC Hydro met directly with property owners who may be impacted to present maps with the reservoir impact lines shown on their specific property, and to discuss their specific property interests.

11.3.2.2 Transmission Line

BC Hydro has an existing statutory right-of-way for a transmission line between the dam site and the existing Peace Canyon Dam. The existing statutory right-of-way contains two 138 kV transmission lines. As part of the Project, BC Hydro would construct, maintain and operate two new 500 kV transmission lines, replacing the two 138 kV transmission lines within the same corridor. The existing statutory right-of-way document allows for these new lines, so the lines can be almost contained entirely within the existing right-of-way area. Any additional rights would be acquired from two private owners and the Province.

At either end of the transmission line corridor, the lines would be tied into a facility at Peace Canyon Dam and at the Site C dam site. For these portions of new right-of-way, and areas where the existing corridor may have to be widened, BC Hydro would acquire a statutory right-of-way on the underlying Crown land.

11.3.2.3 Project Access Road

BC Hydro intends to extend the existing Jackfish Lake Road to connect the existing road directly to the dam site area. This extension, called the Project Access Road, would be constructed mainly inside the north boundary of the transmission line right-of-way. It would be used primarily for hauling construction materials directly to the dam site and would therefore be constructed to a high standard. Given the frequency of construction-related traffic, it is proposed that the road would be classified as a private road to restrict public access to ensure safe operation. As this road would also provide long-term access to both the dam site and the transmission line, BC Hydro would obtain a permanent statutory right-of-way from the Province and two private property owners to accommodate this road.

11.3.3 Temporary Tenure Required

Temporary tenures, including Licences of Occupation, leases, and temporary statutory rights-of-way, would be required within the dam site area, the proposed conveyor route from the 85th Avenue Industrial Lands, construction access and clearing roads, quarried and excavated construction materials, areas of potential disturbance for Highway 29 realignment construction, and a one-time clearing zone along the existing transmission line statutory right-of-way. These tenures would be acquired for a defined period of time and for a specific use or uses, after which they would be returned to the owners.

Table 11.3.3 below provides an estimate of temporary tenures that are anticipated to be required for the Project, pending further information based on procurement and contractor requirements.

Table 11.3.3 Estimated Temporary Tenure Required – Pending Procurement and Contractor Requirements

Project Component/Activities	Area of Private Land (ha)	Area of BC Hydro Land (ha)	Area of Crown Land (ha)	Total (ha)
Proposed conveyor route (85th Avenue Industrial Lands)	11	0*	0	11
Transmission line: one-time clearing zone (14 m)	12	0	91	103
Dam site temporary components, including: worker areas, roads, generating, storage, laydown areas, construction offices	313	241	988	1,543
Construction access and clearing roads	16	1	285	302
Quarried and excavated construction materials	25	96	468	589
Borrow sources and potential aggregate sources	15	10	14	40
Highway 29 realignment – areas of potential disturbance	27	9	10	45

NOTE:

Due to rounding of the individual areas, the individual areas may not add up to the total area shown; however, the total area is correct.

This table reflects information as of November 15, 2012, and is subject to change due to changes in property ownership.

The conveyor portion that would be within the 85th Avenue Industrial Lands is excluded from this table, as this land is owned by BC Hydro.

Additional temporary tenure (temporary statutory right-of-way, licences, leases, etc.) on private and Crown land may be required for:

- Working areas to construct the highway, reslope driveways, etc.
- The extraction of construction materials, quarries, etc.
- Detours to be used during construction of the highway realignments

Quarried and Excavated Construction Materials include: 85th Avenue, Wuthrich, West Pine, Portage Mountain, Del Rio, inundation areas, commercial pits, and Area E. These areas are under consideration for use by BC Hydro.

11.3.3.1 Proposed Conveyor Route (85th Avenue Industrial Lands) to Dam Site Area

As of November 2012, BC Hydro owns 96 ha of land at 85th Avenue south of Fort St. John that is referred to as the 85th Avenue Industrial Lands. BC Hydro would use these lands to extract construction materials and to stockpile material, and for construction offices, laydown, and storage.

Material from the 85th Avenue Industrial Lands would be transported to the dam site on a conveyor belt to a transfer point where the material would be moved by trucks to the dam. Where the route crosses private lands, BC Hydro would acquire tenure for the construction and use of the conveyor belt by way of a temporary statutory right-of-way.

11.3.3.2 Construction Access and Clearing Roads

Temporary access roads would be required for the construction phase of the Project. Where feasible, existing access roads would be used, and upgraded as required.

Rights for the use, upgrade, or construction of access roads would be acquired through the issuance of a licence of occupation from the Province, or from private land owners. In some cases, the existing access roads are already licensed by third parties and BC Hydro would enter into Road Use, Joint Use, or Maintenance Agreements for the use and maintenance of the road. It is expected that any licence issued by the Province where there is an overlapping interest would be provided on the condition that BC Hydro enter into a road use agreement.

BC Hydro would also require temporary licences of occupation on Crown land or temporary statutory rights-of-way for the construction and development of access roads, the use of work and laydown areas, the transportation of construction materials, and to restore disturbed lands as required. These would be required across all Project activity zones at various times during the Project.

For the Highway 29 realignments, the Project would also require temporary tenure to construct the realigned highway outside dedicated areas. These temporary tenures would take the form of a licence of occupation on Crown lands and licences over private lands during construction of the Project to accommodate construction activities (e.g., highway work areas, reinstatement of driveways, laydown areas).

11.3.3.3 Dam Site Area

To facilitate construction of the dam site, BC Hydro would also initially seek a temporary Licence of Occupation over Crown lands required for worker accommodation, construction offices, temporary construction areas, material storage, staging areas, warehouse facilities, maintenance and workshops, concrete batch plants, access roads, and parking areas. Where exclusive use of the land is required, e.g., for worker accommodation, BC Hydro would enter into a lease agreement for specific areas. Some of these facilities would also be constructed on BC Hydro-owned lands.

11.3.3.4 One-Time Clearing Zone

BC Hydro would require licences of occupation on Crown land to permit additional clearing adjacent to the transmission line corridor. Also, BC Hydro may require a temporary licence from two private property owners during the construction of the transmission lines.

11.3.3.5 Quarried and Excavated Construction Materials

To the extent possible, BC Hydro intends to use existing quarries on Crown land to extract construction materials for the Project. To access this resource, a licence would be obtained from the Province with terms consistent with the Ministry of Forests, Lands and Natural Resource Operations Aggregate and Quarry Materials policy. The following sites have been identified as potential construction material sources: 85th Avenue, Wuthrich, West Pine, Portage Mountain, Del Rio, inundated areas, commercial pits, and Area E.

11.3.4 Third-Party Crown Land Tenures

Portions of Crown land may also be subject to third-party tenure previously granted by the Province for commercial use and natural resources including leases, licences, rights-of-way, and registered traplines, as well as map reserves for forestry, guide outfitter territories, tourism and recreation, oil and gas exploration, mineral exploration, aggregate extraction, grazing rights, agriculture, and water rights. BC Hydro continues to identify any overlap between these third-party tenures and BC Hydro's proposed tenure over Crown land and would address them through discussions and, where appropriate, agreements with the tenure holders. The detailed description of these tenures and potential effects of the Project are outlined in Volume 3 Economic and Land and Resource Use Effects Assessment. Table 11.3.4 below identifies the third-party tenures that are within the Project activity zone; maps outlining the location of these tenures relative to the Project activity zone can be reviewed in Volume 2 Appendix C Land Status, Tenure, and Project Requirements Maps, Figures 3 to 10 entitled Forestry tenures, Guide outfitter areas, *Land Act* interests, Oil and gas tenures, Recreation tenures, Trapline areas and *Water Act* tenures.

Table 11.3.4 Third-Party Crown Land Tenure within the Project Activity Zone (Number of Tenures)

Third-Party Crown Land Tenure	Dam Site incl. Sub-station	Reservoir – Inundation	Reservoir – Existing River	Reservoir – Impact Lines	Transmission Line	Quarried & Excavated Construction Materials	Construction Access Roads: Highway 29 Realignment, Clearing, and Conveyor (85th Avenue Industrial Lands)	Total Tenures Impacted Within the Project Activity Zone
Forestry	10	17	16	32	29	23	89	104
Guide outfitter	1	4	4	4	3	4	4	4
Land Act	16	44	36	57	23	35	133	163
Ministry of Energy, Mines and Natural Gas	8	23	22	27	20	23	55	74
Oil and gas	23	64	17	111	70	48	620	714
Recreation	1	8	8	2	N/A	N/A	8	9
Trapline	2	13	13	13	7	9	18	18
Water Act	1	28	10	20	N/A	16	10	46

NOTES:

The above tenures overlap one another as well as the Project activity zone; therefore, there is some duplication in the numbers above.

11.4 Surface Water Regime

Surface water regime refers to the quantity, timing, and rate of change of flow and water level. This subsection describes the existing surface water regime of the Peace River (baseline conditions) and potential changes during the construction and operational phases of the Project. Information on the pre-regulation (i.e., pre-W.A.C. Bennett Dam) surface water regime of the Peace River is also included to provide context for the changes that are expected with the Project.

The spatial boundary selected for the characterization of potential changes to the surface water regime as a result of the Project extends from the outlet of the Peace Canyon Dam to Peace Point, Alberta, over 1,000 km downstream. This downstream boundary was selected because surface water data for that location are available, and because at that location, any changes in the surface water regime were expected to be negligible in relation to the natural variability of the baseline flow regime.

11.4.1 Regulatory and Policy Setting

BC Hydro currently holds water licences for the storage of water and operation of hydroelectric generating stations at G.M. Shrum (Williston Reservoir) and Peace Canyon Dam (Dinosaur Reservoir). Water licences for the storage of water and the generation of power would be required prior to construction of the Project.

At Peace Canyon, BC Hydro is permitted under its water licence to discharge water for the purpose of generating power up to 1,982 m^3/s through turbine generation. Under the August 2007 *Water Act* Order, BC Hydro is also required to maintain, at all times, a minimum flow of 283 m^3/s at Hudson's Hope for fisheries and riparian habitat, downstream water consumption, and recreational access. While the minimum flow may be provided by any combination of spill or turbine generation discharge, under normal operations, it is provided solely by generation.

Spilling is the discharge of water other than through the turbines of the generating station. While infrequent, spills may occur when total project inflows exceed the sum of available storage and the lesser of generation capacity or generation requirement. Operations during such an event are managed with additional due diligence associated with dam and facility safety, public safety, and environmental concerns. BC Hydro's environmental response to forecast spills or actual spills from the Peace River projects, including spill risk assessment, notification, and monitoring, is documented in the Peace Spill Protocol of the Peace Water Use Plan.

11.4.2 Baseline Conditions

11.4.2.1 Overview of Peace River Hydrology and Physiography

The two major headwater tributaries to the Peace River, the Finlay and Parsnip Rivers, originate in the Omineca and Rocky Mountain ranges of north-central B.C. An overview of the Peace River is provided in Volume 1 Section 4.1 Project Location and in Figure 4.1 of this section. The Peace River flows eastward through the Rocky Mountains into Williston Reservoir, a T-shaped reservoir with a total surface area of about 1,770 km^2 at full pool. This reservoir provides the storage and regulation for the G.M. Shrum generating station at W.A.C. Bennett Dam. Downstream of Williston

Reservoir is the Dinosaur Reservoir, impounded by the Peace Canyon Dam located approximately 20 km downstream of G.M. Shrum. The Peace Canyon generating station reuses the water that flows through the G.M. Shrum generating station to generate electricity a second time. Downstream of the dams, the Peace River flows eastward and northeastward across the Alberta Plateau within a deeply incised valley. Below Fort Vermilion, the river drops through a bedrock chute onto the Peace-Athabasca Lowland as it approaches Lake Athabasca in northeastern Alberta. From the Vermilion Chutes to the Slave River confluence, the Peace River flows within a wider, less incised valley. The Slave River flows into Great Slave Lake in the Northwest Territories and the Mackenzie River flows out of Great Slave Lake northwest into the Beaufort Sea. Figure 11.4.1 is a map of the Peace River watershed, and the watershed of its largest tributaries.

Mean annual inflow into the Williston Reservoir is approximately 1,135 m^3/s. Inflows into Williston Reservoir are composed of, on average, 60% snowmelt and 40% rainfall. There are no large glaciers that feed the Williston Reservoir; therefore, glacial melt is a small component of inflows. Figure 11.4.2 illustrates the annual division of total inflow to the Williston Reservoir between the various sources.

The seasonal runoff pattern into Williston Reservoir is characterized by low inflows during December through April, and much higher inflows when the snow melts in late April through July. Heavy summer rains can create high inflows from June through July. Moderate inflows due to rainfall typically occur in August through November. Approximately 63% of the inflow into Williston Reservoir occurs in the May through July period, with the peak inflow typically occurring due to snowmelt between mid-May and mid-June. Only 9 m^3/s of inflow is associated with local tributary inflow into Dinosaur Reservoir downstream of the W.A.C. Bennett Dam.

The average inflows to the Peace River between Peace Canyon Dam and the Site C dam site (i.e., the inflows to the proposed Site C reservoir) are approximately 100 m^3/s. Three-quarters of this inflow typically comes from the Halfway River, about one-tenth comes from the Moberly River, and the rest from Cache Creek, Farrell Creek, Lynx Creek, and residual drainage areas between these tributaries. The seasonal runoff pattern of inflows to the proposed Site C reservoir is similar to that described above for Williston Reservoir, though the spring freshet in this lower-elevation basin typically occurs sooner. Figure 11.4.3 illustrates the sub-basins within the Project watershed.

11.4.2.2 Water Survey of Canada Flow Measurements

The characterization of baseline water levels and flows described in this subsection is based on observations at several Water Survey of Canada hydrometric stations along the Peace River and its tributaries. Table 11.4.1 summarizes the Peace River stations including location (river chainage), drainage area upstream of each gauge, mean annual flow for a common period of record (1992–2010), and corresponding unit runoff (mean annual flow divided by drainage area). The river chainage system is used to identify locations on the Peace River. Chainage refers to the distance downstream of the W.A.C. Bennett Dam (e.g., the Town of Peace River is located near chainage 400 km, or approximately 400 km downstream of the W.A.C. Bennett Dam along the river centreline). Figure 11.4.4 illustrates the location of the Water Survey of Canada stations and the river chainage system.

Table 11.4.1 Water Survey of Canada Stations on the Peace River

Water Survey of Canada Station (Station ID)	Distance from W.A.C. Bennett Dam (km)	Drainage Area (km^2)[a]	Mean Annual Flow (m^3/s)[b]	Unit Runoff ($l/s/km^2$)
Peace River at Hudson's Hope (07EF001)	27.7	73,100	1,176	16.1
Peace River upstream of Pine River (07FA004)	111.4	87,200	1,278	14.7
Peace River near Taylor (07FD002)	123.3	101,000	1,440	14.3
Peace River upstream of Alces River (07FD010)	163.8	121,000	1,546	12.8
Peace River at Dunvegan Bridge (07FD003)	295.7	135,397	n/a	n/a
Peace River at Peace River (07HA001)	396.8	194,374	1,906	9.8
Peace River near Carcajou (07HD001)	650.7	216,813	n/a	n/a
Peace River at Fort Vermilion (07HF001)	831.8	227,026	n/a	n/a
Peace River at Peace Point (07KC001)[c]	1,136	293,000	2,032	6.9

NOTES:

[a] Drainage areas as published by Water Survey of Canada

[b] Mean annual flow is presented for a common period of record (1992–2010) where data are available

[c] Mean annual flow is not available at Peace Point for 2007 and 2009

Table 11.4.2 summarizes the Water Survey of Canada hydrometric stations on the largest tributaries of the Peace River between Peace Canyon Dam and Peace Point, Alberta. As shown, the largest tributary in terms of drainage area and mean annual flow is the Smoky River, which flows into the Peace River just upstream of the Town of Peace River, Alberta. The second largest in terms of drainage area is the Wabasca River, which flows into the Peace River downstream of Fort Vermilion, Alberta. Although the Wabasca River has a drainage area almost three times that of the Pine River in B.C., the Pine River watershed has a higher mean annual flow. The watershed areas of these tributaries are shown on Figure 11.4.1.

Table 11.4.2 Water Survey of Canada Stations on Major Tributaries of the Peace River

Water Survey of Canada Station (Station ID)	Distance of confluence from W.A.C. Bennett Dam (km)	Drainage Area (km^2)	Mean Annual Flow (m^3/s)[a]	Unit Runoff ($l/s/km^2$)
Halfway River near Farrell Creek (07FA006)	66	9,330	73	7.8
Moberly River near Fort St. John (07FB008)	105	1,520	11	7.2
Pine River at East Pine (07FB001)	121	12,100	181	15.0
Beatton River near Fort St. John (07FC001)	143	15,600	55	3.5
Kiskatinaw River near Farmington (07FD001)	156	3,640	10	2.7
Pouce Coupe River downstream of Henderson Creek (07FD007)	175	2,850	6	2.1
Clear River near Bear Canyon (07FD009)	189	2,880	n/a	n/a
Smoky River at Watino (07GJ001)	389	50,300	294	5.8
Heart River near Nampa (07HA003)	395	1,970	3	1.5
Whitemud River near Dixonville (07HA005)	454	2,010	n/a	n/a
Notikewin River at Manning (07HC001)	565	4,680	12	2.6
Boyer River near Fort Vermilion (07JF002)	841	6,600	n/a	n/a
Ponton River upstream of Boyer River (07JF003)	847	2,440	n/a	n/a
Wabasca River at Highway No. 88 (07JD002)	886	35,800	69	1.9

NOTE:

[a] Mean annual flow is presented for a common period of record (1992–2010) where data are available

11.4.2.3 Changes to Surface Water Regime due to Regulation

The construction of the W.A.C. Bennett Dam and subsequent formation of the Williston Reservoir in the late 1960s and early 1970s resulted in changes in the flow regime of the Peace River. Prior to the regulation of the river, mean winter flows were less, and mean spring/summer flows were greater than they are today. Figure 11.4.5 compares monthly average flow hydrographs at various locations on the Peace River pre- and post-regulation.

Table 11.4.3 and Table 11.4.4 summarize a comparison between pre- and post-regulation maximum and minimum flows at various Water Survey of Canada stations on the Peace River. These flows were calculated by averaging the maximum and minimum daily flows of each year over the pre- and post-regulation periods. As shown, peak daily flows have decreased due to regulation, whereas minimum daily flows have increased.

Table 11.4.3 Average Annual Maximum Daily Flow Pre- and Post-Regulation

Water Survey of Canada Station	Pre-regulation (m^3/s)	Post-regulation (m^3/s)	Difference (m^3/s)	Difference (%)
Hudson's Hope	6,165	2,013	-4,152	-67%
Taylor	7,525	2,926	-4,599	-61%
Town of Peace River	9,157	5,622	-3,535	-39%
Peace Point	9,817	5,927	-3,889	-40%

NOTE:
Due to data availability, the period of record for each station is not the same; hence, flows should not be compared between stations

Table 11.4.4 Average Annual Minimum Daily Flow Pre- and Post-Regulation

Water Survey of Canada Station	Pre-regulation (m^3/s)	Post-regulation (m^3/s)	Difference (m^3/s)	Difference (%)
Hudson's Hope	198	344	146	+74%
Taylor	229	576	347	+152%
Town of Peace River	252	742	490	+195%
Peace Point	336	939	603	+179%

NOTE:
Due to data availability, the period of record for each station is not the same; hence, flows should not be compared between stations

The daily pattern of flows on the Peace River has also been influenced by regulation. Prior to regulation, changes in river flows and levels were generally more gradual, with the possible exception of the spring freshet period. Today, regulated flows vary to match electricity demand, typically with higher flows during the day and lower flows at night. The regulated flow pattern is more prominent directly downstream of the point of regulation (i.e., downstream of Peace Canyon Dam) and diminishes in the downstream direction due to natural attenuation and tributary inflows.

The following section describes the current post-regulation flow regime of the Peace River in more detail.

11.4.2.4 Baseline Flows and Water Levels

Flows in the Peace River downstream of the BC Hydro facilities are dependent on Peace Canyon outflows as well as natural inflows from tributaries. Water levels on the Peace River are dependent on flow rate, the size and shape of the channel, the slope of the riverbed, the roughness of the channel bottom, and the ice conditions in the river. Baseline flows and water levels in the Peace River are described in this subsection at monthly, daily, and within-day time frames for the purpose of characterizing seasonal flows, extreme high and low flows, and within-day patterns of flow.

The current post-regulation flow regime reflects not only the variability of the Peace River inflows but also the changes over time in BC Hydro's system load, system resources, and electricity market conditions. For this reason, it is important to consider the historical flow regime as dynamic. Although long-term (i.e., multi-year) average flows have not changed due to operations, the pattern of releases has and will continue to be dependent on these variables, with or without the Project.

BC Hydro's existing facilities on the Peace River are described in Volume 2 Section 11.1 Previous Development. Operation of BC Hydro's existing Peace River facilities follows a pattern similar to that of domestic electricity use, with higher generation and water discharges in the winter, and lower generation and discharges in the spring. Similarly, discharges from existing facilities can be higher during weekdays and lower on weekends, and higher in the daytime and lower at night. These are long-term historical patterns. However, for any particular day, there may be operational constraints or other issues that lead to a deviation from these patterns, as long as reservoir levels and power plant discharges remain within water licence requirements.

11.4.2.4.1 Seasonal Flows

It is useful to analyze monthly average flows to understand the seasonal pattern of flows in the Peace River. As described above, the operation of the existing hydroelectric projects on the Peace River have an influence on the Peace River flows downstream, the extent of which depends on the location and on the time of year. The relative contribution of flow from Peace Canyon to the total Peace River flow decreases with increasing distance downstream due to the inputs from other major tributaries such as those listed in Table 11.4.2. The regulated component of the total flow downstream is higher in the winter when Peace Canyon generation is high and natural tributary inflows are low. In the spring the opposite is true: Peace Canyon generation is typically low and tributary inflows are high.

Figure 11.4.6 illustrates the average monthly flow at Hudson's Hope (located approximately 7 km downstream of Peace Canyon Dam) and at several locations downstream in B.C. and Alberta. This Figure is similar to the bottom chart of Figure 11.4.5, but additional stations are included, and the period of record is shorter (to ensure a common period of record for all stations: 1992–2010). As shown in Figure 11.4.7, the relative contribution of regulated flows (i.e., flows observed at Hudson's Hope) to the total flow at downstream locations is highest in the winter.

11.4.2.4.2 Daily Average Flows and Water Levels

From one day to the next, there is variability in flow and water level on the Peace River due to the pattern of hydroelectric generation at Peace Canyon as well as the natural tributary inflows to the river. Daily average flows at the Hudson's Hope Water Survey of Canada gauge are representative of the pattern of hydroelectric generation, as there are no major tributaries between Peace Canyon Dam and this gauge. As more tributaries enter the Peace River with increasing distance from Peace Canyon Dam, the seasonal pattern of tributary inflows becomes more apparent. Figure 11.4.7 through Figure 11.4.10 illustrate daily average flow hydrographs based on observed Water Survey of Canada gauged flows at Hudson's Hope, Taylor, the Town of Peace River, and Peace Point from 1973 to 2010 (where data are available). Five individual years (1983, 1986, 1990, 1996, and 2002) are highlighted by coloured traces to more clearly illustrate the variability throughout some example years; the average daily hydrograph is also shown. Operational spills occurred from the Williston Reservoir in three of the highlighted years (1983, 1996, and 2002). As shown on Figure 11.4.7, flows at Hudson's Hope vary over a small range compared to the locations downstream, typically between about 350 m^3/s and 2,000 m^3/s. Further downstream, natural variability is more pronounced, and spring freshet becomes more apparent; these characteristics reflect the natural inflows from tributaries downstream of the Peace Canyon Dam.

11.4.2.4.3 Within-Day Flow and Water Level Variations

Within-day variations in flow and water level on the Peace River occur in part due to hydroelectric operations at Peace Canyon, where outflows fluctuate within the water licence limits throughout the day to meet variable electricity demand. The variability is most pronounced directly downstream of Peace Canyon; in general, this variation is reduced with distance downstream.

To characterize the frequency and magnitude of within-day water level variations, the daily range of water levels were analyzed based on three recent years of observed data (2008, 2009, and 2010). Table 11.4.5 summarizes the daily range of water levels at various Water Survey of Canada stations on the Peace River for three recent years. In general, the range is reduced with distance downstream, from approximately 0.5 m at Hudson's Hope, to 0.1 m at Fort Vermilion. One apparent anomaly is at the Water Survey of Canada gauge at the Alces River location, which has a higher daily range than further upstream at Taylor; this is due to the relatively narrow cross-section of the river at this location, leading to a greater change in water level in response to a change in flow.

Table 11.4.5 Daily Water Level Range (2008–2010)

Water Survey of Canada Station	Daily Water Level Range (m)			
	2008	2009	2010	Average
Peace River at Hudson's Hope	0.51	0.51	0.60	0.54
Peace River near Taylor	0.26	0.25	0.28	0.26
Peace River upstream of Alces River	0.34	0.34	0.45	0.38
Peace River at Dunvegan	0.26	0.25	0.28	0.26
Peace River at Peace River	0.14	0.13	0.15	0.14
Peace River at Fort Vermilion	0.08	0.09	0.08	0.08
Peace River at Peace Point	0.09	0.11	0.09	0.10

11.4.3 Surface Water Conditions During Construction

This section describes the approach and methods used to identify potential changes in surface water conditions during the construction of the Project, the expected changes based on the outcome of these studies, and the uncertainties related to the study predictions. The Site C dam site construction phase activities are described in Volume 1 Section 4 Project Description.

11.4.3.1 Approach and Methods

To investigate the changes to upstream and downstream flows and water levels during the channelization and diversion periods of construction, a decade of historical Peace River flows was simulated using hydraulic models representing each stage of construction. A one-dimensional numerical hydraulic model (MIKE 11) of the Peace River between Peace Canyon Dam and Peace Point, Alberta was set up and calibrated for existing conditions as described in Volume 2 Appendix D Surface Water Regime Technical Memos, Part 2 Downstream Flow Modelling (1D). For the analysis of changes during construction, the geometry of the river was modified in the model to represent the hydraulics during the channelization and diversion stages of construction. The hydraulic model predicts water levels, wetted width, average cross-sectional velocity, and other hydraulic parameters based on flow and river geometry. Water years 2000 to 2009 were selected for the analysis of hydraulic changes associated with construction. This period includes representative wet, dry, and average annual flows, and captures unique extreme events pertinent for the analysis of potential changes during construction. Specifically, the highest recorded flow on the Halfway River occurred in 2001 and there was a spill from the upstream Peace Canyon hydroelectric facility in 2002.

Additionally, a two-dimensional, depth-averaged hydraulic modelling software (River2D) was used to analyze the two-dimensional flow patterns, velocities, and bed shear stress estimates in the vicinity of the Site C dam site under existing conditions and during the channelization and diversion stages of construction. The model of existing conditions extends from approximately 1 km upstream of the Site C dam site to approximately 5.5 km downstream at the town of Old Fort. The model of the channelization stage has the same geographic extents, but includes the north bank and south bank Stage 1 cofferdams. The model of the diversion stage extends from the outlet of the diversion tunnels to Old Fort. Figure 11.4.11 illustrates the model domain for each scenario.

The downstream boundary condition specified in the River2D model was a rating curve (relationship between flow and water level) derived based on the one-dimensional hydraulic model described above. The upstream boundary condition was specified as a constant flow in the Peace River. A range of flow scenarios were modelled.

Calibration of the River2D model was completed based on flows of 838 m^3/s and 2,069 m^3/s and corresponding water levels measured in June and August 2011, respectively, along the banks of the two islands in the vicinity of the proposed Site C dam site. The channel bed roughness coefficient was the primary calibration parameter, and it was adjusted (within standard ranges) so that simulated water levels matched observed water levels. The model was calibrated such that simulated water levels were within 0.1 m of observed water levels. Once the River2D model was calibrated for existing conditions, other model scenarios were developed using the existing river model as a baseline and adding in hydraulic structures to represent configurations during both stages of construction.

11.4.3.2 Expected Changes

This section describes the results of the hydraulic simulation of the channelization and diversion periods. A description of periodic flow changes that would be expected during other stages of construction (i.e., river closure and reservoir filling) is also provided.

Figure 11.4.11 presents predicted depth-averaged velocities in the vicinity of the Site C dam site under existing conditions and during Stages 1 and 2 of construction for a flow of 2,100 m^3/s (roughly equal to the sum of the maximum licensed flow from Peace Canyon Dam and the mean annual flow from the tributaries that flow into the Peace River between the Peace Canyon Dam and the Site C dam site). These results (from the River2D modelling described above) suggest that local changes in velocity profiles would be expected in the vicinity of the structures, but that the changes further downstream would be minimal.

11.4.3.2.1 Channelization

Confinement of the main river channel would result in an increase in upstream water levels relative to current conditions, due to the reduced channel conveyance capacity (ability to pass a certain flow at a given water level). At the upstream end of the river constriction, where changes would be most pronounced, water levels would be up to 1 m higher than existing conditions. Water levels further upstream would also rise, but the change (termed a backwater effect) would be reduced with increasing distance upstream. Table 11.4.6 compares the simulated water levels for existing conditions and for the channelization stage. Specifically, the 10th, 50th, and 90th percentile water levels, as well as the maximum and minimum water level over the 10 years of simulation, are compared.

Table 11.4.6 Summary of Changes in Upstream Water Levels during Channelization (2000–2009 Simulation)

Percentile	Water Level at Upstream End of River Constriction		
	Existing Conditions	Channelization	Change
Maximum	412.9 m	413.8 m	0.9 m
90th	411.7 m	412.4 m	0.7 m
50th	411.3 m	411.9 m	0.6 m
10th	410.5 m	411.0 m	0.5 m
Minimum	409.9 m	410.3 m	0.4 m

The top panel of Figure 11.4.12 illustrates the water surface profile upstream of the river constriction for a flow corresponding to the 90th percentile water level (412.4 m) at the upstream end of the river constriction (shown in Volume 1 Section 4.3 Project Description, Figure 4.38). This Figure illustrates the near-maximum influence of the channelization on upstream water levels; the water surface profile for the same flow under existing conditions is included for comparison. Figure 11.4.13 illustrates a plan view of the headpond inundation corresponding to the 50th and 90th percentile water levels during the channelization stage. The 10th percentile water level is not shown, as water levels would be contained within the existing river channel.

Downstream flows and water levels would be unaffected, with the exception of a small increase in water level at the downstream end of the river constriction in the order of 20 cm on average. This change would be negligible within 2 km downstream of the construction site.

11.4.3.2.2 River Closure

This is a transition phase between channelization and diversion stages, during which the Peace River would be diverted from the main river channel through the diversion tunnels. To initiate river closure, flows from Peace Canyon Dam would be reduced to minimum (283 m^3/s) for about one week to allow for construction of the closure berm. Then, for the next five weeks, river flows would be slowly increased as the main cofferdam height is increased. After this six-week river closure period, full Peace Canyon generating station operations would resume. River closure is planned to occur in the fall to allow for the main cofferdam to be completed prior to the following flood season.

11.4.3.2.3 Diversion

During the second stage of construction the Peace River would flow through the diversion tunnels for a period of about 39 months. The diversion tunnels would operate unregulated during this stage and the flow through the tunnels would depend entirely on the head or elevation of the headpond and the capacity of the diversion tunnels. As Peace River flows increase, the headpond level would rise and the diversion tunnel flows would increase; correspondingly, as Peace River flows decrease, the headpond level would fall, and the diversion tunnel flows would decrease. The headpond would dampen changes in Peace River flow rates, resulting in smaller, smoother changes in Peace River flows downstream of the construction site.

Changes to upstream levels during the diversion period would be more pronounced than during channelization due to the reduced flow capacity of the diversion tunnels as compared to the channelized river. Table 11.4.7 compares the maximum, minimum, and 10^{th}, 50^{th}, and 90^{th} percentile simulated water levels at the location of the upstream cofferdam (shown in Volume 1 Section 4.3 Project Description, Figure 4.39) for existing conditions and for the diversion stage of construction. As shown, results suggest that water levels would be increased by 1.5 m or more 90% of the time, and water levels would be increased by 8.6 m or more 10% of the time. The maximum simulated increase in water level was coincident with the flood of record on the Halfway River in 2001, the estimated return period of which is greater than 50 years.

Table 11.4.7 Summary of Changes in Upstream Water Levels during Diversion (2000–2009 Simulation)

Percentile	Water Level at Upstream Cofferdam		
	Existing Conditions	Diversion	Change
Maximum	412.9 m	434.8 m	21.9 m
90^{th}	411.7 m	420.3 m	8.6 m
50^{th}	411.3 m	416.4 m	5.1 m
10^{th}	410.5 m	412.0 m	1.5 m
Minimum	409.9 m	410.5 m	0.6 m

The bottom panel of Figure 11.4.12 illustrates the water surface profile upstream of the diversion for the 90^{th} percentile headpond water level of 420.3 m. This Figure illustrates the influence of the diversion on upstream water levels; the water surface profile for the same flow under existing conditions is included for comparison. Figure 11.4.14 illustrates (in plan view) the headpond inundation corresponding to the 50^{th} and 90^{th} percentile water levels during the diversion stage. The 10th percentile water level is not shown, as water levels would be contained within the existing channel.

Downstream of the diversion tunnel outlets, both the extreme maximum and minimum water levels as well as the rate of change of water levels would be less than under existing conditions. Hydraulic changes would be negligible at Taylor and further downstream.

11.4.3.2.4 Reservoir Filling

Volume 1 Appendix B Reservoir Filling Plan includes a description of the expected changes to the surface water regime of the Peace River during this phase of construction.

11.4.3.3 Uncertainties

The following is a summary of the main sources of uncertainty in the prediction of changes to the surface water regime during construction.

- The one-dimensional MIKE 11 hydraulic model of the existing river has been calibrated to within 0.3 m of observed water levels for a range of flows, as described in Volume 2 Appendix D Surface Water Regime, Part 2 Downstream Flow Modelling (1D). The model of the channelization period has a similar accuracy; the uncertainty in the predictions of water level during the diversion period is governed by the diversion tunnel design noted below.
- The two-dimensional River2D hydraulic model of the existing river has been calibrated to within 0.1 m of observed water levels for a range of flows. The model of the channelization period is expected to have a similar accuracy; the uncertainty in the predictions during the diversion period is governed by the diversion tunnel design noted below.
- Since the analysis described in Section 11.4.3.1 was completed, the diversion tunnel design was updated and the diameter of the diversion tunnels was increased (10.8 m instead of 9.8 m). Larger diversion tunnels would lead to less influence on the flow regime, as the tunnel capacity would be more similar to existing conditions. Hence, the results presented herein present a conservative estimate of the expected changes during this phase of construction.

11.4.4 Surface Water Conditions During Operation (Reservoir)

A description of the proposed Site C reservoir is provided in Volume 1 Section 4.3.2 Reservoir. This includes a summary of reservoir characteristics such as volume, bathymetry, maximum and minimum surface areas, active storage volume, and residence time. Mapping of the land flooded by the Site C reservoir is provided in Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report.

This section provides an overview of the approach and methods used for the analysis of BC Hydro operations with and without the Project, the expected reservoir levels and change in operational releases, and the uncertainties related to the predictions. Further details are provided in Volume 2 Appendix D Surface Water Regime Technical Memos, Part 1 Operations Study.

11.4.4.1 Approach and Methods

To assess the potential changes to the surface water regime during operation of the Project, optimization modelling was completed to estimate possible future operations of the Peace River hydroelectric facilities in combination with the three largest hydroelectric facilities on the Columbia River. Two future scenarios were simulated: with and without the Project. This modelling captures the operation of the entire BC Hydro energy system, including planned generating assets, transmission capabilities, loads, and market conditions. A 60-year historical inflow sequence was input to the models to capture the historical variability of flows; forecasted loads and market prices for electricity for the year 2028–2029 were also input to the model. With this knowledge about future conditions (also referred to as foresight), the models calculate the most economically optimal way to dispatch the various generation resources to maximize the value of the system generation. The operations predicted by the model are more economically optimal and have lower operational variability than could be achieved in reality, where foresight of inflows, loads, and electricity prices is inherently subject to some uncertainty. Hence, optimization modelling is better suited for analyzing differences between modelled scenarios than for predicting actual operations in the future.

The Hydro Simulation Model (HYSIM) was used first to simulate the operation of BC Hydro's generation system on a monthly basis over the entire 60-year study period. The Generalized Optimization Model (GOM) was subsequently used to optimize the hourly operation of the hydropower system, guided by the month-end storage targets predicted by HYSIM for the Williston and Kinbasket reservoirs, which are the two main storage reservoirs of BC Hydro's integrated hydroelectric system. Outputs of the models include reservoir water levels and outflows from each of BC Hydro's major hydroelectric generating facilities.

A sensitivity analysis was used to assess Site C reservoir levels under a different BC Hydro future load/resource balance from that assumed in the GOM study. The analysis considered an additional scenario, one that assumes that the Project would be more heavily relied upon to meet system load requirements, and limits foresight related to market and inflow conditions to one week.

Inflow uncertainty is an important cause of spills in actual operations. Because the GOM model assumes perfect foresight of inflows, the frequency and magnitude of spills are likely under-represented by the model results. A re-operation of the GOM model was conducted to limit inflow foresight, which led to a more reasonable estimation of the frequency of project spills. This foresight limitation was not applied for predicting normal reservoir releases because the shaping of reservoir releases between months, which would be facilitated by the forecast of seasonal inflow patterns spanning several months, is an important determinant in the actual operation of the Williston Reservoir. A supplemental analysis based on historical flows was also conducted to gain perspective on the project spills that would result based on historical flows. This approach is explained further in Section 11.4.4.2.3.

11.4.4.2 Expected Changes

11.4.4.2.1 Site C Reservoir Water Levels

As mentioned above, two approaches were used to estimate the operation of the Site C reservoir; it is expected that actual conditions would be somewhere between the two results. The GOM model results describe how the Site C reservoir would be operated under a base case future resource development and load growth scenario. Under this modelled load/resource balance, the Site C reservoir would be operated near the normal maximum reservoir level for the majority of the time with drawdown of the reservoir beyond the top 0.6 m required less than 1% of the time. An alternate scenario analysis describes how the Site C reservoir would be operated under a different future load/resource balance – for example, where planned resource development is delayed, load growth is exceeded, or transmission capacity to external markets is expanded. That approach predicted that reservoir levels would be maintained within the top 0.6 m of the normal operating range 83% of the time and within the top 1.2 m 94% of the time.

The daily range of Site C reservoir levels (i.e., the difference between the maximum and minimum reservoir level in one day) was also predicted using the two approaches. Actual conditions are expected to be somewhere between the two results. The GOM model results suggest the daily range would be less than 0.6 m over 99 percent of the time. The scenario analysis predicted that the daily range could be larger particularly in the winter period, when the daily range is expected to be 0.6 m or less 60% of the time, and 1.0 m or less 75% of the time. Figure 11.4.15 presents an illustration of the expected range of Site C reservoir levels during operation of the Project.

11.4.4.2.2 Operational Flow Releases

The operation of the Project would be co-ordinated with the operation of existing facilities upstream on the Peace River, as well as other available system resources, to meet provincial demand for electricity in a safe, reliable, and efficient manner. Accordingly, Project discharges would follow the same general pattern as the provincial demand for electricity: higher during the winter and lower during the summer on a seasonal basis, higher during weekdays and lower during weekends on a weekly basis, and higher during daylight hours and lower during late night hours on a daily basis.

Although upstream operations would be maintained within their current water licences, the optimization model results suggest that the Project would lead to differences in the timing of releases from the upstream facilities. The difference in monthly average flows at the Site C tailrace between the two scenarios was estimated to be within two percent with the exception of the months of August, September, October, and November. With the Project, monthly average flows were predicted to be lower in October and November (seven and six percent lower, respectively), and higher in August and September (seven and 14 percent higher, respectively), than without the Project. The magnitude and direction of these changes varied for each month within the 60 year simulation period; however, the changes were within the variability of the existing pattern of releases. Figure 11.4.16 presents the comparison of simulated Peace Canyon Dam hourly releases on an annual and seasonal basis using duration curves. A duration curve is a graphical summary of data that shows the percentage of time that any data value is equalled or exceeded over the period of consideration. These percentages are referred to as exceedance probabilities. The three seasons for which results are presented are as follows:

- Typical winter operations period (November 15 – February 15)
- Typical freshet operations period (May 1 – July 15)
- Typical summer operations period (July 16 – September 30)

Figure 11.4.17 presents the comparison of simulated hourly flows at the Site C dam site with the Project (i.e., operational releases from Site C generating station) and without the Project (i.e., operational releases from Peace Canyon generating station plus tributary inflows, routed downstream to the Site C dam site using a hydraulic model, as described in Section 11.4.5 below).

11.4.4.2.3 Spill Frequency, Magnitude, Duration and Seasonality

The Site C spillway is being designed to safely pass a design flood that is defined as the most severe flood that may reasonably be expected to occur at a particular location. The design flood and spillway capacity are described in Volume 1 Section 4 Project Description and in Volume 5 Section 37 Requirements for the Federal Environmental Assessment. At the other end of the spectrum, lower magnitude spills, though infrequent, are expected under normal operations and could occur at any time. These events are driven by normal operating requirements, including uncertainties associated with inflows, unit outages, transmission restrictions, electricity market prices, and system energy needs.

The combined turbine capacity of the Site C generating station would be approximately 2,520 m^3/s which is about 25% greater than the current turbine capacity of the G.M. Shrum or Peace Canyon generating stations. This increased capacity, along with an active storage volume of roughly six times that of the Dinosaur Reservoir, would provide the Project with operating flexibility to limit the occurrence of spills.

For the characterization of expected frequency, duration, and magnitude of spills at the Site C dam, two approaches were used: one based on a forecasted future operation using the GOM model, the other based on historical flows at the location of the Site C dam site. Both approaches predict the spills that could occur considering one particular set of conditions (inflows, load/resource balance, unit outages, transmission availability, and market conditions) and hence a range of possible outcomes is provided. In addition to spills that may results from regular operations, spills would be expected to occur during Project commissioning and spillway testing.

The first approach used the GOM model with inflow foresight limited to one month. Given that the model is able to operate the Site C reservoir within its normal 1.8 m water level range, it typically chooses to drawdown the reservoir level prior to large inflows that would otherwise lead to spill. Due to its tendency to react in this manner, the model could underestimate the incidence of spills due to short-term inflow events that are difficult to accurately forecast (e.g., rainstorm-driven inflows). On the other hand, inflow foresight of one month could lead the model to overestimate spill at times when forecasts are accurate further than one month into the future (e.g., actual forecasts for the spring freshet period based on basin snowpack observations).

The second approach was based on historical flows at the location of the Site C dam, taken as the flows measured at Water Survey of Canada station Peace River upstream of the Pine River confluence (period of record 1979–2012). In this analysis, spill was assumed to occur whenever the flow exceeded the Site C generating station turbine capacity, and no operation of the Site C reservoir was considered (i.e., the reservoir was fixed at a constant water level). It was assumed that one of the six turbine units was out of service for annual maintenance, such that a spill occurred whenever the total flow exceeded the capacity of five Site C turbines (approximately 2,100 m^3/s). While simple in method, this approach captures historical variability in flows that occurred due to unexpected circumstances at G.M. Shrum and Peace Canyon generation stations. Table 11.4.8 summarizes the results of the two analyses.

Table 11.4.8 Estimated Project Spills

	Generalized Optimization Model	Historical Analysis
Frequency	Five of 60 years with spill (average one year in 12), total of nine spill events	13 of 33 years with spill (average one year in three), total of 18 spill events
Magnitude	Average 226 m^3/s (maximum daily flow 879 m^3/s)	Average 416 m^3/s (maximum daily flow 1,940 m^3/s)
Duration	Average 39 days (range: three to 93 days)	Average four days (range: one to 19 days)

While both approaches have limitations, together the two approaches provide perspective on the frequency, magnitude, and duration of spills that could be expected at the Site C dam.

Regarding the expected seasonality of spills from the Project, operational spills could be expected at any time of year, whereas spills due to local basin floods would be expected to occur in June or July, consistent with the typical timing of the peak freshet flow on the Halfway River.

11.4.4.3 Uncertainties

The current operation of BC Hydro's existing hydroelectric system has the fundamental objectives of generating sufficient electricity to meet domestic demand, and maximizing the value of generation through electricity trade. Within the current licensed operational ranges and within the physical and operational constraints of all of BC Hydro's generating assets, flows are released to meet the above-noted objectives. These objectives would not change as a result of the Project.

Simulation of the future operation of the BC Hydro integrated hydroelectric system with or without the Project is subject to the uncertainties inherent in the forecasts used as input to the models. The main source of this uncertainty is the natural inflows. This uncertainty has been addressed by modelling 60 years of historical inflow records to capture a range of inflow conditions.

The purpose of the optimization model is not to provide a single definitive forecast of actual expected operations, but rather to facilitate an unbiased comparison of different operational scenarios under an otherwise common set of input assumptions. Therefore, despite uncertainty in the inputs to the optimization model, the results are useful for the prediction of the influence of the Project on flow releases to the Peace River.

11.4.5 Surface Water Conditions During Operation (Downstream)

11.4.5.1 Approach and Methods

For the analysis of changes to the surface water regime downstream of the Site C dam, results of the operational modelling were input into a hydraulic model of the downstream river. This one-dimensional backwater hydraulic model extends from the outlet of the Peace Canyon Dam to Peace Point, Alberta, approximately 1,100 km downstream. A 10-year subset of hourly GOM model output for the scenarios with and without the Project were simulated in the downstream reach to produce estimates of flow, water level, wetted width, and average cross-sectional velocity in the Peace River. Measured and estimated inflows from major tributaries were included in the modelling. Additional details on the model setup, inputs, and calibration are included in Volume 2 Appendix D Surface Water Regime Technical Memos, Part 2 Downstream Flow Modelling (1D).

A two-dimensional hydraulic model was used to conduct a more detailed analysis of potential changes in flows and water levels in the vicinity of four side-channel areas between the Site C dam site and Old Fort, at Pallings Flat and Raspberry Islands in B.C., and at Many Islands in Alberta. These reaches have more complex flow patterns and thus two-dimensional modelling was required. Inundation mapping was prepared to compare maximum and minimum wetted areas and depths with and without the Project. Additional details on the model setup, inputs, and calibration are included in Volume 2 Appendix D Surface Water Regime Technical Memos, Part 3 Downstream Flow Modelling (2D).

11.4.5.2 Expected Changes

Changes to downstream flows and water levels would be more noticeable directly downstream of the Site C dam, and less noticeable with increasing distance downstream. Section 11.4.5.2.1 describes the reasons that changes in the surface water regime would be expected with the Project. The subsequent sections describe the study results in terms of changes in the timing of releases, the frequency and magnitude of high and low flows, daily water level fluctuation, wetted width, and average cross-sectional velocity. Detailed results are presented in Volume 2 Appendix D Surface Water Regime, Part 2 Downstream Flow Modelling (1D).

There is a fixed relationship between flow and water level for each cross-section in the hydraulic model based on the channel shape, channel bed material, and slope of the channel bed. Results are typically presented in terms of water level, as that parameter is more tangible than flow rate. It should also be noted that the hydraulic modelling does not consider the hydraulic influence of ice. The objective of the analysis of potential changes in the surface water regime is to provide an indication of the relative changes that could be expected due to the Project. Hence, the presentation of hydraulic model results assuming open water conditions (no ice) is still valuable.

11.4.5.2.1 Reasons to Expect Change

Prior to describing the results of the analyses outlined above, the following is an explanation of why changes to the surface water regime would be expected with the addition of the Project.

The Site C reservoir water level would be relatively stable, with limited daily storage, and would typically operate in approximate hydraulic balance with the upstream facilities over any given day. As such, the water flowing into the Site C reservoir would be approximately equal to the water released through the turbines. In general, the limited amount of active storage (storage within the normal operating range) limits the degree to which the Project could change the downstream flow regime. The factors that would be expected to influence the downstream flow regime include the following. Each point is discussed further below.

- Shifting the point of regulation of the Peace River from the Peace Canyon Dam to a location 85 km downstream
- Having the ability to capture a portion of the spring freshet flows from the tributaries that flow into the Peace River between Peace Canyon Dam and the Site C dam
- Having a different range of operational releases at the farthest facility downstream
- Adding the Site C generating station to the integrated hydroelectric generation system

Under existing conditions, the greatest daily variability in flows and water levels is experienced immediately downstream of the point of regulation (i.e., at the Peace Canyon Dam outlet or tailrace). This daily variability is generally reduced in the downstream direction due to natural attenuation and tributary inflows. The Project would shift the existing point of regulation by a distance of 85 km downstream (along the river centreline) and hence increase the daily variability of flows and water levels at that location, and for some distance downstream.

During the spring, when natural inflows are typically high in the tributaries between Peace Canyon and the Site C dam site (including flows from the Halfway and Moberly Rivers), there would be the potential for the Site C reservoir to store some of the inflows, thereby reducing the peak flow experienced downstream.

The operational releases of the Peace Canyon Dam are bounded by the minimum flow requirement of 283 m^3/s and the maximum licensed discharge of 1,982 m^3/s. The proposed minimum flow for the Project is 390 m^3/s; this value was calculated by adding the current minimum flow requirement of 283 m^3/s at Hudson’s Hope to the mean annual flow of the drainage basin between the Peace Canyon Dam and the Site C dam. The proposed maximum discharge capacity of the Project is about 2,520 m^3/s. This larger range of operational releases with the Project would lead to more rapid fluctuations in flows and water levels immediately downstream of the Site C dam at times when releases were varied from minimum to maximum or vice versa.

As would be expected from the addition of any new resource to the integrated electrical generation system, it is likely that the dispatch of the various resources would be different with the addition of the Site C generation station. In the operations study (Volume 2 Appendix D Surface Water Regime, Part 1 Operations Study), these differences were analyzed by holding other assumptions (including load, inflow, and market conditions) constant between the two future scenarios, with and without the Project.

11.4.5.2.2 Timing of Release

The timing of releases from the Site C generating station would be expected to follow the BC Hydro system load pattern and hence would be similar to the timing of releases from the Peace Canyon Dam today. Due to the time required for water to flow between the Peace Canyon outlet and the location of the proposed Site C tailrace, operational changes at points downstream of the Site C dam would be noticed approximately 10 to 12 hours sooner with the Project. For example, if flow releases were increased from Peace Canyon at 6 a.m. today, the flow increase would be noticeable at the Site C dam site between 4 p.m. and 6 p.m. (depending on the magnitude of the flow). With the Project, the flow increase at the Site C tailrace would be evident immediately (i.e., 10 to 12 hours sooner than under current conditions).

As is the case today, at a certain point downstream of the dam the daily pattern of operational releases would not be apparent due to natural hydraulic attenuation and the inflow from tributaries. This location is dependent on the flow condition but in general the daily pattern is largely attenuated by the Town of Peace River.

11.4.5.2.3 Magnitude of High and Low Flows

Flows immediately downstream of the Site C dam would be less extreme than flows at the same location under current conditions. Currently, the annual maximum flows at this location typically occur either due to high operational releases from Peace Canyon or due to the spring freshet of the Halfway River, the largest tributary of the drainage area between Peace Canyon Dam and the Site C dam. Of these annual maximum flows, the highest flows observed at this location have coincided with the peak of the Halfway River freshet. With the Project, flows from the Halfway River would enter the Site C reservoir, which would have the potential to store some flow, thus reducing the peak flow downstream.

Sixteen kilometres downstream of the Site C dam site on the Peace River is the confluence with the Pine River. The mean annual flow of this tributary is approximately 70% greater than the mean annual flow of the drainage area between Peace Canyon and the Site C dam site. Although the peak flows immediately downstream of the Site C dam would be reduced as described above, the spring freshet of the Pine River (which has peak freshet flows that are on average two and a half times greater than Halfway River peak flows) would not be influenced by the Project. Therefore, the reduction in the most extreme high flows would only be apparent in the 16 km reach between the Site C dam and the Pine River confluence.

At the other end of the spectrum, the lowest flows at the location of the Site C tailrace today typically occur either during early spring or late summer (i.e., before or after the spring freshet of the Halfway River), when electricity demand is low and inflows into upstream reservoirs are typically stored for use in the following winter. Since 1994, there has been a minimum flow requirement of 283 m^3/s at Hudson’s Hope (approximately 7 km downstream of the Peace Canyon Dam). Operationally, the minimum release from Peace Canyon has been slightly higher (approximately 310 m^3/s) due to high vibrations experienced at lower flows, which can reduce the life of the turbine. The lowest flows at the location of the proposed Site C dam occur when tributary inflows are low and the Peace Canyon Dam is releasing near its minimum flow. Flows at this location have been as low as 360 m^3/s since 1994. The minimum flow from the Project is proposed to be

390 m^3/s as described above; hence, it is expected that the lowest flows in the reach downstream would be higher with the Project than the lowest flows that can occur today.

11.4.5.2.4 Frequency of High and Low Flows

As described above, if the Project were constructed, the magnitude of the highest and lowest flows at the location of the Site C tailrace would be less extreme than under current conditions. However, the frequency of high and low flows would be expected to increase with the Project. This result is apparent in Figure 11.4.17, which presents flow duration curves at the outlet of the Site C dam (with and without the Project) based on the 10 years of downstream flow modelling. As shown in the full year plot, results suggest that flows would exceed 2,000 m^3/s approximately 5% of the time with the Project, compared to less than 1% of the time without the Project. At the other end of the flow range, results suggest that flows would be less than 500 m^3/s approximately 21% of the time with the Project, compared to only 7% of the time without the Project. An investigation into potential changes during particular seasons suggests that the change in the frequency of high and low flows could be different depending on the time of year (see Figure 11.4.17).

The above-noted changes in the frequency of high and low flows at the outlet of the Site C dam would be diminished with increasing distance downstream. At Taylor, there would be little difference in the frequency of any particular flow. Smaller changes are apparent further downstream when particular times of the year are viewed in isolation. This relates to the shift in the timing of releases from upstream facilities between months, as described above in Section 11.4.4.2.2. and shown in Figure 11.4.16. The resulting downstream changes are apparent in the flow duration curves included in Appendix D of Volume 2 Appendix D Surface Water Regime, Part 2 Downstream Flow Modelling (1D).

The downstream boundary of the surface water regime study is at Peace Point. In light of comments received regarding the spatial scope of the environmental assessment, including requests to include the Peace Athabasca Delta in the assessment area (as referred to in Section 8.4.1 of the EIS Guidelines), the predicted changes at the downstream boundary were analysed to determine whether there was a technically valid concern with respect to the downstream study boundary. As explained below, consideration of the magnitude and timing of the predicted change and the mechanisms that are understood to be related to the flooding of the Peace Athabasca Delta demonstrates that the spatial boundary is appropriate.

The simulated operation of the integrated hydroelectric system suggests differences between the cases with and without the Project. Differences are expected when using this type of model; the optimal operation determined by the model is dependent on the inputs, some of which are necessarily different in the two scenarios. The downstream hydraulic routing of the simulated operational releases under the two scenarios (with and without the Project) [as described in Volume 2 Appendix D Surface Water Regime, Part 2 Downstream Flow Modelling (1D)], demonstrates that the differences between scenarios become less apparent with increasing distance from the point of regulation (i.e. the Peace Canyon Dam in one scenario and the Site C dam in the other). At Peace Point, the downstream extent of the hydraulic model (approximately 1,030 km downstream of the Site C dam site), a small increase in the frequency of low flows with the Project, particularly in the typical winter operations period (defined in this study as

November 15 to February 15), is predicted. Further analysis shows that with the Project, the frequency of low releases was predicted to be greater during the months of October and November, and a corresponding increase in the frequency of relatively higher flows was predicted for the months of August and September. The predicted changes are small relative to the range and natural variability of flows at Peace Point and would not have any influence on the hydrology of the Peace Athabasca Delta in the open water period. However, the hydrology of the Peace Athabasca Delta is influenced by the frequency of ice-jams in the lower reaches of the Peace River. Freeze-up in the lower Peace River typically occurs in November. The possibility of a relationship between the freeze-up stage (water level) and the probability of dynamic break-up and ice-jams in the spring has been researched (Ashton 2003; Beltaos et al. 2006). It is unlikely that the probability of ice jamming would be influenced by the relatively lower flows that are predicted to occur periodically in October and November with the Project. Ice cover set in at a low level during a period of relatively low flow in November would re-freeze at a higher level as flows increase in December. This is because with increasing flows, the floating portion of the ice cover in the main channel would release from the border ice attached to the banks, float up to accommodate a higher flow beneath it, and re-freeze to the banks at a new, higher freeze-in level. This phenomenon is described by Beltaos et al. (2006). Consequently, low flows in November would not influence the freeze-in level that may be related to the frequency of ice-jams in the lower reaches of the Peace River. The small predicted changes do not justify extension of the spatial boundary.

11.4.5.2.5 Daily Water Level Range

Results suggest that, with the Project, the range of water levels over a day would typically be greater at the Site C tailrace compared to existing conditions. This result would be expected due to the shifting of the point of regulation from Peace Canyon to a location 85 km downstream. Today, the water level fluctuations that are apparent at the Peace Canyon tailrace are naturally attenuated along this river length. The difference is also due to the larger operational flow range that would be expected with the Project.

Table 11.4.9 presents the average simulated daily water level fluctuation at the Site C tailrace and locations downstream based on the 10-year simulation.

Table 11.4.9 Average Simulated Daily Range of Water Levels (with and without the Project)

	Without the Project	With the Project	Difference
Site C Tailrace	0.48 m	1.01 m	0.53 m
Taylor	0.43 m	0.76 m	0.33 m
Alces	0.50 m	0.85 m	0.35 m
Town of Peace River	0.16 m	0.20 m	0.04 m
Peace Point	0.07 m	0.07 m	0.00 m

11.4.5.2.6 Wetted Width and Average Cross-Sectional Velocity

Wetted width is defined as the horizontal distance across the wetted portion of the channel, calculated at model cross-sections. At each model cross-section, there is a specific relationship between wetted width and flow and between average cross-sectional velocity and flow. The influence of the Project on wetted width and average cross-sectional velocity follow the same general patterns as the influence of the Project on flow and/or water level.

11.4.5.2.7 Summary of Expected Changes

As described in Section 11.4.5.2.1, the limited amount of active storage in the Site C reservoir limits the degree to which the Project could change the downstream flow regime. The analysis predicts changes of varying magnitudes throughout the study reach; however, the changes predicted downstream of the Town of Peace River are negligible, considering the magnitude of the predicted change in relation to the natural variability of the baseline flow regime. The most notable changes expected as a result of the Project are as follows.

- Reduction in the magnitude of peak flows; negligible change downstream of the Pine River confluence
- More frequent high flows; negligible change at Taylor and further downstream
- More frequent low flows; negligible change at Taylor and further downstream
- Increase in daily range of water levels; negligible change at Town of Peace River and further downstream

11.4.5.3 Uncertainties

Uncertainty in the results of the downstream flow modelling can be divided into two parts: the uncertainty in the flow inputs predicted through the operations modelling (described in Section 11.4.4.3), and the uncertainty in the hydraulic model, described below.

The one-dimensional hydraulic model that was used to predict flows and water levels on the Peace River based on the results of the operations modelling was calibrated at eight Water of Survey of Canada hydrometric stations between Hudson’s Hope and Peace Point (see Figure 11.4.4), and at five additional locations between Hudson’s Hope and Old Fort. Maximum water level differences were within 0.3 m, and the timing of observed flow patterns were adequately reproduced by the model (modelled flows were generally within one to two hours of observed flows). This calibration result provides confidence that the model can reliably be used for the prediction of the relative difference in flows and water levels under two scenarios (with and without the Project), given the time series of operational releases obtained through the operations modelling (the uncertainty of which is described in Section 11.4.4.3).

11.4.5.4 Influence on Existing Hydrometric Stations

The creation of the Site C reservoir would flood the Water Survey of Canada hydrometric station located at Hudson’s Hope (Station 07EF001), which is shown on Figure 11.4.4. Another Water Survey of Canada hydrometric station exists on the Halfway River near Farrell Creek (Station 07FA006), approximately 20 km upstream of the confluence with the Peace River. It is unclear whether or not the Site C reservoir would lead to a backwater effect to this location.

It is expected that other Water Survey of Canada hydrometric stations on the Peace River and its tributaries would not be affected by the Project.

11.4.6 Climate Change

As part of its climate change adaptation strategy, BC Hydro has been working to determine how climate change has affected the water supply in the past and to predict potential changes in the future. BC Hydro has conducted internal studies to investigate the historical influence of climate change on reservoir inflows, and has partnered with the Pacific Climate Impacts Consortium and the Western Canadian Cryospheric Network to collaborate on studying the potential influence of climate change on the water resources managed as part of BC Hydro's hydroelectric generating system. Volume 2 Appendix T Climate Change Summary Report provides a summary of the work that has been conducted specific to the Peace River region. The main findings of the studies are as follows:

- Although not statistically significant, the BC Hydro analysis of historical trends in reservoir inflow suggests that annual inflows to the Williston Reservoir have increased over the 1984 to 2007 period, and that trends exist in the seasonality of inflows over this period: fall-winter inflows have increased and late summer flows have declined
- Despite uncertainty in the magnitude of projected changes, there is scientific consensus on the direction of climate change with respect to natural inflows to the Peace River. Annual streamflow is projected to increase, though late summer flows are expected to decline. There is evidence of an earlier spring freshet onset and a shift in peak flows from June to May.

The influence of the Project on the surface water regime of the Peace River has been analyzed based on 60 years of historical inflows, including wet and dry years, as described in Section 11.4.5.2.1. The median projected change in annual streamflow for the 2050s and 2080s periods is within the variability observed in the historical 60-year inflow record used in operations modelling. Therefore, the operation of BC Hydro’s generating facilities on the Peace River under a future climate with higher inflows could be inferred from the simulation of operations in years with higher inflows. No requirement for changes to the existing water licences would be expected as a result of climate change.

As a federal requirement of the environmental assessment of the Project, a discussion of the effects of climate change on the Project (in terms of electricity generation potential and extreme floods) is described in Volume 5 Section 37.1.

11.5 Water Quality

This section describes existing water quality conditions and sediment quality in the Peace River and its tributaries in accordance with Section 9.3.2 of the EIS Guidelines for the Project. Water quality parameters discussed include nutrient and metal concentrations, suspended sediment levels, dissolved gas pressure levels, pH, alkalinity, and temperature. Sediment quality parameters discussed include metal and polycyclic aromatic hydrocarbon concentrations.

11.5.1 Regulatory and Policy Setting

Water quality data were compared to guidelines to evaluate baseline conditions. Water quality guidelines used were British Columbia guidelines for the protection of aquatic life, drinking water, wildlife, recreation and aesthetics, irrigation and livestock watering (BCMOE 2010); Canadian Council of Ministers of the Environment (CCME) guidelines for protection of aquatic life, and recreation and aesthetics (CCME 2012a); guidelines for drinking water (Health Canada 2012); and Alberta water quality guidelines for the protection of aquatic life, human health, and wildlife health (Alberta Environment and Water 1999). Guidelines from multiple sources were included because no single source has a guideline for every parameter.

Sediment results were compared to CCME sediment quality guideline for the protection of aquatic life (CCME 2012b), including the lower interim sediment quality guideline (ISQG) and the higher probable effects level (PEL) guideline.

11.5.2 Baseline Conditions Water Quality

The technical study area for water quality extends from the forebay of the Williston Reservoir, through the Dinosaur Reservoir and the Peace River valley to upstream of the confluence with the Alces River (Figure 11.5.1). The technical study area also incorporates the major tributaries, including Maurice Creek, Lynx Creek, Farrell Creek, Halfway River, Cache Creek, Moberly River, Pine River, and Beatton River that drain to the Peace River. The downstream boundary of the technical study area was chosen to correspond to the limit in which changes to water quality from the Project would be negligible (i.e., 10% or less from baseline). A difference of 10% or less is acceptable because analytical uncertainty can be as high or higher than 10%; a difference of 10% or less is unlikely to be statistically significant, and effects to aquatic organisms are unlikely to be detectable for a change of 10% or less in a substance concentration (Volume 2 Appendix P Aquatic Productivity Reports, Part 2 Hydrodynamic, Water Quality, and Productivity Modelling for the Site C Project).

Baseline water quality conditions were determined by completing a review of 1) data collected through field programs in support of the Project; and 2) available monitoring data collected by government agencies (1971 to 2011). Water quality field data were collected in the technical study area for the period of 2006 to 2011, excluding 2009, at stations established for the Project. There were no water quality field programs conducted in 2009. In total, 23 stations were established (Table 11.5.1). Locations of sampling locations are shown on Figure 11.5.1 and provided in Volume 2 Appendix E Water Quality Baseline Conditions in the Peace River. Data collected from government agencies were included to better understand baseline variability.

The water bodies within the technical study area have been categorized into three main groups, as follows:

- Reservoirs
  - Williston Reservoir in the dam forebay upstream of W.A.C. Bennett Dam (W-01, water samples collected at shallow and deep water depths)
  - Dinosaur Reservoir – downstream of W.A.C. Bennett Dam to upstream of the Peace Canyon Dam (Dino-US, Dino-MID, Dino-DS; water samples collected at shallow and deep water depths)
- Peace River Mainstem
  - Downstream of the Peace Canyon Dam, but above the proposed Site C dam location (Peace-01, Peace-02, Peace-03)
  - Downstream of the proposed Site C dam to the confluence with the Alces River (Peace-04, Peace-14, Peace-15, Peace-05)
- Tributaries
  - Tributaries between Peace Canyon Dam and the proposed Site C dam (Lynx Creek, Farrell Creek, Halfway River, Boudreau Creek, Cache Creek, Moberly River)
  - Tributaries between the proposed Site C dam to the confluence with the Alces River (Pine River, Beatton River)

Table 11.5.1 Water Quality Stations in the Technical Study Area and Sampling Effort

Water Body Group	Stations	Years Water Quality Samples Collected				
		2006	2007	2008	2010	2011
Reservoirs	W-01	—	—	—	yes	yes
	Dino-US	—	—	—	yes	yes
	Dino-MID	—	—	—	yes	yes
	Dino-DS	—	—	—	yes	yes
Peace River	Peace-01	—	yes	yes	yes	yes
Tributaries	Lynx 10	—	yes	yes	—	—
	Farrell 11	—	yes	yes	—	—
Peace River	Peace-02	—	yes	yes	yes	yes
Tributaries	Halfway-DS	—	yes	yes	yes	yes
	Halfway-MID	—	yes	yes	yes	yes
	Halfway-US	—	—	—	—	yes
	Boudreau 13	—	yes	yes	—	—
	Cache 12	—	yes	yes	—	—
Peace River	Peace-03	yes	yes	yes	yes	yes
Tributaries	Moberly-DS	—	—	—	yes	yes
	Moberly-US	—	yes	yes	yes	yes
	Moberly-US far	—	yes	yes	—	—
Peace River	Peace-04	yes	yes	yes	yes	yes

Water Body Group	Stations	Years Water Quality Samples Collected				
		2006	2007	2008	2010	2011
Tributary	Pine-16	—	—	—	yes	yes
Peace River	Peace-14	—	—	—	yes	yes
Tributary	Beatton-17	—	—	—	yes	yes
Peace River	Peace-15	—	—	—	yes	yes
	Peace-05	yes	yes	yes	—	—

NOTES:

— not sampled

Stations shown on Figure 11.5.1

More details provided in Volume 2 Appendix E Water Quality Baseline Conditions in the Peace River

The following sections summarize baseline conditions for water quality in the existing reservoirs, the Peace River mainstream, and the tributaries of the technical study area. Detailed information on baseline conditions of water and sediment quality in the technical study area are provided in Volume 2 Appendix E Water Quality Baseline Conditions in the Peace River.

11.5.2.1 Total Dissolved Gas Pressure

Total dissolved gas (TDG) pressure is a measure of nitrogen, oxygen, and other gases in solution. TDG is relevant to fish health since it can result in gas bubble disease/trauma resulting from supersaturation of gases in solution (Golder 2009). The guideline to protect aquatic life is ≤110% saturation (BCMOE 2004).

TDG was measured in 1972 to 1974, and 1995 to 1998, at the Peace River W.A.C. Bennett Dam and generating station and at the Peace Canyon Dam and generating station to understand seasonal variability as it relates to dam and generating station operations (BC Hydro 1999). The measurements showed that elevated levels of TDG occurred during periods of spillway discharge and periods of low discharge. TDG pressure averaged 125% during an emergency spillway release in the summer of 1996 (due to dam safety concerns during high river discharge), but during moderate discharge periods, TDG levels did not exceed 110%.

TDG pressure was measured in Dinosaur Reservoir and the Peace River in 2008 (Golder 2009). In the Peace River, TDG often reached, but seldom exceeded, 103%. In Dinosaur Reservoir, TDG was most variable at the upstream station, and at all stations, was highest at the 5 m and 10 m depth, as compared to surface or deeper stations. In the reservoir, TDG ranged from 103% to 111%.

11.5.2.2 Temperature

Williston and Dinosaur reservoirs are mainly isothermic (i.e., same water temperature through the water column), but they do show evidence of weak stratification occurring in the summer period (i.e., July and August) (Volume 2 Appendix P Aquatic Productivity Reports, Part 1 Baseline Aquatic Productivity in the Upper Peace River). Surface waters in the reservoirs, Peace River, and tributaries freeze in the winter, and reach highs of 16ºC to 17ºC in the summer. More information on the current thermal regime and ice conditions in the Peace River is provided in Section 11.7 Thermal and Ice Regime, and in Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report.

11.5.2.3 Dissolved Oxygen

Surface water in the technical study area is well oxygenated, with mean values of 10 mg/L (90% saturation) or higher in the reservoirs, Peace River, and tributaries across all seasons and stations. Dissolved oxygen is above the most stringent guideline for aquatic life (more than 9.5 mg/L for early life cold water species); therefore, the waters are considered well oxygenated.

11.5.2.4 Total Suspended Solids

Total suspended solids (TSS) include all solid particles suspended in the water column. Elevated TSS levels on fish can affect fish behaviour, physiology, and habitat (Robertson et al. 2006). Many riverine ecosystems such as the Peace River have concentrations of TSS that fluctuate naturally over the seasons, due to runoff from the watershed, and aquatic biota have adapted to these conditions. The CCME protection of aquatic life guideline for TSS is a narrative guideline that recognizes two separate flow conditions: clear flow and high flow. The narratives concerning these two flow conditions are as follows:

- **Clear Flow** Maximum increase of 25 mg/L from background levels for any short-term exposure (e.g., 24-hour period); maximum average increase of 5 mg/L from background levels for longer term exposures (e.g., inputs lasting between 24 hours and 30 days)
- **High Flow** Maximum increase of 25 mg/L from background levels at any time when background levels are between 25 and 250 mg/L; should not increase more than 10% of background levels when background is >250 mg/L

TSS concentrations ranged from 1.5 to 2,760 mg/L across all samples. Measured TSS concentrations are lower in the reservoirs than in the tributaries and the Peace River (See Figure 3-6 in Volume 2 Appendix E Water Quality Baseline Conditions in the Peace River). The lower concentrations of TSS in the reservoirs compared to the Peace River or tributaries is due to the settling out of TSS in the lower energy (still water) environment of the reservoir.

TSS was highest in spring, compared to summer or fall in the reservoirs, Peace River, and tributaries. In the Peace River, there was also an increase in TSS from upstream of the Halfway River (Station Peace-02, overall mean through all seasons = 17 mg/L) to downstream of the Halfway River (Peace-03; overall mean through all seasons = 75 mg/L).

Studies were also conducted on fluvial geomorphology and sediment transport for the EIS. Findings of these studies are provided in Section 11.8 Fluvial Geomorphology and Sediment Transport, and Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report.

11.5.2.5 Alkalinity and pH

Total alkalinity varies seasonally and spatially, and ranged from 27 to 458 mg/L across samples collected in the reservoirs, Peace River, and tributaries. Total alkalinity concentrations were similar in the reservoirs and Peace River, but higher in the tributaries (Volume 2 Appendix E Water Quality Baseline Conditions in the Peace River).

In the reservoirs, median total alkalinity concentrations were 85 mg/L in spring, 81 mg/L in summer, and 77 mg/L in fall. In the Peace River, median alkalinity concentrations were 89 mg/L in spring, 85 mg/L in summer, and 82 mg/L in fall. In the tributaries, median alkalinity was 100 mg/L in spring, 152 mg/L in summer, and 152 mg/L in fall. These measured concentrations of total alkalinity in the technical study area indicate that the waters are well buffered against acid deposition. There are no Canadian guidelines for alkalinity.

Measured pH ranged from 5.8 to 8.8 across all samples, and pH in the technical study area is described as neutral to slightly basic. One of 393 measurements had values below the lower chronic aquatic life limit guideline value of 6.5 for the protection of aquatic life (Peace-04, winter).

11.5.2.6 Nutrients

Nutrients include nitrogen and phosphorus compounds that are required in small quantities for plant growth. Nitrogen in fresh waters may be present in various forms, such as ammonia, nitrate, nitrite, and organic nitrogen. Total phosphorus includes measures of particulate phosphorus, dissolved organic phosphorus, and dissolved inorganic phosphorus.

Total Kjeldahl nitrogen (TKN), which is the sum of organic nitrogen and ammonia, ranged from 0.025 to 0.51 mg/L in the reservoirs, from 0.025 to 2.5 mg/L in the Peace River, and from 0.025 to 4.3 mg/L in the tributaries. There are no Canadian guidelines for TKN, but measured concentrations of TKN provide information on nitrogen in the aquatic ecosystem.

Total ammonia ranged between 0% and 46% of TKN in the samples. Ammonia concentrations ranged from 0.0002 mg/L (Williston Reservoir) up to 0.21 mg/L (maximum level recorded at Cache Creek in the winter). Total ammonia concentrations did not exceed guidelines for the range of temperatures and pH conditions during sampling within the technical study area. The ammonia guideline is for unionized ammonia; the amount of unionized ammonia in a sample increases as pH and temperature increase. Seasonal (spring, summer, and fall) median concentrations of ammonia were similar in the Peace River (0.01 mg/L, 0.01 mg/L, and 0.0034 mg/L, respectively) and tributaries (0.01 mg/L, 0.01 mg/L, and 0.0043 mg/L, respectively), and were lower in the reservoir (0.0024 mg/L, 0.067 mg/L, and 0.0029 mg/L, respectively).

Nitrate concentrations did not exceed the chronic or acute guidelines for the protection of aquatic species, or guidelines for drinking water quality. Median concentrations of nitrate by season (spring, summer, and fall) were similar in the reservoirs (0.051 mg/L, 0.052 mg/L, and 0.051 mg/L, respectively) and the Peace River (0.05 mg/L, 0.041 mg/L, and 0.041 mg/L, respectively), but lower in the tributaries (0.026 mg/L, 0.0074 mg/L, and 0.0016 mg/L, respectively).

Concentrations of total phosphorus ranged from 0.001 mg/L to 2.3 mg/L in 307 measurements, with the maximum concentration recorded at Cache Creek. Total phosphorus is often positively correlated with TSS because the molecule adsorbs onto colloidal particles. As with TSS, there was a similar spatial trend of total phosphorus in the Peace River in spring, and less distinct spatial differences in summer and fall. Median total phosphorus across all stations on the Peace River was highest in the spring (0.069 mg/L) and lower in the summer (0.017 mg/L) and fall (0.012 mg/L). Monitoring data indicate that all tributaries contribute similar concentrations of total phosphorus to the Peace River in the spring, but the Halfway River and the Moberly River contribute higher concentrations of total phosphorus to the Peace River in summer. Variability in total phosphorus concentrations is due to weathering of materials in the watershed that are flushed downstream during high flows and biological uptake of dissolved forms during biologically active periods (summer and fall) (Volume 2 Appendix P Aquatic Productivity Reports, Part 1 Baseline Aquatic Productivity in the Upper Peace River).

11.5.2.7 Metals

Metals are naturally present in surface waters in small quantities (typically less than 1 mg/L). The level at which metals are toxic varies by metal and can be dependent on the hardness of the water.

Detailed and specialized studies were conducted on methylmercury with results provided in Section 11.9 Methylmercury and Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report. A summary of metals measured in the reservoirs, the Peace River, and the tributaries of the technical study area are summarized in this section and in Volume 2 Appendix E Water Quality Baseline Conditions in the Peace River.

Metals with at least one value that exceeded a total metal guideline included aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, selenium, silver, thallium, vanadium, and zinc. Dissolved metal parameters with at least one value that exceeded a guideline included aluminum and iron. Aquatic life guidelines were developed to provide protection to aquatic life from anthropogenic stressors (CCME 1999), but it is recognized that aquatic ecosystems may naturally have concentrations of water quality constituents above guidelines, as based on local factors such as geology, soils, climate, and weather. In these cases, aquatic organisms have adapted to their environment, and exceedance of guidelines does not imply that the aquatic system is unhealthy. Understanding of baseline conditions prior to anthropogenic disturbances is necessary to understand the sensitivities of the aquatic environment, and to track potential future changes. Guidelines are developed and updated based on the most recent toxicological data (CCME 1999). As toxicological data are not available for all metals measured in water, not all metals have guidelines; as such, baseline data provide benchmarks for use in future studies.

Concentrations of total metals that most often exceeded guidelines included aluminum, dissolved aluminum, arsenic, cadmium, chromium, copper, iron, dissolved iron, lead, and zinc. The proportion of samples, by water body group (i.e., reservoir, Peace River, tributaries), with total metal concentrations that exceeded the lowest guideline (chronic aquatic life) are provided in Table 11.5.2. Other guidelines that were also exceeded are as follows:

- Acute aquatic life (aluminum, arsenic, chromium, copper, iron, and zinc)
- Drinking water (aluminum, arsenic, lead)
- Human health (aluminum and lead)

- Wildlife health (aluminum)

Table 11.5.2 Percent of Samples with Concentrations Above Guidelines (by Water Body Type and Metal)

Metal	Reservoirs	Peace River	Tributaries
Aluminum	76%	83%	94%
Aluminum – dissolved	5%	7%	22%
Arsenic	0%	5%	13%
Cadmium	19%	54%	67%
Chromium	6%	43%	67%
Copper	5%	34%	45%
Iron	10%	53%	82%
Iron – dissolved	0%	3%	8%
Lead	0%	11%	24%
Selenium	2%	1%	34%
Zinc	3%	15%	34%

Of all metals, total aluminum most often exceeded the guideline (in 76% of samples from the reservoirs, 83% of samples from the Peace River, and 94% of samples from the tributaries). Dissolved aluminum exceeded the guideline in less than 10% of samples (5% of samples from the reservoirs, 7% of samples from the Peace River, and 22% of samples from the tributaries. For all metals summarized in Table 11.5.2, tributaries had the highest percentage of samples with concentrations that exceeded the guidelines, while reservoirs had the lowest percentage of samples with concentrations that exceeded the guidelines.

Many of the total metals have a positive correlation to TSS, and similar trends are evident in their hydrologic distributions, with highest concentrations of metals measured in the tributaries, moderate concentrations in the Peace River, and lowest concentrations in the reservoirs. High concentrations of metals are expected during conditions of high flows and high TSS movement. TSS concentrations were highest in the tributaries, lower in the Peace River, and lowest in the reservoirs, as such highest concentrations of total metal concentrations in the tributaries is not unexpected.

For most metals, there was also a strong spatial trend, where the proportion of samples with concentrations exceeding guidelines increased with distance downstream from the Peace Canyon Dam. For many metals, concentrations were higher downstream of the Halfway River (Peace-03) as compared to downstream of the Peace Canyon Dam (Peace-01), and then higher again downstream of the Kiskatinaw River (Peace-05) as compared to upstream of the Kiskatinaw River (Peace-15). This spatial trend was most evident in the spring as compared to the summer or fall (i.e., during freshet, when weathered materials are flushed downstream). This downstream spatial trend is also not unexpected because the size of the contributing watershed increases in a downstream direction, and thus the potential contribution of metals, or other parameters, also increases in a downstream direction.

11.5.2.8 Drinking Water Sources

Public drinking water sources within the technical study area have been reviewed and are discussed in detail in Volume 4 Section 30 Community Infrastructure and Services. Communities and drinking water sources in the technical study area are summarized in Table 11.5.3. There are also 48 registered and seven non-registered drinking water wells within a 2 km distance from the proposed reservoir (Volume 2 Appendix F Groundwater Regime Technical Data Report).

Table 11.5.3 List of Communities and Water Sources in the Technical Study Area

Community	Water Source
Fort St. John	Groundwater (formerly Charlie Lake) Peace River (future expansion)
Taylor	Shallow wells in the Peace River (near the confluence of Pine and Peace Rivers)
Hudson's Hope	Peace River

NOTE:

See Volume 4 Section 30 Community Infrastructure and Services for more information on community drinking water sources

11.5.3 Baseline Conditions Sediment Quality

Baseline sediment quality conditions were determined by completing a review of data collected through field programs in support of the Project. Sediment quality field data were collected in the technical study area in 2007, at stations established for the Project. Sediment data were not available for B.C. from government agencies.

The technical study area for sediment quality is the same as the technical study area for water quality. The technical study area extends from the forebay of the Williston Reservoir, the Dinosaur Reservoir, and the Peace River valley to the confluence with the Alces River, including major tributaries (Cache Creek, Halfway River, Moberly River, Pine River, Beatton River) (Figure 11.5.1).

Thirteen samples were collected in 2007 for sediment quality analysis from stations on the Peace River, Moberly River, and Halfway River. Depositional areas were targeted for sampling. Sediment composition was classified as sandy. Arsenic exceeded the ISQG in all samples except from one station on the Peace River upstream of the Halfway River. Cadmium exceeded the ISQG in three samples (Peace-02, Peace-03, and Halfway River). In all other samples, cadmium was less than the ISQG. No other metals had concentrations above the ISQG, and no metals had concentrations above the PEL.

A review of metal data in the sediments does not show a strong spatial trend with increasing concentrations in a downstream direction. Concentrations of polycyclic aromatic hydrocarbons did not exceed the PEL. Concentrations of 2-methylnaphthalene were above ISQG guidelines in 10 samples, concentrations of naphthalene were above ISQG guidelines in four samples, and concentrations of phenanthrene were above ISQG guidelines in seven samples. Concentrations were not above the PEL values.

11.6 Groundwater Regime

11.6.1 Introduction

The following subsections describe the groundwater regime in terms of both baseline conditions and potential changes as a result of the reservoir creation. A detailed description of the groundwater regime is presented in Volume 2 Appendix F Groundwater Regime Technical Data Report. Additional information on the groundwater regime can be found in Volume 2 Appendix B Geology, Terrain Stability, and Soil Reports, Part 1 Terrain Stability Mapping, Part 2 Preliminary Reservoir Impact Lines, and Part 3 Contaminated Sites Report.

The component of the Project that would influence the groundwater regime is the reservoir. Reservoir creation would cause the groundwater table to rise in certain areas inland from the reservoir shoreline. The distance inland and the amount of groundwater table rise depends on the geology, the groundwater levels, and the amount of rise in the surface water from the creation of the reservoir. An understanding of the groundwater flow regime and of potential changes to the groundwater flow caused by the creation of the reservoir were used in the evaluation of potential effects of the Project on agriculture (Volume 3 Section 20 Agriculture), on groundwater use, and on underground infrastructure such as municipal water systems (Volume 4 Section 30 Community Infrastructure and Services).

An evaluation of project construction on groundwater quality indicated that there is a low likelihood that groundwater chemistry would undergo change and affect groundwater use.

11.6.2 Technical Study Area

The technical study area for the groundwater regime study is from Peace Canyon Dam to the Site C dam. This can be defined as the region to be covered by the reservoir (i.e., the area to be flooded), including the tributary valleys that would be inundated by the reservoir. Areas adjacent to the reservoir that would undergo influence on physical groundwater flow as a result of the creation of the reservoir have also been included within the technical study area (see Figure 11.6.1).

11.6.3 Regulatory and Policy Setting

Groundwater in B.C. is regulated under the B.C. *Water Act,* the B.C. Ground Water Protection Regulation, the B.C. *Environmental Management Act*, and the B.C. Contaminated Sites Regulation.

The B.C. Water Quality Guidelines (B.C. Ministry of Environment 2006, 2010) are not directly applicable to assessing groundwater quality, as the guidelines were developed for protecting surface water quality. However, the groundwater analytical results were screened against the guidelines to evaluate whether or not the groundwater contains naturally occurring constituents that, upon discharge to surface water, may influence surface water quality.

The B.C. Contaminated Sites Regulation (B.C. Ministry of Environment 2011) provides standards to determine if concentrations of substances in groundwater are acceptable for the water uses (e.g., drinking water, aquatic life) present at a site. In addition to the chemical contaminants listed in the Contaminated Sites Regulation, the Guidelines for Canadian Drinking Water Quality: Summary Table (Health Canada 2012) provides guidelines to address microbiological and radiological contaminants as well as physical characteristics that could affect taste and odour.

11.6.4 Approach and Methods

The groundwater regime, terrain stability, and preliminary impact line studies were informed by the same data, and the three studies provide information on baseline conditions and on potential changes to groundwater elevations as a result of reservoir creation. The specific approach and methodology associated with the data collection and analytical approach is described in detail in the following sections of the EIS:

- Volume 2 Section 11.2 Geology, Terrain, and Soils
- Volume 2 Section 11.2.3.5 Groundwater Flow
- Volume 2 Appendix B Geology, Terrain Stability, and Soil
  - Part 1 Terrain Stability Mapping
  - Part 2 Preliminary Reservoir Impact Lines
- Volume 2 Appendix F Groundwater Regime Technical Data Report

The description below provides a summary of the tasks completed to define the baseline (i.e., prior to creation of the reservoir) and to predict future potential changes to the groundwater regime (flow and quality).

11.6.4.1 Review of data sources

Geology

The following geological studies in the technical study area were reviewed:

- Investigations of bedrock and overburden materials by Irish (1958), Mathews (1978), Stott (1982), Cornish and Moore (1985), Hartman (2005), and Hartman and Claque (2008)
- A surficial map of the area by Hickins and Fournier (2011)
- Extensive surface and subsurface investigations associated with the proposed Site C dam, completed by Thurber Consultants Ltd. (1978) and BC Hydro (1981)
- Engineering geology work documented by Imrie (1991), Bidwell (1999), and Klohn Crippen Berger Ltd. and SNC-Lavalin (2009)
- Recent detailed surface mapping and drilling completed by BGC (BGC 2012)

Information on geology, terrain, and soils in the technical study area can be found in Volume 2 Section 11.2 Geology, Terrain, and Soils.

Groundwater Elevations, Seepage Locations, and Springs

Groundwater elevation, seepage data and project-specific historical geotechnical data were reviewed. Additional geotechnical surface mapping was conducted in 2010 and

2011 (BGC 2012). Forty-five new drill holes were completed and piezometers installed and instrumented for groundwater seepage, slope stability, and groundwater quality analysis. Groundwater level data were obtained from these locations, and hydraulic conductivity tests were performed to gain an understanding of the local groundwater regime (BGC 2012). The surface mapping, drilling, water level, and hydraulic conductivity data were analyzed and used to construct representative geological cross-sections for two-dimensional seepage analysis. They were also used to predict groundwater levels and the occurrence of potential seepage locations and springs, and to support slope stability modelling work.

Drinking Water

A regional water well search was conducted using the Ministry of Environment online water well registry databases, to assist in identifying water wells within a 2 km lateral distance from the proposed reservoir. In addition, a mail-in survey was sent to property owners within the site area in April 2011 in an effort to identify additional “non-registered” water wells in the region. The results of this work identified 48 registered and seven non-registered drinking water wells within a 2 km lateral distance from the proposed reservoir.

Infrastructure and Land Use

Infrastructure and land use information was obtained from various sources, including:

- Historical aerial photographs, orthophotos, and satellite imagery
- Utility and service maps
- Ministry of the Environment databases containing information pertinent to water well licences, permits, and site registry listings
- Municipal water and wastewater coverage information obtained from the District of Hope and the Peace River Regional District
- Terrestrial ecosystem mapping data

Assessment of Contaminated Sites

Findings from the potential contaminated sites study within the project region were reviewed (see Volume 2 Appendix B Geology, Terrain Stability, and Soil Reports, Part 3 Contaminated Sites Report).

11.6.4.2 Field Study

Piezometer Installation

A total of 63 standpipe piezometers and two vibrating wire piezometers were installed in existing boreholes in 2011. The locations of the piezometers are shown in Volume 2 Appendix F Groundwater Regime Technical Data Report. Piezometers were installed with depths ranging from 7 m to 145 m below ground. Prior to the commencement of piezometer installation, drill holes were flushed with water to remove remaining drilling cuttings and residual drilling fluid.

Groundwater Monitoring and Sampling

Current groundwater conditions within the proposed inundation area were evaluated through records of seepage during surface inspections, measuring water levels in the installed standpipe piezometers by using dip meters, and estimating hydraulic conductivity through packer and slug testing. Level recorders were installed in 10 piezometers in the south bank drill holes in October 2011. Level recorders were installed in drill holes on the north bank in March 2012.

Piezometer Sampling

Baseline groundwater quality was evaluated through monitoring and sampling of 15 piezometers and associated nested piezometers within various lithologies to establish the baseline groundwater chemistry. Samples were collected in August 2012. A total of 21 samples were analyzed for the following parameters:

- Dissolved metals
- Dissolved anions
- Speciated alkalinity
- Total dissolved solids (TDS)
- Total suspended solids (TSS)
- Dissolved organic carbon (DOC)

Results were compared to the B.C. Water Quality guidelines (B.C. Ministry of Environment 2006, 2010).

Drinking Water Well Sampling

Baseline groundwater quality was also evaluated through drinking water well sampling. Samples were collected from five drinking water wells in July 2012. The samples were analyzed for the following parameters:

- Alkalinity
- Colour
- Hardness
- pH
- Total dissolved solids (TDS)
- Turbidity
- Chloride
- Fluoride
- Nitrate
- Nitrite
- Sulphate
- Dissolved Metals

- Total Metals
- Coliforms

Results were compared to the Guidelines for Canadian Drinking Water Quality (Health Canada 2012) and the B.C. Contaminated Sites Regulation (B.C. Ministry of Environment 2011).

11.6.4.3 Flow Models

Twenty-five geologic cross-sections were created for both the low bank and high bank slopes along the proposed reservoir, using new and historical data along with surface LiDAR topography. Each cross-section is 600 m to 2,000 m long, generally perpendicular to the Peace River. These geologic cross-sections were combined with hydraulic conductivity testing results and a review of historical data and regional literature to develop a conceptual hydrogeological model for the river valley (BGC 2012).

The conceptual hydrogeological model was used to develop a series of cross-sectional numerical groundwater flow models, aligned with the geological cross-sections. Each cross-section was imported into SEEP/W (GeoStudio 2007, Version 7.17), an industry standard two-dimensional finite element groundwater seepage analysis software developed by GEOSLOPE International Ltd. The resulting 25 seepage models were calibrated against field-observed water level and hydraulic conductivity test data. The water table and pore water pressure results were used for stability analysis as well as in the evaluation of changes to groundwater levels due to inundation of the proposed reservoir.

11.6.4.4 Analysis

Groundwater level changes due to the proposed reservoir were predicted along 25 cross-sections, using SEEP/W. Changes to the water table elevation (i.e., head increase) and subsurface pore pressures were evaluated along each simulated cross-section. The specific predictions along the cross-sections were used to estimate groundwater level and pore pressure impacts at other locations along the reservoir.

To determine the likelihood that reservoir formation (i.e., water table rise) could influence groundwater quality due to the presence of the potentially contaminated sites, the locations of these properties were cross-referenced with the predicted rise in water table at set transects/cross-sections located along the reservoir. In situations where the predicted water table elevation increased by greater than 1 m (within model accuracy) beneath the contaminated site, it was considered possible that the groundwater quality could be influenced by potentially contaminated soils existing immediately beneath the property. This 1 m rule was not applied at properties where a perched aquifer is present, as the perched aquifer would be at a relatively higher elevation and not in communication with the regional water table and therefore not influenced by the reservoir formation.

Determination of the influence on groundwater chemistry due to water table rise into new geologic materials was analyzed by similar methods. The geologic cross-sections used for model construction and model-predicted flow were viewed to see where the water table rise would result in groundwater coming into contact with new geologic materials. Areas where the predicted water table rise would occur within new geologic materials and those geologic materials were unsaturated (i.e., no perched water tables within them) were considered potential regions where the groundwater chemistry could be influenced.

11.6.5 Results

11.6.5.1 Baseline Conditions

The groundwater regime within the slopes adjacent to the proposed reservoir typically consists of water tables perched on lower permeability silt and clay or bedrock units, with the sandier interbeds providing drainage to the slope face, resulting in groundwater exiting as springs. Further description of the baseline groundwater flow regime is provided in Volume 2 Section 11.2 Geology, Terrain, and Soils, Section 11.2.3.5 Groundwater Flow.

Baseline drinking water and groundwater monitoring indicated the presence of parameters in excess of guidelines/criteria. Specifically, samples collected from accessible drinking water wells in the Technical Study Area were found to be in exceedance of the Guidelines for Canadian Drinking Water Quality for various parameters (pH, total dissolved solids, barium, iron, manganese, and sodium). One drinking water sample exceeded the B.C. Contaminated Sites Regulation standard for sodium. Coliforms were also present in three of the five wells. The results of the drinking water well monitoring program are presented in Table 4-4: Drinking Water Analytical Results, found in Volume 2 Appendix F Groundwater Regime Technical Data Report.

Each of the 21 analyzed samples collected from the piezometer sampling program exhibited alkalinity and/or concentrations of at least one of the analyzed metals greater than the B.C. Water Quality Guidelines. The results of the piezometer monitoring program are presented in Table 4-3: Groundwater Analytical Results – Piezometers, found in Volume 2 Appendix F Groundwater Regime Technical Data Report.

The groundwater geochemistry within the piezometers varied, based on spatial location within the technical study area as well as geologic unit sampled. This variation is anticipated, as the groundwater chemistry reflects the mineralogy of the different lithologic units over which the piezometers were screened.

No anthropogenic sources for the non-coliform exceedances were apparent, and therefore the exceedances may be natural background concentrations.

11.6.5.2 Groundwater Regime Predictions

On a reservoir-wide scale, the smallest predicted changes in groundwater levels occur upstream, where the reservoir would have little effect on surface water levels, while the largest changes would occur closer to the Site C dam site, where the reservoir water level would increase by up to 50 m compared to the current Peace River water level. The stratified bedrock and overburden sediments near the reservoir edge would limit changes in groundwater levels within the overburden, due to reservoir formation. The results show that changes in groundwater level do occur, due to reservoir level rise in some of the modelled reservoir cross-section locations. The predicted increases in the deeper groundwater elevations in the valley slopes at the proposed reservoir shoreline range from 1.6 m to 14 m. Groundwater level increases of up to 6 m are predicted at distances up to 1,600 m from the reservoir shoreline in one cross-section containing a local buried valley. For the majority of sections analyzed, the predicted increase in groundwater level is less than 3 m at a distance of 1,600 m from the proposed shoreline.

A series of two-dimensional cross-sections at representative reservoir locations where reservoir filling could affect slope stability, land, or resource use are shown in Volume 2 Appendix F Groundwater Regime Technical Data Report, Appendix B Figures 1 to 21. In the cross-sections, subsurface geology, aquifers, and water table positions are shown for the baseline conditions and estimated for reservoir conditions.

The locations of existing water wells, springs, infrastructure, and land use that could be affected by changes are shown in Volume 2 Appendix F Groundwater Regime Technical Data Report, Figures 8 to 24, and are described in the section below. In accordance with page 3 of Section 1.2 of the EIS Guidelines, information about the locations of potentially contaminated sites has not been provided.

11.6.6 Potential Implications of Groundwater Regime Changes

Future potential changes to groundwater quality are directly linked to the amount of rise in the water table. If the water table elevation increases beneath a site, causing the groundwater to come into contact with contaminated soils (if present), groundwater quality may be locally influenced. Results of the predictive modelling indicate that only five properties with potentially contaminated sites may experience a sufficient (i.e., in the order of several metres above baseline conditions) water table rise to influence groundwater quality. The limited number is in part attributable to the fact that these potential contaminated properties are primarily located either in Hudson's Hope or Fort St. John. Generally, reservoir levels and therefore groundwater levels are expected to increase the most in the vicinity of the dam site and increase the least furthest upstream (Hudson's Hope area). Fort St. John is located well above the proposed reservoir level, and Hudson's Hope is furthest upstream on the proposed reservoir. In addition to potential changes to groundwater quality, direct inundation of these sites may also influence surface water quality. In accordance with page 3 of Section 1.2 of the EIS Guidelines, information about the locations of potentially contaminated sites has not been provided.

There are also agricultural lands within the proposed reservoir area. Upon reservoir formation, these properties would experience full or partial inundation and water table rises, which may influence both groundwater and surface water quality if pesticides, herbicides, or fertilizers were used and are present in soil or groundwater. The potential for pesticides, herbicides, or fertilizers to be present in soil and groundwater is dependent on many factors (e.g. chemical content, rates of application, absorption, solubility, persistence, soil type, etc.). Management of these lands is discussed in Section 11.6.9.

When an increase in groundwater table elevation occurs and results in the groundwater coming into contact with new geologic materials (e.g., soil/rock types) of different composition, the groundwater chemistry may be influenced. Based on the predicted water table rise in the technical study area, there is a low likelihood that groundwater chemistry would change as a result of groundwater coming into contact with new geologic materials. Some localized influence on groundwater chemistry may occur in areas where the water table rises into thin units (if present) that differ in physical characteristics and chemical composition.

11.6.7 Groundwater Use

Many of the existing water wells would experience some degree of influence. Of the approximately 55 known/identified water wells along the reservoir, six are expected to undergo direct submersion (i.e., reservoir would submerge the wells). The remaining wells are anticipated to experience a relative increase in the water level in the well ranging from less than 1 m to 10 m, depending on their relative location along the reservoir and distance away from the reservoir edge. The increase in water level is not anticipated to influence the quality of the groundwater within the well or influence operation but may, in fact, result in greater well yield due to increasing the amount of water in the well. However, groundwater quality could become influenced in situations where either a flooded septic field or a contaminated site with impacted groundwater is located in close proximity to an operating water well. General regions where this may occur are adjacent to the proposed reservoir in the Hudson's Hope, Lynx Creek, and Farrell Creek areas.

11.6.8 Infrastructure and Land Use

Groundwater-related influence on infrastructure (e.g., building foundations and septic fields) is anticipated in regions where these structures are located in close proximity to the future reservoir. As the majority (approximately 90%) of the lands containing infrastructure are located topographically above the proposed reservoir levels, only limited inundation or influence related to water table rise is anticipated. These include single residential properties containing buildings and likely septic fields.

Groundwater-related influence on agricultural land use may occur in areas where the water table is anticipated to rise within 1 m of ground surface. Agricultural properties located in low terraces and banks near the proposed reservoir may experience reduced agricultural capacity. However, the majority of the cultivated lands within the technical study area are located topographically above the proposed reservoir levels by more than a metre, and therefore only limited inundation or influence related to water table rise is anticipated. These areas are primarily limited to low bank areas in the vicinity of the creeks (e.g. Lynx Creek, Dry Creek, Farrell Creek, south bank of KM 49-62 (BC Hydro River Kilometre markings, measured downstream from Bennett Dam along the main channel of Peace River), Halfway River, Cache Creek, Wilder Creek) and the Peace River. Loss of agricultural land may extend from the reservoir's edge to directly adjacent land as a result of an increase in groundwater elevation in the underlying soils.

11.6.9 Management of Potential Implications

Prior to reservoir filling, building infrastructure, groundwater wells, and septic tanks/fields at properties within the proposed inundation area would be decommissioned to reduce the potential for affecting groundwater quality for existing water well users.

Prior to reservoir inundation, further investigation and, as warranted, site remediation, would be conducted on potentially contaminated properties and on properties where residual pesticides and herbicides may be present at concentrations of concern.

11.6.10 Conclusions

The following conclusions are formulated based on the results of this study:

- Perched conditions and dry monitoring wells are common in the overburden hydrostratigraphic units below the plateau and in the valley slopes. Bedrock hydraulic conductivities are low and impede groundwater seepage. Where the bedrock contact is above the Peace River elevation, the water table generally occurs in the overburden near the top of the bedrock.
- Baseline (prior to creation of the reservoir) groundwater monitoring indicates the presence of parameters in excess of B.C. Water Quality Guidelines and the Contaminated Sites Regulation standards for the protection of drinking water and aquatic life. Exceedances of the Guidelines for Canadian Drinking Water Quality were also observed.
- Predicted groundwater level changes are influenced by the local geology, current groundwater conditions, distance from the proposed reservoir shoreline, and topography
- The stratified bedrock and overburden sediments near the reservoir edge would limit changes in groundwater levels within the overburden due to reservoir formation. Around most of the proposed reservoir, this results in a low potential for the proposed reservoir to influence groundwater flow in the overburden sediments above the operating reservoir elevation of 461.8 m (maximum normal reservoir level).
- Predicted increases in the deeper groundwater elevations at the proposed reservoir shoreline range from 1.6 m to 14 m. The largest predicted changes occurred within the glacially carved bedrock depression in the Hudson's Hope to Farrell Creek stretch of the Peace River, and between Halfway River and Cache Creek. At a distance of 1,600 m from the proposed shoreline for the majority of sections analyzed, the predicted increase in groundwater level is generally less than 3 m.
- Five out of 40 of the identified potentially contaminated sites properties may experience adequate water table rise to potentially influence groundwater quality
- There is a low likelihood that groundwater chemistry would undergo change affecting groundwater use as a result of it coming into contact with new geologic materials. Some localized influence on groundwater chemistry may occur in areas where the water table rises into thin interbedded units (if present) that differ in physical characteristics and chemical composition.
- Six out of 55 known water wells would likely undergo direct inundation during reservoir infilling. A rise in the height of the water table ranging from <1 m to 10 m is anticipated for the remaining known wells. The rise in the water levels is expected to result in increased well yield.
- The majority (approximately 90%) of the lands within the technical study area containing infrastructure or designated within the Agricultural Land Reserve are located topographically above the proposed reservoir levels. Inundation or influence related to water table rise would only be anticipated below the maximum proposed reservoir levels and in directly adjacent areas where groundwater elevation may

affect crop growth (i.e., at locations where groundwater is anticipated to rise within 1 m of ground surface).

- Contaminated Site and Groundwater Quality Management Plans would be developed prior to construction to mitigate potential influences from potentially contaminated sites and septic systems

11.7 Thermal and Ice Regime

The section summarizes more detailed analyses presented in Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report, Volume 2 Appendix G Downstream Ice Regime Technical Data Report, and Volume 2 Appendix E Water Quality Baseline Conditions in the Peace River (namely, water temperature analysis). Three technical study areas are outlined for these analyses. The technical study area for the reservoir water temperature and ice regime was the Site C reservoir (between the Peace Canyon Dam and the Site C dam) at the maximum normal operating level. For the downstream ice regime study, the technical study area extended from the Peace Canyon Dam (for the scenario without the Project) or the Site C Dam (for the scenario with the Project) to Fort Vermillion, AB, approximately 726 km downstream. This location was selected as the downstream boundary as this is usually the first location at which the ice front location is recorded in each ice season. Also, previous modelling results indicated that this location is well downstream of where changes to the ice regime would occur as a result of the Project. Finally, changes to water temperature downstream of the Site C dam were analysed as part of the water quality study, the boundaries of which extended from the forebay of the Williston Reservoir to upstream of the confluence with the Alces River.

11.7.1 Baseline Conditions

The geography of the Peace River is shown in Figure 11.7.1, along with a number of locations relevant to the thermal and ice regime. The Peace River flows eastward from the W.A.C. Bennett and Peace Canyon dams for about 400 km towards the Town of Peace River, Alberta, where the river turns north. Approximately 300 km downstream of the Town of Peace River is Tompkins Landing, a ferry crossing near High Level. From there, the river turns east and flows for another 550 km, passing through the town of Fort Vermilion and the community of Peace Point, before joining with a number of tributaries to form the Slave River, which eventually flows into Great Slave Lake in the Northwest Territories.

The following sections describe the baseline thermal and ice conditions in the Peace River.

11.7.1.1 Baseline Thermal Regime

The Peace River is regulated by the W.A.C. Bennett Dam, which impounds Williston Reservoir, and to a lesser extent by the Peace Canyon Dam, which impounds Dinosaur Reservoir. The hydrologic characteristics of the Peace River, its tributaries, and variations in flow due to regulation are described in Volume 2 Section 11.4 Surface Water Regime. The baseline thermal and ice conditions in the Peace River include the influence of existing reservoirs and regulated discharges. The primary consequences of regulation are the storage of water in Williston Reservoir and the release of that water throughout the year, resulting in a different seasonal pattern of flows than the pre-regulation period. This storage of water can also be considered a reservoir of thermal energy. In the winter, relatively warm water exits Williston Reservoir and gradually loses heat to the cold ambient air as it moves downstream through Dinosaur Reservoir and then the Peace River. At some point, this water cools to a point where ice starts to form. Similarly, in summer, water that is relatively cool leaving the reservoir is warmed by solar energy and heat transferred from the ambient air as it travels downstream.

For the characterization of the baseline thermal regime, water temperature data were collected at three locations in Dinosaur Reservoir, at five locations in the Peace River, and at eight tributaries between 2007 and 2010 (Volume 2 Appendix E Water Quality Baseline Conditions in the Peace River). The monitoring stations discussed in this section are shown in Figure 11.7.1. Temperature was recorded hourly by BC Hydro in the tailrace (outlet) of Peace Canyon Dam from 1999 to 2012, and in the tailraces of the W.A.C. Bennett Dam from 2009 to 2012. Hourly records of the existing Peace River temperatures near Old Fort, 6.5 km downstream of the proposed Site C dam, were available from the Water Survey of Canada hydrometric station 07FA004 (Peace Above Pine) from 2007 to 2012. Hourly records of the existing Peace River temperatures at the Alces River confluence, 4.3 km upstream of the B.C.–Alberta border, were available from 2007 to 2008 at the Peace 5 station.

Hourly temperature time series data collected at locations downstream of the proposed Site C dam (i.e., the Peace Above Pine Water Survey of Canada hydrometric station and the Peace 5 station) are useful for comparison with predicted water temperatures with the Project to characterize changes due to the Project. Upstream of the Site C dam, there would be a different thermal regime than today, as the existing river would be transformed to a deep reservoir. The expected thermal regime in the Site C reservoir is described separately from the Peace River thermal regime in Section 11.7.3.3.

Daily average temperatures at the Peace Canyon Dam, Peace Above Pine, and Peace 5 stations are presented in Figure 11.7.2. The periods of record for the Peace 5 and Peace Above Pine temperature data overlap for one year, 2008, and this period is used to characterize the existing thermal regime. The following is a discussion of the existing thermal regime of the Peace River, with an explanation of how the existing reservoirs influence water temperature downstream.

Williston Reservoir has a large volume of water, and water temperature changes are slow, compared to a river. This leads to cooler outlet water temperatures in the spring and warmer outlet water temperatures in the fall than would be expected without Williston Reservoir. Due to small volume and the short flow-through times of the Dinosaur Reservoir, it has little influence on temperatures when compared to the influence of Williston Reservoir. Close to the Peace Canyon Dam, water temperatures in the Peace River are determined by the temperatures in the upstream reservoir. As water moves downstream, its temperature is influenced by air temperature and local meteorological conditions. For example, temperatures observed in the Peace Canyon tailrace peak an average of 40 days later than river temperatures 89 km downstream at the Peace Above Pine station, based on four years of data. Temperatures a further 51 km downstream at Peace 5 peak at the same time as Peace Above Pine, based on one year of overlapping data. The maximum summer temperatures at Peace Above Pine are between 5 and 6°C warmer than at Peace Canyon Dam, while the temperatures at the Peace 5 station are up to 9.5°C warmer than at the outlet of Peace Canyon Dam. This pattern is reversed in winter, with water at Peace 5 cooling earlier than at Peace Above Pine, and the greatest temperature decreases are near 2°C at Peace Above Pine and 3°C at Peace 5.

11.7.1.2 Baseline Ice Regime

This section describes ice formation processes and terminology as well as the observed ice conditions in the Peace River. Water at the outlet of the Peace Canyon Dam never freezes, nor does the immediate downstream reach of the Peace River. As discussed above in Section 11.7.1.1, during winter, water cools as it flows down the Peace River due to its exposure to cooler air temperatures. The point at which the water temperature reaches 0°C, allowing ice formation to begin, is referred to as the zero-degree isotherm.

Near this zero-degree isotherm, suspended frazil ice, or small ice crystals, starts to form throughout the water column. The frazil ice eventually sticks together and floats to the water surface as its buoyancy overcomes the river's turbulence. After the frazil ice rises to the water surface, it forms frazil pans or circular ice floes of a few metres in diameter. These pans continue to travel downstream, growing in number and extent, and can join together to form frazil rafts. The pans also start to solidify and thicken, forming a hard-frozen crust on the top, while more 'slushy' frazil ice rises to the surface and deposits on the underside of the ice pans or ice cover.

On the Peace River, the frazil pans can have solid ice crusts that range from a few centimetres thick up to 20 to 30 cm. Total ice pan thickness, which includes the frozen crust underlain by porous slush, can be 30 cm to 1 m thick. The solid ice that forms the top of these floes is referred to as thermal ice.

Initially, frazil ice forms, remains suspended in the water, and flows downstream along with the river. Downstream of the zero-degree isotherm, stationary border ice, which is attached to the shore of the river, also starts to grow. This border ice forms in low velocity areas close to shore, in back channels and around gravel bars. Border ice reduces the channel width, and at some point frazil pans or rafts jam, and solid ice covers the entire width of the river. Once ice cover starts developing, frazil pans or rafts accumulate at the upstream leading edge of the ice cover and the location of this stoppage point advances upstream. The initial stoppage point is known as lodgement, and the leading ice edge is also referred to as an ice front.

Since 1973, observations of the locations of the ice front in the Peace River have been collected annually by Alberta Environment and BC Hydro (Figure 11.7.3). When plotted as an overlapping time series, the ice front locations with respect to the W.A.C. Bennett Dam provide a concise representation of the timing of freeze-up and breakup and the duration of the ice cover each year at any location along the river. The colours of the lines in this Figure represent the degree-days of freezing of the winter, a measure of the severity of the winter in terms of air temperatures. Degree-days of freezing is calculated as the cumulative total of daily average below freezing air temperatures. The modelled winters cover the range of observed ice conditions in the Peace River.

As the ice front advances upstream, water levels typically rise by between 1 m and 5 m due to the increased resistance and thickness of the ice cover. It is important to note that this increase in water level is not attributable to any change in the flow releases from upstream dams during the ice cover formation period. Peak winter water levels are generally higher than the summer peak water levels, but below bank-full levels.

How much the water level increases as a result of the ice cover formation depends on whether the ice cover is juxtaposed or consolidated. With a juxtaposed ice cover, the ice floes initially arrive at the ice front and gently come to rest edge to edge, without overturning, to form an ice cover that consists of ice pans that are a single layer thick. This can cause the river stage, or water level, to increase approximately 1 m to 2 m. A photograph of a juxtaposed ice cover on the Peace River is shown in Figure 11.7.4.

In certain reaches of the river, the juxtaposed ice cover can collapse and consolidate. As the ice pans build up for tens of kilometres, compressive forces from water drag on the ice cover and the river slope can cause the juxtaposed ice cover to collapse. The ice pans then overturn on each other and can thicken the ice cover from less than a metre to several metres thick in just a few minutes. A photograph of a consolidated ice cover on the Peace River is shown in Figure 11.7.4. This process typically occurs every few hours as the ice front is advancing, and is generally limited to the first 2 km to 5 km of ice cover downstream of the ice front. These types of collapses are termed primary consolidations and produce a relatively uniform, thick ice cover over many kilometres of channel length. The thickened ice cover provides a greater contact area between the channel banks and the ice mass, thereby transferring the downstream forces on the ice cover laterally to the banks rather than to ice downstream, strengthening the ice against further collapse. A consolidated ice cover can cause the river stage, or water level, to increase approximately 3 m to 5 m.

A secondary consolidation can also occur, especially during freeze-thaw cycles. For example, an ice cover can advance through the process of juxtaposition up to 100 km upstream over several days. The entire 100 km length can then suddenly consolidate, and due to the buildup of momentum, the collapse can extend downstream of the newly formed ice into a previously consolidated ice cover, increasing water levels another 1 m to 4 m above the 3 m to 5 m already associated with the initial consolidation event. These secondary consolidations can be triggered by a warming in the weather after a cold spell.

River stage, or water level, can also gradually decrease over time due to ice transport processes. Once freeze-up occurs at a specific location, the frazil slush underneath the cover is eroded from fast-moving areas and deposited in slower-moving areas. This process increases the channel conveyance capacity and causes the river level to gradually decrease after freeze-up even if discharges remain constant or increase. Water levels can slowly decrease by 0.5 m to 1.5 m over several months due to this mechanism. This phenomenon allows for increasing generation and outflows from the BC Hydro hydroelectric facilities later in the winter once the ice cover has sufficiently solidified.

The thermal and ice regime in the Peace River has been simulated by BC Hydro using the Comprehensive River Ice Simulation System Program (CRISSP) model to aid in managing the risk of ice-related flooding downstream. CRISSP is a comprehensive state-of-the-art ice simulation model that is able to simulate river ice processes and associated flow conditions. The ice processes include water temperature; the concentration of suspended and surface ice; ice cover formation, progression, and consolidation; undercover transport and accumulation; ice jam evolution; thermal growth and decay of the ice cover, including the influence of a snow cover; cover stability; initiation of breakup; breakup ice runs; and jam formation. The reliability and uncertainty of CRISSP and other models are discussed in Section 11.7.3.2 below.

11.7.1.3 Timing of Ice Formation and Breakup

The location of ice lodgement, the point that initiates the ice front, on the Peace River is not well known because the initial formation of the ice cover has proven difficult to observe. However, it is thought to form either somewhere in the slower and milder-sloped reaches between Tompkins Landing (km 694) and the Vermilion Chutes (km 912) or farther downstream in the Peace-Athabasca Delta reach. (Note that, in this section, locations on the Peace River are referenced based on river chainage, which is indicated as the distance in kilometres downstream of the W.A.C. Bennett Dam.) It is also possible that multiple lodgement sites occur, and since systematic observations of freeze-up in these reaches have not been made, it is not known exactly how and where the ice cover begins. This lack of observational data is not problematic for this study, as lodgement in the model was set each year to correspond with the observed date at which the ice front arrived at the downstream end of the model (near Fort Vermilion).

Once lodgement occurs, the leading edge of the ice cover (or ice front) continues to advance upstream. Depending on the severity of the winter, freeze-up at Fort Vermilion can occur anytime between mid-November and late December. At the Town of Peace River, it can occur anywhere from early December to late February. Figure 11.7.3 shows the observed ice front location during the winters of 1973–1974 to 2010–2011. The start of the ice front line does not indicate the lodgement locations, but rather the first observation at Fort Vermilion. The lines move upstream (down the vertical axis) with time until they reach the maximum ice front extent, and then retreat downstream (up the vertical axis) as the ice cover breaks up.

After freeze-up at the Town of Peace River, historically between late December and late February, the ice cover continues to advance farther upstream and generally reaches its maximum upstream extent sometime in March. The post-regulation historical range of its maximum extent is from just downstream of Dunvegan (km 300) in warm years to around the proposed Site C dam site (km 105) in cold years. However, the winter of 2011–2012 was the warmest on record, and the ice front advanced upstream only as far Shaftesbury Crossing (km 368), about 27 km upstream of the Town of Peace River. There have been no extreme cold winters in the last 15 years, and as a result, the ice front has not advanced upstream of Taylor (km 123) since 1997.

With the onset of warming temperatures, longer days, and increased solar radiation in March, the ice front starts receding downstream. It has historically passed through the Town of Peace River anywhere from late March to late April. In most years, the breakup at the Town of Peace River is relatively benign, with the ice cover melting in place, resulting in little or no increase in water level. This is known as a thermal breakup. In some years, discharges in the river at breakup can increase dramatically as a result of snowmelt runoff from the prairies. A major source of this runoff is the Smoky River, which enters the Peace River just 6 km upstream of the Town of Peace River. This runoff can cause a dynamic breakup that can lead to the formation of ice jams and potentially flooding. Three conditions must be met before a breakup ice event at the Town of Peace River becomes a potential threat:

- The ice front on the Peace River is located upstream of the Town of Peace River
- The snow pack in the lower elevation (prairie portion) of the Smoky River Basin is above normal

- There is a rapid and sustained warming in the weather

A historical and statistical analysis of breakups from 1971 to 1999 indicated that dynamic breakups can threaten the Town of Peace River with flooding in about 30% of the years; in 70% of the years, the breakup was determined to be a benign thermal event (Andres 2002). A dynamic breakup at the Town of Peace River has typically occurred sometime in the first three weeks of April. The timing of a thermal breakup at the Town of Peace River can range from mid-March to late April.

The ice front has reached the Site C dam location twice in the past 17 years (Figure 11.7.3); the Peace River in the reservoir area has otherwise been ice cover-free under current conditions, with short episodes of flowing frazil ice pans during cold spells almost every winter.

11.7.2 Thermal and Ice Regime During Construction

The thermal and ice regime in the Peace River during existing conditions were simulated using the CRISSP model, and these results were used to predict the regime during construction of the Site C dam.

Construction of the Site C dam would occur in two stages. Stage 1 (channelization) consists of restricting the channel, and Stage 2 (diversion) consists of diverting the flow through tunnels in order to isolate the area where the earthfill dam would be constructed across the Peace River. Stage 1 would constrict the river to a width of 220 m within the deeper main portion of the channel. In Stage 2 of construction, the river would be diverted through two diversion tunnels approximately 10 m in diameter and 700 to 800 m in length.

11.7.2.1 Construction Stage 1 – Approach and Expected Changes

The Stage 1 channelization is expected to last through two or three winters. CRISSP simulations of the existing Peace River were used to predict ice conditions at the construction site. An analysis of hydraulics during Stage 1 using the River2D model (described in Section 11.4 Surface Water Regime) indicates that the river would move quickly enough through the construction areas that ice would not lodge at the Stage 1 constriction. Therefore, the amount of ice passing this reach would not differ from the existing conditions. The increase in residence time upstream of the Stage 1 constriction would be negligible, so the hydraulic or thermal heat exchange would be similarly negligible.

11.7.2.2 Construction Stage 2 – Approach and Expected Changes

In Stage 2 of construction, expected to last through three winters, the two tunnels would flow full and be submerged at both ends for all flow conditions; the discharge through them would be governed by upstream flows and the difference in water level between the upstream headpond and downstream tailrace ends of the tunnels. The headpond water level could vary by approximately 15 m for the full operational range of Peace Canyon Dam (283 to 1,982 m^3/s), with higher flows resulting in higher water levels in the headpond.

At low flows and water levels, ice would be drawn down through the tunnels. However, winter discharges are typically on the higher end of the operational range due to seasonal power demand and, therefore, headpond levels are expected to be in the top 5 m of the 15 m range. The Stage 2 headpond is predicted to trap some ice during high flows and water levels. Ice cover during high flows would reduce heat loss, since the headpond would be insulated by ice cover at times and it is deeper than the natural channel. These factors would cause the zero-degree isotherm and the maximum upstream extent of the ice cover to be somewhat downstream of the baseline condition.

Based on the hydraulics of the Stage 2 headpond, it is expected that the ice regime downstream of the Stage 2 diversion would be somewhere in-between the existing conditions and those with the Site C dam in place. The ice regime upstream of the Stage 2 diversion would depend on the releases from Peace Canyon Dam, with the downstream thermal and ice regime changing less during low headpond water levels. Even at high water levels, the Stage 2 headpond would be approximately half the depth of Dinosaur Reservoir and three-quarters of the length. The residence time of water in the headpond must therefore be much shorter than that of Dinosaur Reservoir and the thermal influence of the headpond proportionally smaller than that of the upstream reservoir.

It is expected that under low headpond elevations (i.e., low Peace Canyon discharges), ice would pass through the tunnels and that, under high flows, ice would be held upstream of the tunnels in the headpond. The velocity through the tunnels would range from 2 m/s to 13 m/s for the operational range of Peace Canyon discharges. These velocities are well above the erosion velocity of 1.5 m/s for ice. Therefore, ice is not expected to jam inside the tunnels, and any potential issues with ice in the headpond can be operationally addressed by maintaining higher discharges out of Peace Canyon.

11.7.3 Thermal and Ice Regime During Operation

11.7.3.1 Approach and Methods

Potential changes to the thermal and ice regime in the Peace River during operation of the Project were investigated using a series of numerical models. Models, when calibrated and validated to existing conditions or similar environments, can represent the changes of a system in response to external events such as the construction of a dam. Three models were used to represent different aspects of the reservoir and downstream changes.

Thermal and ice characteristics of the Site C reservoir were modelled using a three-dimensional hydrodynamic model, H3D (Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report). This model integrated input flow with water temperature and atmospheric data to predict the water temperature within the Site C reservoir and the outflowing water. H3D also predicted the ice characteristics of the reservoir in the form of ice cover and thickness. Water temperatures and ice cover were simulated based on observed and estimated atmospheric and flow conditions from 1995 to 2011.

The thermal characteristics of the Peace River downstream of the proposed Site C dam were simulated using CE-QUAL-W2, a two-dimensional hydrodynamic and water quality model that was used for aquatic productivity modelling as discussed in Section 11.5 Water Quality and Volume 2 Appendix E Water Quality Baseline Conditions in the Peace River. This model used predicted outflow temperatures at the Site C dam from the H3D model, as well as meteorological, hydrologic, and water quality data to simulate water temperature, dissolved oxygen, nutrients, total suspended solids, and phytoplankton and periphyton biomasses for the years 2000–2009. Water temperature was simulated for the river's reach between the Site C dam and the Water Survey of Canada station Peace River at Alces River, 62 km downstream.

The downstream ice regime in the Peace River was simulated using the CRISSP model, introduced in Section 11.7.1.2 above.

The general approach to each numerical modelling study is similar. First, a model is set up for existing conditions to check that it produces realistic results in a measurable way. The time period chosen is generally a historical period with sufficient observational data to serve as both model input and results comparison. The H3D and CE-QUAL-W2 models were both validated against water temperature observations from the existing Dinosaur Reservoir. The downstream implementation of CE-QUAL-W2 was validated against water temperature observations from the Peace River. The CRISSP model was validated against historical ice front observations, water temperatures, water levels, and surface ice concentrations. Details on the calibration and validation of the models are included in Section 11.7.3.2 below.

Following calibration and validation, the models were run during the same historical time period with and without the Site C dam and reservoir in place. The differences between the modelled post-construction case and the modelled existing conditions case could then be attributed to the Project. This approach was used for the models of the downstream temperature (CE-QUAL-W2), and downstream ice (CRISSP). An additional scenario based on the presence of the proposed Dunvegan project was examined using the CRISSP model. The Site C reservoir temperature and ice model (H3D) was validated against observations in the existing Dinosaur Reservoir and results from H3D were compared against observations. The results of all modelling studies are discussed in terms of the historical time period used for comparison; for example, the ice conditions were modelled for the winter of 1996–1997 as if the reservoir had existed at that time.

The Dunvegan project is a potential run-of-river hydroelectric facility in Alberta near Dunvegan. The location of the project, as indicated in Figure 11.7.1, would be about 190 km downstream of the Site C dam. The headpond would be entirely contained within the natural river channel and would be 26 km long. Glacier Power, a wholly owned subsidiary of Canadian Hydro, received environmental approval for the project in 2008. Since then, the project was purchased by TransAlta Corporation, and construction has not started as of this writing. Additional information about the Dunvegan project can be found in the Environmental Impact Assessment for the Dunvegan Project (Jacques Whitford 2006), and the details of the ice regime analysis are described in Andres and Healy (2006). The CRISSP ice simulations were run for three scenarios: the existing case, with the Project, and with the Project and the Dunvegan Project.

The CRISSP model was also used to evaluate the influence of projected climate change on the thermal and ice regime of the Peace River. For these simulations, estimates of future air temperature changes were applied to the meteorological data used as input to the CRISSP model. While other climate variables such as precipitation might be different with climate change, ice modelling experience suggests that air temperature would be the single most important change for ice conditions, so other climatic components were assumed to remain unchanged from historical conditions.

11.7.3.2 Model Validation, Sensitivity and Uncertainty

Details of model structure, validation, sensitivity, and uncertainty can be found in the respective technical data reports (Volume 2 Appendix E Water Quality Baseline Conditions in the Peace River, Volume 2 Appendix G Downstream Ice Regime Technical Data Report, and Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report) and are summarized here.

The accuracy of the H3D model was quantified by modelling a similar water body, Dinosaur Reservoir, located just upstream of the Site C reservoir. Water temperature measurements in Dinosaur Reservoir and observed data on ice formation were used to calibrate and validate the model. H3D was able to simulate temperatures at the outlet of Dinosaur Reservoir, with a root-mean-square difference of 0.2°C, and a long-term average difference of -0.01°C. The root-mean-square difference is a measure of instantaneous accuracy in temperature prediction, whether positive or negative; the long-term average difference is an average of the difference between observed and predicted results, and a near-zero value indicates that there is no persistent temperature offset or bias in the results.

The sensitivity of the modelled Site C outlet temperatures was tested in scenarios with increased wind speeds, alternate intake hydraulics near the dam, and using an implementation of H3D with suspended sediment included. For most tests, the sensitivity of the outlet temperature was within 0.1°C. The sensitivity to a different assumption regarding outlet hydraulics (stronger currents at depth) was up to 0.4°C in the summer, but still less than 0.1°C for the rest of the year. The sensitivity of outlet temperatures to air temperature is discussed in regards to climate change in Section 11.7.3.4 below.

CE-QUAL-W2 was calibrated and validated in a similar manner to H3D against temperature observations in the existing Dinosaur Reservoir. The downstream Peace River implementation of CE-QUAL-W2 was validated against the Peace 4 and Peace 5 stations (locations shown in Figure 11.7.1). Calibration resulted in modelled temperature predictions within 1° of observations and presenting no temperature offset. This calibration resulted in root-mean-square and long-term average differences of 0.5°C and -0.02°C, respectively.

The calibration and validation of the H3D and CE-QUAL-W2 models for the simulation of water temperatures in Dinosaur Reservoir and the Peace River provides confidence in the use of the models for the prediction of potential changes in water temperature resulting from the Project. The sensitivity of the model to the various inputs was tested, and results suggest that the conclusions made are reliable.

Calibration of the CRISSP model has been ongoing since its development in 2006. The original calibration was based on four winters: 1995–1996, 2002–2003, 2003–2004, and 2005–2006. The last three winters were chosen, as they contained the most comprehensive field data to date, and 1995–1996 was chosen in order to include a very cold year that did not occur during the intensive three-year field program. The first step in the CRISSP calibration was to ensure that water temperatures and the timing of the zero-degree isotherm were modelled correctly. This was done by first selecting a suitable heat transfer coefficient. Next, the porosity of the frazil slush in the frazil pans had to be incorporated into the model to reproduce observed frazil ice pan thickness and surface ice concentrations. Then ice jam parameters, such as hydraulic roughness, needed to be selected to give the correct total ice cover thickness and correct rate of ice front recession, and to reproduce water levels at measured locations.

When these calibration coefficients were applied to the other 12 years in the study, the model was reasonably accurate in predicting the ice fronts for those years as well. This accuracy was quantified by comparing the observed freeze-up and breakup dates at the Town of Peace River as well as the most upstream extent of the ice covers (Table 11.7.1).

Table 11.7.1 Comparison of Observed and Simulated Baseline Maximum Upstream Ice Cover Extents and Freeze-up and Breakup Dates at the Town of Peace River

	Max. Ice Front Progression (km)			Date of Freeze-Up at Town of Peace River			Date of Breakup at Town of Peace River		
Winter	Observed	Simulated	Difference	Observed	Simulated	Difference (days)	Observed	Simulated	Difference (days)
1995–1996*	101	98	-4	10-Dec-95	10-Dec-95	0	20-Apr-96	21-Apr-96	1
1996–1997*	125	123	-2	21-Dec-96	21-Dec-96	0	17-Apr-97	19-Apr-97	2
1997–1998	280	270	-10	13-Jan-98	13-Jan-98	0	29-Mar-98	27-Mar-98	-2
1998–1999	217	215	-3	05-Jan-99	06-Jan-99	1	03-Apr-99	03-Apr-99	0
1999–2000	219	220	1	16-Jan-00	14-Jan-00	-2	31-Mar-00	30-Mar-00	-1
2000–2001	298	298	0	10-Feb-01	10-Feb-01	0	19-Mar-01	15-Mar-01	-4
2001–2002*	207	197	-10	19-Jan-02	17-Jan-02	-2	22-Apr-02	26-Apr-02	4
2002–2003	228	226	-1	27-Jan-03	29-Jan-03	2	14-Apr-03	15-Apr-03	1
2003–2004	217	226	9	9-Jan-04	11-Jan-04	2	3-Apr-04	3-Apr-04	0
2004–2005*	169	174	6	5-Jan-05	5-Jan-05	0	3-Apr-05	29-Mar-05	-5
2005–2006	310	289	-21	27-Feb-06	26-Feb-06	-1	3-Apr-06	5-Apr-06	2
2006–2007	178	178	-1	11-Jan-07	13-Jan-07	2	24-Apr-07	22-Apr-07	-2
2007–2008	205	202	-3	10-Jan-08	8-Jan-08	-2	30-Mar-08	1-Apr-08	2
2008–2009*	195	193	-2	27-Dec-08	27-Dec-08	0	13-Apr-09	17-Apr-09	4
2009–2010	254	227	-27	31-Dec-09	30-Dec-09	-1	21-Mar-10	30-Mar-10	9
2010–2011	140	134	-6	29-Dec-10	26-Dec-10	-3	19-Apr-11	20-Apr-11	1
Average	209	204	-5	11-Jan	11-Jan	0	07-Apr	08-Apr	1
Standard Deviation	59	56		19	19		11	12	

NOTE:
* – indicates a winter in which there was at least one juxtaposed reach imposed

The comparisons of ice front progression, freeze-up dates, and breakup dates show that the CRISSP ice front simulations are a reliable representation of the observed ice front positions. The differences between observed and simulated ice conditions help to characterize the model's uncertainty. The CRISSP model was able to simulate the maximum upstream extent of the ice cover in most years to within 10 km, with some outliers of up to 30 km. Simulation of the timing of freeze-up of the ice cover at the Town of Peace River was accurate to within three days and breakup to within nine days. The CRISSP model was able to reproduce normal ice-related water levels and open water levels to within about 0.5 m. CRISSP cannot accurately simulate secondary consolidations at freeze-up and thus cannot predict extreme high water levels resulting from these events. The model is also unable to simulate a dynamic breakup of the Peace River triggered by breakup of the Smoky River, and thus cannot predict extreme high water levels resulting from these events. However, since the model is able to simulate the necessary conditions for these to occur (i.e., the presence or absence of an ice cover), this is not an impediment for assessing the influence of the Site C dam on the frequency of secondary consolidations and dynamic breakup events triggered by the Smoky River.

The calibration of the CRISSP model to adequately simulate the observed ice fronts, water levels, water temperatures, and ice production and melt rates gives confidence in the reliability of the model. The fact that the model is able to simulate 16 winters with the same calibration coefficients indicates that uncertainties in the input variables and calibration coefficients are not high enough to manifest themselves as large errors in the output.

11.7.3.3 Expected Changes

Changes to the thermal and ice regime of the Peace River due to the Project are described separately for the Site C reservoir and the Peace River downstream of the Site C dam.

11.7.3.3.1 Expected Thermal Regime in the Site C Reservoir

The H3D model results for the Site C reservoir indicated that it would acquire the characteristics of a moderately deep lake, forming a two-layer thermal structure, separated by a thermocline (stratifying layer) forming in the summer and winter, and mixing completely in the fall and spring. A thermocline is a layer in a lake or reservoir where temperature changes quickly with depth, in the summer separating warm water near the surface from cooler water at depth. This vertical variation, or stratification, occurs naturally in lakes in both summer and winter. Winter stratification is due to the fact that fresh water is most dense at 4°C, and water at this ‘warm’ temperature can exist at the lake bottom during sub-zero air temperatures, while colder water (and ice) remains at the surface. Stratification can be destroyed by energy from strong winds (when there is no ice cover), by gradual cooling of the surface in the fall or, in the case of a reservoir, by withdrawal of both distinct layers out through the intakes of a dam. The residence time of a body of water is defined as the mean flow rate through the water body divided by the volume of the water body, and can be thought of as the time it takes for a typical parcel of water to travel through the water body. The average residence time of the water in the Site C reservoir would be about 22 days, as opposed to two to three days for Dinosaur Reservoir and within one day for an 83 km stretch of the existing Peace River.

In the first 20 km of the Site C reservoir, just downstream of Peace Canyon Dam, the model predicted that shallow bathymetry and consequently high velocities would result in a vertically uniform temperature. At greater distances downstream, the surface warming in summer would result in a stable thermocline. The reservoir would develop 5 to 15 degrees of temperature stratification in most summers. Stratified conditions would typically start in the middle of May after reservoir water temperatures exceed 4°C. Mixing is predicted to occur in the fall, typically in mid-October. This reduction and loss of stratification, which is often referred to as the fall overturn, results from factors such as increased vertical mixing due to winds and cooling surface waters. Maximum surface temperatures are predicted to reach between 16°C and 21°C in the years modelled, while the temperatures at the bottom of the reservoir gradually increase throughout the summer, but reach only 9 to 11°C before mixing completely with surface waters during the fall overturn.

In winter, there would be reverse stratification in the reservoir, with temperatures ranging from nearly 0°C under the ice at the surface to 2°C at the bottom of the reservoir. The reverse stratification arises due to the density processes described above; the reservoir would cool more at the surface than at the bottom, while simultaneously being protected from wind mixing energy by ice cover.

11.7.3.3.2 Expected Thermal Regime at the Site C Dam Outlet

Simulated water temperatures at the Site C outlet were compared with existing Peace River water temperatures at the Peace Above Pine hydrometric station, 6 km downstream of the proposed dam. The outlet of the Site C reservoir (i.e., the intakes to the Site C generating station) would span depths between approximately 3 m and 21 m, blending water from both the warm surface waters and cooler waters at depth during stratified conditions in the summer. The modelled monthly average temperatures at the Site C intakes were compared to observed temperatures at Peace Above Pine (Figure 11.7.5), for the period October 2007 to October 2012. This time period corresponds with available temperature observations at the Peace Above Pine hydrometric station. The daily range in modelled and observed temperatures is displayed on the Figure as vertical error bars.

Modelled temperatures at the outlet of the Site C dam were warmer than observed temperatures between July and January, ranging from 0.3°C higher than existing conditions in July to 1.5°C higher than existing conditions in October. The monthly average modelled outlet temperatures were between 0.4°C and 0.9°C cooler from March to June and, in all months, had a smaller daily range than the existing river.

The changes in temperature due to the Site C reservoir can partially be characterized as a time delay instead of an absolute difference. Instead of measuring the vertical distance (i.e., temperature) between the simulated and observed time series in Figure 11.7.5, the horizontal distance between the curves represents time. The differences in time indicate that, seasonally, water temperatures in the Peace River with the reservoir in place would be approximately one to two weeks late compared to existing conditions.

11.7.3.3.3 Expected Thermal Regime in the Peace River Downstream of the Site C Dam

The water temperature of the Peace River between the Site C dam and the confluence of the Alces River, approximately 62 km downstream, was modelled with CE-QUAL-W2. The expected water temperatures at the Site C dam served as the upstream input to the downstream water quality model, and CE-QUAL-W2 simulated temperature, along with other water quality components for two scenarios: existing conditions, and with the Project in place. Comparison of the two scenarios identified the changes in water temperature due to the presence of the Project. The monthly average modelled temperatures were compared at the Peace 5 station, the location of which is shown on

Figure 11.7.1, which is the downstream boundary of the CE-QUAL-W2 modelling study. Model results with and without the Project are shown in Figure 11.7.6. The predicted temperature changes range from 0.9°C cooler in May to 0.7°C warmer in November. The predicted temperature changes at Peace 5 are less than the changes predicted at Peace Above Pine, reflecting the increased distance from the Site C dam over which the Peace River temperatures are influenced by atmospheric conditions, solar radiation, and inflows from tributaries.

11.7.3.3.4 Expected Ice Regime in the Site C Reservoir

The H3D model predicts ice cover in the Site C reservoir in terms of area covered and ice thickness. Ice cover in the Peace River upstream of the project location is rare under the baseline regulated flow regime, but ice would be expected to form on the Site C reservoir. The model predicted that ice would start forming in tributary arms of the reservoir at the beginning of the winter in November or December. Later in the winter, ice would start forming first near the Site C dam, where the reservoir would be deeper and wider with lower velocities, and then propagate upstream. In the winter of 2007–2008, which was an average winter based on air temperatures, the first major onset of ice covered two-thirds of the reservoir in 11 days before partially melting again. The ice would form faster on the north side of the reservoir than on the south side due to the deflection of flowing water to the south by the Coriolis effect. The last area to be covered by ice would be the centre of the reservoir, which would also be the first place to melt.

Figure 11.7.7 shows a time series of the air temperature, the percentage of the reservoir covered by ice (area covered by ice divided by total area of the reservoir), and the mean ice thickness over the ice-covered part of the reservoir (calculated as the volume of ice divided by the ice-covered area of the reservoir), as predicted by the H3D model for the years 1995–2011. During most of the cold periods, the reservoir ice cover extended upstream past the Halfway River (about 60% coverage) and, during the coldest days, it reached Lynx Creek (about 90% coverage). Cycles of formation and melting occurred a couple of times during most winters, depending on the air temperature and wind conditions. A typical amount of ice melt in one event would be 20% of the reservoir area. The upstream 20 km of the reservoir from the Peace Canyon Dam, which includes Hudson's Hope, would occasionally be covered by ice. This part of the Site C reservoir closest to the Peace Canyon Dam would have higher velocities, which reduces ice formation, and the temperature of water exiting the Peace Canyon Dam is always above 0°C, suppressing ice formation. Higher velocities near Lynx Creek and downstream of Farrell Creek also inhibit ice formation, whereas a widening of the reservoir at Hudson's Hope allows a thin ice cover to form. The maximum coverage over the simulation period occurred in mid-January 1996, reaching 98% coverage after nearly a week with air temperatures below -40°C. Typical annual maximum ice cover for the simulation period was between 80% and 90% of the reservoir area, and occurred in late January or February. Annual maximum average ice thicknesses were typically about 0.5 m and occurred in late February or early March, after the maximum ice cover.

11.7.3.3.5 Expected Ice Regime in the Peace River Downstream of the Site C Dam

The expected changes to the ice regime in the Peace River downstream of the Project were characterized by comparing CRISSP model predictions of baseline conditions with model predictions of the scenario with the Project. Results were compared to determine the potential change of the following characteristics as a result of the Project:

- Timing of ice cover formation and breakup
- Maximum upstream extent of ice cover
- Ice thickness
- Conditions that affect river transportation

CRISSP predicted that both the Project and the combination of the Project with the Dunvegan Project would change the maximum upstream extent of the ice cover on the Peace River. Figure 11.7.8 and Figure 11.7.9 show an example of the ice front simulation results for two of the 16 winters analyzed, the first for a relatively cold winter, and the second for a warmer winter. The figures show that the presence of the Project would generally move the maximum upstream extent of the ice cover farther downstream, compared to existing conditions. The ice front cannot propagate as far upstream due to the warmer water exiting the dam in winter, as compared with existing conditions (Figure 11.7.5), and because ice generated in the Site C reservoir would remain behind the dam.

When the Project and the Dunvegan project were considered together, the ice front behaviour was more complex. The Dunvegan project would provide a lodgement location and would trap ice floes, initiating a second ice front upstream of it. The second ice front can be seen in Figure 11.7.8 and Figure 11.7.9 as a green line starting at Dunvegan in late December. Even with the Site C dam in place, the Dunvegan ice front would occasionally travel farther upstream than the historical ice front, especially in warmer winters, such as in Figure 11.7.9. Further details on the interactions of the Project and the Dunvegan project are presented in Volume 2 Appendix G Downstream Ice Regime Technical Data Report.

Results suggested that on average, over the 16 winters simulated, no changes would be expected at Carcajou, which is approximately 550 km downstream of the Site C dam. These results indicate that the Fort Vermilion downstream boundary of the ice models was far enough downstream to capture the entire extent of Project's influence. Under baseline conditions, the thermal ice usually gains sufficient thickness (5 to 10 cm) to support an individual or a large animal within a day or two of the ice cover formation, and this is not expected to change with the Project alone or with the combination of the Project and the Dunvegan project.

Some general statements can be made about annual ice-related events and probabilities for various locations:

- **Site C dam:** The modelling suggested that the ice front would never advance upstream to the Site C dam, with or without the Dunvegan project in place
- **District of Taylor:** With the Project, the ice cover would not reach the District of Taylor, even if the Dunvegan project were in place
- **British Columbia–Alberta Border:** Under the existing conditions, the annual probability of the ice front advancing into B.C. is about 22%. With the Project, this would decrease to about 10%. With both the Project and the Dunvegan project, the annual probability of the ice cover advancing into B.C. is about 16%.

- **Shaftesbury Crossing:** Under existing conditions, the ice cover has always advanced upstream as far as Shaftesbury Crossing. This would not change with the Project. With both the Project and the Dunvegan project, the annual probability of ice cover advancing upstream to Shaftesbury Crossing is reduced to about 88%.
- **The Town of Peace River:** Under all scenarios, the 16 years of simulation indicated that ice cover would advance past the Town of Peace River every winter

The date of freeze-up and breakup at the Town of Peace River is another way to present the changes due to the Project. Table 11.7.2 presents the existing date of freeze-up and breakup, as well as the number of days the freeze-up or breakup would change due to the presence of the Project alone, or the Project and the Dunvegan project together. A negative 'delay' indicates that the predicted date with the project(s) in place is earlier than the existing scenario.

Table 11.7.2 Changes in Timing of Ice Freeze-up and Breakup at the Town of Peace River

	Freeze-Up			Breakup		
Winter	Existing Date	Delay Due to the Project (days)	Delay Due to the Project + Dunvegan (days)	Existing Date	Delay Due to the Project (days)	Delay Due to the Project + Dunvegan (days)
1995–1996	10-Dec-95	4	8	21-Apr-96	2	1
1996–1997	21-Dec-96	3	3	19-Apr-97	3	3
1997–1998	13-Jan-98	2	14	27-Mar-98	1	2
1998–1999	6-Jan-99	3	12	3-Apr-99	0	0
1999–2000	14-Jan-00	3	19	30-Mar-00	1	0
2000–2001	10-Feb-01	3	8	15-Mar-01	-2	-1
2001–2002	17-Jan-02	6	8	26-Apr-02	0	-1
2002–2003	29-Jan-03	6	18	15-Apr-03	-2	-2
2003–2004	11-Jan-04	5	13	3-Apr-04	1	1
2004–2005	5-Jan-05	2	7	29-Mar-05	0	0
2005–2006	26-Feb-06	3	16	5-Apr-06	-2	-5
2006–2007	13-Jan-07	1	9	22-Apr-07	0	-2
2007–2008	8-Jan-08	3	7	1-Apr-08	4	3
2008–2009	27-Dec-08	2	6	17-Apr-09	-1	-1
2009–2010	30-Dec-09	3	6	30-Mar-10	1	-1
2010–2011	26-Dec-10	3	9	20-Apr-11	-1	-1
Average	11-Jan	3	10	8-Apr	0	0

11.7.3.3.6 Ice Bridge and Ferry Crossing at Shaftesbury

Both the Project and the Dunvegan project have the potential to change the timing and duration of the ice bridge crossing and ferry operations at Shaftesbury. The Shaftesbury crossing is located about 25 km upstream of the Town of Peace River or about 266 km downstream of the Site C dam site. Vehicles cross at the location by ferry in the summer and by ice bridge in the winter. There are a few weeks, or even months in some years, where neither ferry nor ice bridge crossing is possible.

Typically, the ferry starts operating soon after the ice front recedes past the crossing location at km 370.6 between late March and the middle of April. High ice concentrations typically end ferry operations in November or December. Additional time is required after ferry operations end for the ice front to arrive at Shaftsbury and for the ice cover to gain sufficient strength for an ice bridge to be constructed. The ice bridge can commence operations as early as December in a cold year or as late as March in a warm winter. In the warmest of winters, ice bridge construction is not possible. The ice bridge remains in place until shortly before breakup of the ice cover. CRISSP model results were used to predict the times during which ferry or ice bridge crossings are both possible under baseline conditions, with the Project in place, and with both the Project and the Dunvegan project in place.

On average, there would be no delay in the start-up dates of ferry operations as a result of the Project alone, or with both the Project and the Dunvegan project. The ending date of ferry operations was predicted to be extended by an average of four days with the Project in place. In some years, the model suggested that the ferry could operate for a few weeks longer before freeze-up occurs. With both the Project and the Dunvegan project in place, the average delay of ferry closure is three days, compared to a delay of four days with the Project alone. However, there are a few outlying years that skew the calculation from the average. Calculation using the median values suggested that there is almost no change in the ferry closure date with either the Project alone or with both the Project and the Dunvegan project in place.

Results suggest that with the Project in place, ice bridge operations would start on average five days later than under existing conditions, with a year-to-year range of between zero and 14 days later. With both the Project and the Dunvegan project in place, the average delay would be 17 days. With both projects in place, the results suggested that, out of the 16 years simulated, there would be two years when the required ice thickness would not be attained.

For the purposes of modelling changes, the date the ice bridge crossing was closed was assumed to be the day the ice front receded past Shaftesbury Crossing, and the number of days during which the ice bridge was operable was calculated. The results showed that the ice bridge would be usable for an average of 75 days under existing conditions, 71 days with the Project, and 58 days with both the Project and the Dunvegan project. However, the decrease in ice bridge days with the Project would be nearly the same as the projected increase in days during which the ferry was operable. Therefore, the Project is not predicted to change the total number of crossing days at Shaftesbury. On average, the Project and the Dunvegan project combined would reduce the number of crossing days by 15 days.

11.7.3.3.7 Freeze-up and Breakup Water Levels

The CRISSP models of the Peace River, under existing conditions, with the Project alone, and with both the Project and the Dunvegan project, included prediction of water levels. The model simulated the process of primary consolidation, or the initial collapse of the juxtaposed ice cover and the associated increase in water levels. Secondary consolidations, which can produce the largest increases in water level, were not simulated. However, the risk of a secondary consolidation is highest during swings in temperature that drive a rapid advance of the ice front. Models with the Project in place suggested that the speed of ice front advance would be slower than existing conditions, and therefore the risk of secondary consolidation could be slightly reduced.

Comparisons of the water levels at freeze-up between the three model scenarios suggest that there would be no systematic change in water level due to the Project alone or the combination of the Project and the Dunvegan project. However, freeze-up water levels depend on the timing of ice formation at a particular location, and the atmospheric and flow conditions that exist at the time of freeze-up. As described above, a small delay in the timing of ice formation is expected (an average of three days at the Town of Peace River) so there could be small changes in freeze-up water levels due to different conditions at the time of freeze-up, but these changes would not be systematic and would be within the variability of freeze-up water levels experienced today.

High water levels at breakup would remain unchanged from existing conditions, as they occur when the Smoky River ice cover breaks up dynamically into an intact Peace River ice cover. Since neither the Project alone nor the combination of the Project and the Dunvegan project would change the average timing of the thermal breakup of the Peace River ice cover at the Town of Peace River, peak breakup water levels would not change from those experienced under existing conditions.

The response time in implementing flow regulation that helps to mitigate the risk of flooding due to ice breakup would improve with the Project in place. Under existing conditions, flows from the Peace Canyon Dam are controlled during certain periods to mitigate ice breakup risks. Since the Site C dam is about 85 km closer to the Town of Peace River than Peace Canyon Dam, reduction of flow at the Site C dam would lead to a reduction of water levels at the town about 12 hours sooner than under existing conditions, where flow is controlled at Peace Canyon Dam. This faster response time could reduce ice flooding risks at the Town of Peace River.

11.7.3.4 Climate Change

As described in Volume 2 Appendix T Climate Change Summary Report, air temperatures in the Peace region have increased approximately 1.2°C over the past century, and are projected to increase 1.9°C to 2.5°C by the 2050s and 2.5°C to 3.9°C by the 2080s. The increase in mean air temperatures has been, and is expected to be, mostly due to warmer temperatures in winter. An increase in tributary flow and earlier freshets are expected in the Peace region. The sensitivity of temperatures in the Site C reservoir to climate change was tested with a series of H3D model runs, and the sensitivity of the downstream ice regime to climate change was tested with the CRISSP model.

11.7.3.4.1 Thermal Regime with Climate Change

A series of H3D model runs were conducted with air temperature increases ranging from 1°C to 4°C. These constant increases are simpler than time-varying climate change scenarios, but span the range of temperature increases projected for the 2050s and 2080s time periods.

The model predicted that the increase in outflow temperature at the Site C dam averaged 20% of the air temperature increase for the months of March through October. Winter temperature increases were less than 5% of the air temperature increase. For example, for a 4°C increase in air temperatures, outflowing water is expected to be about 0.8°C warmer in the summer and fall, and less than 0.2°C warmer in winter.

The response of the Site C reservoir to climate change would also depend on the response of Williston Reservoir to a warming climate, but in the absence of quantitative predictions in Williston, the Site C reservoir response was tested without changing the temperature of the inflowing water. Studies in the Great Lakes predicted that surface water temperatures will increase along with air temperature. However, bottom waters were predicted to warm less than surface waters (Great Lakes 2003). Assuming the same pattern in Williston Reservoir, and considering that most of the water at the W.A.C. Bennett Dam is drawn at depth, it is expected that waters entering the Site C reservoir would warm less than predicted future air temperatures. An additional sensitivity test with warmer inflowing water confirmed that the assumption of no change in inflow temperatures is the most conservative in terms of evaluating the influence of the Site C reservoir on water temperatures (i.e., this approach led to a larger change attributable to the Project).

The ice conditions on the existing Peace River under future climate scenarios corresponding to the 2050s and 2080s time periods were modelled with CRISSP during the months of November through April. The water temperatures in the 2050s are predicted to be warmer by 0.3°C at Peace 5, and by 0.6°C at the Town of Peace River. In the 2080s, the water temperatures are predicted to be warmer by 0.4°C at Peace 5 and by 1.0°C at the Town of Peace River. Presented relative to the projected air temperature increase for the 2050s and 2080s, the warming predicted for the existing Peace River at Peace 5 is 10% to 16% of the air temperature increase, and 24% to 40% at the Town of Peace River.

11.7.3.4.2 Ice Regime with Climate Change

The 16 winters considered in the downstream ice study were simulated under two future climate scenarios corresponding to the 2050s and 2080s time periods. Monthly air temperature offsets were applied to hourly historical data from the three climate stations used in the CRISSP model (Fort St. John, Town of Peace River, and High Level) over the same 16 simulated years. The Peace Canyon and Site C reservoir outlet water temperatures were assumed to be unchanged with climate change in the ice study, as it was reasonable to ignore the 5% sensitivity to warmer air temperatures in winter predicted by the H3D model.

The influences of the changed climate on the ice front locations in two representative winters, for the various development scenarios, are shown in Figure 11.7.10 and Figure 11.7.11. These can be directly compared to the ice front simulations without climate change in Figure 11.7.8 and Figure 11.7.9. The ice fronts for all scenarios under climate change conditions would be farther downstream than under current conditions.

According to the CRISSP analysis, changes to the ice regime due to a future climate would be of a similar magnitude to those attributable to the Project alone, or the Project and the Dunvegan project combined. The ice front in a future climate would be pushed further downstream in the order of a few tens of kilometres to about 100 km, depending on its location and depending on winter severity.

Results suggest that there is no difference between project scenarios downstream of about km 650, with and without climate change, indicating the downstream boundary is sufficiently far removed that it is not affected by changes to the ice regime due to the Project alone or the Project and the Dunvegan project combined. It also can be concluded that the influence of the Project on downstream ice conditions is predicted to be similar whether under a baseline climate, a 2050s climate, or a 2080s climate.

11.7.4 Summary of Expected Changes

Model results for the Site C reservoir indicated that it would behave like a lake, forming a two-layer thermal structure. The reservoir is predicted to develop 5 to 15 degrees of temperature stratification in most summers. Stratified conditions typically start in the middle of May, whereas the fall overturn typically occurs in mid-October. Maximum surface temperatures are predicted to reach between 16°C and 21°C in the years modelled, while the temperatures at the bottom of the reservoir would gradually increase throughout the summer but would reach only 9 to 11°C before mixing completely with surface waters during the fall overturn.

Modelled temperatures in the Peace River just downstream of the Site C dam were warmer than existing conditions between July and January, with differences ranging from 0.3°C in July to 1.5°C in October. The monthly average temperatures are expected to be between 0.4°C and 0.9°C cooler from March to June, and in all months to have a smaller daily range than the existing river. The monthly average modelled temperatures were also compared to a location 62 km downstream of the Site C dam. The temperature changes at the downstream station would range from 0.9°C cooler in May to 0.7°C warmer in November.

Typical maximum ice cover in the Site C reservoir is predicted to be between 80% and 90% of the reservoir area, and to occur in late January or February. Typical average ice thicknesses are expected to peak at approximately 0.5 m and occur in late February or early March, after the maximum ice cover.

The behaviour of the ice front in the Peace River is also expected to change due to the presence of the Project. Modelling predicts that the maximum upstream extent of the ice front would generally move farther downstream, compared to existing conditions. When the Project and the Dunvegan project are considered together, the change in ice front locations would behave differently. The Dunvegan project would provide a lodgement location and would trap ice floes, thereby initiating a second ice front upstream of the Dunvegan dam. Whether the Project or the Dunvegan Project would have greater influence on the maximum upstream extent of the ice cover in any one year would depend on the winter severity.

It is expected that changes to the ice regime due to a general climate warming would be similar in magnitude as those attributable to the Project and the Dunvegan Project; the ice front would be pushed further downstream in the order of a few tens of kilometres to about 100 km, depending on its location and on the winter severity. However, results suggest that there would be no difference in ice front location between project scenarios downstream about km 650 under a climate change scenario.

The ice front model results show that the ice bridge at Shaftesbury is usable for an average of 75 days under existing conditions, 71 days with the Project alone, and 58 days with both the Project and the Dunvegan project. However, the decrease in ice bridge days with the Project would be nearly the same as the projected increase in days during which the ferry is operable. Therefore, the Project is not predicted to change the total number of crossing days at Shaftesbury. On average, the Project and the Dunvegan project combined would reduce the number of crossing days by 15 days.

Results of the downstream ice study show that there is no difference in the ice regime between project scenarios downstream of Carcajou (near km 650), with or without consideration of climate change. This indicates that the downstream boundary of the study is sufficiently far removed to capture the entire extent of the Project's influence.

11.8 Fluvial Geomorphology and Sediment Transport Regime

11.8.1 Background

Fluvial geomorphology refers to the physical geometry and bed material characteristics of the river channel. Changes in fluvial geomorphology can occur due to bank or bed erosion, sediment deposition, and/or vegetation encroachment. Sediment transport regime refers to the quantity, temporal pattern, grain-size distribution, and mode of transport of particulate matter by river flows. The sediment transport regime of a river can be altered by the introduction of new sediment sources, by changes in flow patterns, which govern the sediment transport capacity of a river, or by the interruption of downstream sediment transport in sediment sinks such as reservoirs.

Prior to hydroelectric development in 1967, the fluvial geomorphology and sediment transport regime in the Peace River were naturally dynamic due to the localized nature of sediment inputs from tributaries and valley-wall landslides, and due to a seasonal range in flows. Since 1967, the fluvial geomorphology and sediment transport regimes in the Peace River have been in a state of adjustment to the regulated flow conditions. The potential changes in fluvial geomorphology and sediment transport regimes related to the Project have been considered in light of the fact that the baseline conditions in the Peace River are both naturally variable and are undergoing a long-term response to regulation. Thus, not all future changes in the Peace River would necessarily be attributable to the Project. Rather, the potential changes induced by the Project would combine with the changes that would have resulted from the current, ongoing response to river regulation in the absence of the Project. The characterization of past geomorphologic changes and ongoing geomorphologic response to regulation in this section of the EIS draws on long-term research studies by Dr. Michael Church from the University of British Columbia, Department of Geography (Church 2011).

This section of the EIS summarizes the information presented in Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report.

11.8.2 Technical Study Areas

Two spatial technical study areas are considered for the fluvial geomorphology and sediment transport study: the reservoir study area and the downstream study area.

1. The reservoir study area comprises the Peace River valley from the Peace Canyon Dam to the Site C dam site, and the lower reaches of the reservoir tributary valleys. The reservoir study area extends up the tributary valleys (i.e., tributary embayments of the reservoir) to the maximum extent of inundation at full supply level. In the two largest reservoir tributaries, the Halfway and Moberly Rivers, the reservoir study area extends another 10 km up the tributary valleys beyond the extent of reservoir inundation to encompass the potential zones of bedload (gravel and sand) accumulation that may occur upstream of the reservoir confluences. The reservoir study area is shown in Figure 11.8.1.
2. The downstream study area comprises the Peace River valley from the Site C dam site to the community of Peace Point, Alberta. Peace Point is located approximately 108 km upstream of the Peace River confluence with the Slave River, and

corresponds to the downstream limit of the closely related surface water regime study area (Volume 2 Section 11.4 Surface Water Regime). In the downstream study area, the magnitude of the potential changes related to the Project would diminish in a downstream direction due to the moderating influence of water and sediment inputs from tributaries. Project-related changes in fluvial geomorphology and sediment transport regime were expected to be negligible downstream of Peace Point when the downstream study area was established. The study results presented in this section of the EIS confirm this to be the case. The downstream study area is shown in Figure 11.8.2.

Potential changes in fluvial geomorphology and sediment transport during the construction and operational phases of the Project have been analyzed in this study, including separate considerations of the channelization and diversion stages of construction. In the operations phase, sediment dynamics in the reservoir and downstream of the dam site have been considered for the first 10 years of operations. This period was selected to provide a range of annual and seasonal conditions. One aspect of sediment dynamics in the reservoir – deposition on the reservoir bottom – has also been considered over a 50-year time period. The longer time period was selected for this analysis to assess the cumulative sediment deposition that would occur over a period of time containing many floods.

11.8.3 Baseline Conditions

11.8.3.1 River Definition

The Peace River channel was mapped from the Peace Canyon Dam to Peace Point using remote sensing imagery in order to define the baseline planform (map view pattern and dimensions) of the river. The river channel maps delineate “active” and “inactive” channel zone areas based on vegetative and topographic indicators. The channel zone is defined by the outermost river banks, within which the wetted channel, bars, and islands are contained. The “active” portion of the channel zone comprises the wetted channel (at the time of image capture) plus unvegetated bars, which are wetted or overridden by ice with sufficient regularity to inhibit vegetative colonization. The “inactive” portion of the channel zone comprises vegetated bars and wooded islands. Vegetated bars are formerly active portions of the channel that have been colonized by vegetation due to natural river migration and/or due to the lowered flood levels associated with upstream river regulation.

The total area of the Site C reservoir is estimated to be 9,330 ha. The areas of river channel and land that would be inundated by the Site C reservoir are as follows:

- Active river channel inundated: 3,773 ha
- Land inundated (including vegetated river bars and islands): 5,557 ha

The river was divided into six reaches for geomorphic characterization, based on the river definition maps and overview information provided in Church (2011). The reach extents and a summary of geomorphic characteristics are presented in Table 11.8.1. The river chainage system used to define the reach breaks refers to channel distance downstream of the W.A.C. Bennett Dam.

Table 11.8.1 Geomorphic Study Reaches – Summary of Key Characteristics

Peace River Reach		River Chainage (km)		Reach Average Gradient (m/m)	Dominant Bed Material Size
		Start	End		
Reach 1	Peace Canyon Dam to Site C Dam Site	20.4	105.5	0.0005	Gravel/cobble
Reach 2	Site C Dam Site to Alces River Confluence	105.5	163.8	0.0005	Gravel
Reach 3	Alces River Confluence to Smoky River Confluence	163.8	388.6	0.0003	Fine gravel
Reach 4	Smoky River Confluence to Wolverine River Confluence	388.6	655.6	0.0002	Sandy gravel
Reach 5	Wolverine River Confluence to Vermilion Chutes	655.6	916.0	0.0001	Coarse/medium sand
Reach 6	Vermilion Chutes to Peace Point	916.0	1,135.0	0.0001	Medium/fine sand

11.8.3.2 Suspended Sediment Transport

The baseline suspended sediment transport regime was characterized by means of sampling programs in the reservoir study area and in the proximal portion of the downstream study area where the relative changes due to the Project would be greatest. Published information was available for more distal portions of the downstream study area, which permitted a characterization of suspended sediment regime all the way to Peace Point.

The proximal portion of the downstream study area was defined as the section of Peace River between the Site C dam site and the Water Survey of Canada gauging station located immediately upstream of the Alces River confluence (Station 07FD010, Peace River above Alces River). This section of river includes the confluences of three major tributaries – the Pine, Beatton, and Kiskatinaw rivers – which contribute relatively large suspended sediment loads compared to the loads transported out of the reservoir study area. The gauging station near the Alces River confluence was selected as a logical point at which the flows and sediment loads of these three tributaries and the residual drainage area between the tributary confluences could be computed.

Sampling Methods

The suspended sediment gauging program was used to develop relationships between discharge, suspended sediment concentration, and turbidity for all Peace River tributaries (including minor ungauged tributaries and residual drainage areas) between the Peace Canyon Dam and the Alces River confluence. These relationships were used to generate synthetic daily time series of discharge, suspended sediment concentration and load, and turbidity for each tributary and for the Peace River mainstem for the 10-year period 2000-2009. This period was selected because it represents recent (current) hydro-climatic conditions, and because this period contains a range of hydrologic conditions, including a large flood event on the Halfway River and several other Peace River tributaries in 2001.

Suspended sediment gauging programs were carried out in 1975 and 2010–2011. These programs focused on the Peace River and tributaries in the reservoir study area and in the proximal portion of the downstream study area between the Peace Canyon Dam and the Alces River confluence. Sample data collected by the Water Survey of Canada were also available in these areas to augment the baseline studies.

Standard guidelines for a suspended sediment gauging study are provided by ASTM International (ASTM 2009), formerly known as the American Society for Testing and Materials. The ASTM International guidelines draw upon more detailed guidelines for specific study components, primarily developed by the United States Geological Survey (USGS). The 2010–2011 suspended sediment gauging program followed the ASTM International guidelines, as well as the more detailed USGS guidelines for suspended sediment gauging, or the equivalent provincial (British Columbia) guidelines for those portions of the study for which such guidelines exist.

The methodology for installing and operating a streamflow gauging station in British Columbia is provided by the B.C. Ministry of Environment (BCMOE 2009). However, the provincial manual does not cover the use of Acoustic Doppler Current Profiler (ADCP) instrumentation to measure instantaneous discharge. ADCP technology is now widely used by the Water Survey of Canada and USGS. The USGS provides the most comprehensive manual on the use of ADCP (Mueller and Wagner 2009). The Project baseline studies followed the provincial guidelines for the overall streamflow gauging program and the USGS manual for instantaneous discharge measurements using ADCP. The most comprehensive guidelines for installing and operating turbidity sensors for the purpose of estimating suspended sediment concentration are provided by the USGS (Rasmussen et al. 2011). The Project baseline studies followed these guidelines (which were first presented in 2009 and revised in 2011) for the collection of turbidity records in the 2010-2011 gauging program. The most comprehensive guidelines for the collection of representative suspended sediment samples are provided by the USGS (Edwards and Glysson 1999). The Project baseline studies followed these guidelines for sample collection, which include the use of Federal Interagency Sedimentation Project (FISP) depth-integrated samplers to collect depth-integrated samples of the river water column, and the compilation of multiple depth-integrated vertical samples to obtain cross-sectional average concentration values.

Results

The estimated mean annual suspended sediment load at various locations in the Peace River between the Peace Canyon Dam and the Alces River confluence for the period 2000–2009 are provided in Table 11.8.2.

Table 11.8.2 Mean Annual Suspended Sediment Load in the Peace River (2000-2009) – Peace Canyon Dam to Alces River Confluence

Peace River Location	Mean Annual Suspended Sediment Load (t/year)
Peace Canyon Dam	Negligible
Site C Dam	1,360,000
Alces River Confluence	8,730,000

The Halfway River contributes an estimated 75% of the suspended sediment load that passes the Site C dam site. The Pine and Beatton Rivers contribute approximately

1.6 times and 2.8 times the load, respectively, of the Peace River at the Site C dam site. The mean annual suspended load at the Alces River confluence is approximately 6.4 times the load at the Site C dam site.

Further downstream, from Dunvegan to Peace Point, Church (2011) presents the following estimates of mean annual suspended sediment load for the period 1971–1990 (Table 11.8.3).

Table 11.8.3 Mean Annual Suspended Sediment Load in the Peace River (1971-1990) – Dunvegan to Peace Point

Peace River Location	Mean Annual Suspended Sediment Load (t/year)
Dunvegan	15,600,000
Town of Peace River	38,000,000
Peace Point	38,200,000

The large incremental increase in suspended sediment load between the communities of Dunvegan and Peace River is primarily due to inflow from the Smoky River. The small incremental increase between the communities of Peace River and Peace Point is due to low sediment yield downstream of the Smoky River and to net deposition of a portion of the suspended sand load contributed by the Smoky River (Church 2011).

The incremental suspended sediment load inputs from tributaries are shown visually in Figure 11.8.3 (Peace Canyon Dam to the Alces River confluence) and Figure 11.8.4 (Peace Canyon Dam to Peace Point).

Suspended sediment inputs from the tributaries are greatest during the spring snowmelt freshet and during rainstorms. The spring freshet typically peaks in June for tributaries with headwaters in the Rocky Mountains (Halfway, Pine, and Smoky rivers) and in May for other tributaries, which are located mainly on the Alberta Plateau. This results in variable suspended sediment concentration and load in the Peace River throughout the year. The annual and seasonal concentration duration curves for three locations on the Peace River are provided in Figures 11.8.5 and 11.8.6, respectively. On an annual basis (Figure 11.8.5), immediately upstream of the Halfway River confluence, suspended sediment concentration exceeds 20 mg/L approximately 4% of the time. Immediately downstream of the Halfway River confluence, suspended sediment concentration exceeds 20 mg/L approximately 20% of the time.

11.8.3.3 Suspended Sediment Grain Size

The estimated average grain-size composition of the suspended sediments in the Peace River at the Site C dam site is 37% clay (less than 4 μm), 55% silt (4 to 62 μm), and 8% fine sand (62 to 200 μm). These results are based on summing the tributary loads and their sampled grain-size distributions in the reservoir study area tributaries.

Clay and silt do not settle out of suspension in flowing water, but some silt does accumulate in side channels and on channel margins in the Peace River. The sand is marginally in suspension and does settle out or transitions from suspended to bedload under some flow conditions. However, the river also entrains sediment into suspension from within its channel under certain flow conditions. Samples collected in the Peace River indicate grain-size composition similar to the composition derived from the sum of the tributaries, indicating that net deposition of fine sand along the river channel is not large, relative to the total load.

11.8.3.4 Lateral Mixing of Tributary Sediment Inputs

Lateral variability in suspended sediment concentration in the Peace River arises from the long distances required for mixing of tributary sediment inputs. Cross-sectional turbidity transects were collected on the Peace River to characterize the lateral and longitudinal patterns of sediment mixing below major tributary confluences. The results of the turbidity transects indicate that sediment inputs from major tributaries such as the Halfway and Pine rivers create lateral gradients in turbidity (and suspended sediment concentration) for tens of kilometres downstream from the confluences. More complex lateral patterns are found where multiple upstream tributaries contribute to the lateral suspended sediment profile. These lateral patterns exist along the entire length of the Peace River between the Peace Canyon Dam and the Alces River confluence. By logical extension, lateral variability in suspended sediment concentration likely exists for at least tens of kilometres downstream of all major tributary confluences, and further downstream as well, all the way down to Peace Point.

11.8.3.5 Bed Material Grain Size

Bed material grain-size has been characterized at numerous sites along the Peace River between the Peace Canyon Dam and Peace Point. Generalized grain-size information from Church (2011) is summarized by geomorphic reach in Table 11.8.1. A more detailed description of bed material characteristics, based on BC Hydro and other studies conducted between the Peace Canyon Dam and the Alces River confluence, is provided below. This encompasses the reservoir study area, where the riverbed would be inundated by the reservoir and subject to fine sediment deposition, and the proximal portion of the downstream study area, where the relative changes in sediment transport regime would be greatest.

Manual bed material samples (Wolman pebble counts) were collected on the surfaces of exposed gravel bars along the Peace River between the Peace Canyon Dam and the Alces River confluence. At each sample site, a large number of stones (usually 100) was randomly selected and the diameter of each stone was measured. In the local vicinity of the Site C dam site, underwater video sampling of the riverbed surface was conducted in the wetted river channel. Stone dimensions were measured using an automated image analysis software to process selected video images.

The manual surface samples indicate that the bed (bar) material generally becomes finer (smaller) in the downstream direction between Peace Canyon Dam and the Site C dam site. The median bed material particle size (D_{50}) averages about 90 mm toward the upstream end of this reach and 50 mm toward the downstream end of this reach. The overall trend does not continue downstream between the Site C dam site and the Alces River confluence, where D_{50} values also average around 50 mm.

Underwater bed material video sampling in the vicinity of the Site C dam site indicated D_{50} values ranging from 19 mm to 62 mm, which generally agrees with the manual surface samples collected on the exposed gravel bars near the dam site (average D_{50} of 50 mm, as discussed above). Two areas of exposed bedrock were also identified in the underwater video sampling.

Manual bulk samples of subsurface bed material were excavated and sieved at selected sites between the Peace Canyon Dam and the Alces River confluence. The subsurface sample results indicate D_{50} values averaging around 25 mm. It is common for subsurface riverbed material to contain more fines than the surface material and thus to have finer median grain size.

11.8.3.6 Bed Material Mobility

Gravel is supplied in relatively small quantities to the Peace River by the erosion of glaciofluvial and alluvial deposits along the main channel and tributary channels, and from mountain sources in the headwaters of tributaries draining from the Rocky Mountains. Bedload transport in the Peace River has always been much lower in magnitude than the transport of suspended sediment, by an estimated factor of 1% or less (Church 2011). Since the onset of flow regulation in the Peace River, bedload transport in the cobble- and gravel-bed reaches of the Peace River has ceased to occur under the normal range of flow conditions because the flows are not competent to mobilize the bed material. Church (2011) estimated a threshold discharge of 3,000 m^3/s for the initiation of bed material mobilization between the Peace Canyon Dam and the Alces River confluence. Further downstream, the riverbed material becomes finer and the flow regime has been less affected by regulation, so bedload transport continues to occur.

Bed material mobility was assessed in the Peace River between the Moberly River confluence and the Highway 97 crossing near Taylor. The particular area of interest was the section of river extending approximately 3 km downstream from the Moberly River confluence, where bedload material delivered by the Moberly River has been accumulating in the Peace River channel since the onset of flow regulation due to reduced peak flows and corresponding reduction in sediment transport capacity. This section of river was of particular interest because it would be subject to modified hydraulic conditions during construction and operations, and because the reservoir would eliminate bedload supply to the Peace River immediately downstream of the Site C dam site.

Bed material grain-size characteristics were compiled from historical information sources and a more detailed investigation using underwater videography, as described in the previous section. A two-dimensional (2D) hydrodynamic model (River2D) was used to compute bed shear stresses in the Peace River between the Moberly River confluence and Old Fort. At any given flow condition, channel bed areas where the bed shear stress exceeded the critical shear stress for bed mobilization (i.e., areas of competent flow) were identified. Flow competence refers to the ability of a given flow condition to mobilize the bed material in a river. The River2D model is described further in Section 11.4 Surface Water Regime.

The areas of flow competence at a discharge condition of 4,000 m^3/s are shown in Figure 11.8.7. This is a flow condition that has been exceeded at the Site C dam site during only one event since 1967: the 1996 drawdown of Williston Reservoir for dam repairs. Much of the riverbed is shown to be immobile at this flow condition, but some mid-channel bars are shown to be mobilized, including the mid-channel bar near km 107, approximately 2 km downstream from the Moberly River confluence (photograph shown in Figure 11.8.8).

11.8.3.7 Historical Erosion and Deposition Patterns

Three approaches were undertaken to characterize baseline channel erosion and deposition patterns in the Peace River, based on comparisons of river information collected over a period of several decades, which provide characterizations of cumulative erosion and deposition resulting from long periods of gradual change and/or many discrete events. The three approaches are maps of riverbank lines and other river features, cross-sectional bed elevation profiles, and stage-discharge (i.e., water level-flow) rating curve relationships at Water Survey of Canada gauging stations.

The results of these analyses show that the Peace River has responded, and continues to respond, to flow regulation in the following ways:

- Tributary bedload material has been accumulating in the Peace River channel below tributary confluences since the onset of river regulation, including the areas downstream of the Moberly and Pine river confluences
- Alluvial fans at tributary confluences have expanded laterally into the Peace River, forcing the river to erode its banks opposite from the confluences
- Terrestrial vegetation has encroached onto formerly active gravel bars and into secondary channels

11.8.4 Construction

11.8.4.1 Suspended Sediment Regime Downstream of the Site C Dam Site

Approach and Methods

Two potential sources of suspended sediment during construction were considered: in-stream construction activities and shoreline erosion in the diversion-stage headpond.

- In-stream construction activities – The timing and sediment loading of various in-stream activities were estimated by Klohn Crippen Berger Ltd. The analysis is presented in Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report, Appendix H.
- Shoreline erosion in the diversion-stage headpond – The timing and sediment loading from shoreline erosion were estimated by J.D. Mollard and Associates. The analysis is presented in Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report, Appendix F.

In addition to these two sediment sources, sediment would likely be generated from onshore construction activities in the vicinity of the dam site. Sediment inputs to the river from onshore construction activities would need to be kept below the effluent criteria to be set out in the Environmental Management Plan (Volume 5 Section 35 Summary of Environmental Management Plans).

The suspended sediment load of the Peace River comprises sediment finer than 200 μm, so 200 μm was selected as the upper limit for sediment size considered in the in-stream construction and headpond shoreline analyses. The sediment inputs due to in-stream construction activities and headpond shoreline erosion were treated as event-type pulses, which reflects the probable nature of their timing and produces greater potential increases in concentration than if the sediment loads were introduced over longer periods of time. For each sediment input event, a range of incremental increases in suspended sediment concentration was computed, based on a consideration of the ranges in input load, ambient river flow, and the fraction of the river flow into which the sediment would be mixed. The sediment input events were grouped by season for comparison to seasonal baseline concentration values.

In-stream Construction Activities

Seventeen construction activities with an in-stream component were identified. The in-stream construction activities would occur in three periods of time:

1. In Year 1, at the start of the river channelization stage, as the north bank haul road, lateral cofferdams and containment dykes are constructed
2. In Year 4, at the start of the river diversion stage, as the inlet and outlet channels are excavated, and the diversion channels and tunnels are flushed
3. In Year 7, toward the end of the river diversion stage, as the tailrace/discharge channel is excavated and flushed

The fine sediment loads associated with each activity were estimated based on a consideration of construction material volume and grain size, and the historical range of river flows, levels, and velocities encountered in the corresponding season in which the construction activity is planned to occur. The estimates were made using the finest grain-size gradation curve for the construction materials and contain no special allowances to minimize sediment generation. Therefore, these are considered to be upper bound estimates that could be reduced if mitigative practices or adjustments in the timing of works were applied.

The minimum duration of wetted work associated with each activity was estimated based on construction volumes, equipment productivity rates, and the seasonal range of river levels. For a given sediment loading, the minimum duration of wetted work provides the maximum incremental increase in concentration. The minimum durations of wetted work for most of the activities range from a few hours to a few days.

The range of concentration computed for each activity reflects the range in activity duration and ambient river discharge into which the sediment inputs would be diluted. For each activity, the associated concentration in 5% of the river discharge and 100% of the river discharge were computed. The former condition is expected to be observed relatively close to the construction site, whereas full mixing into 100% of the river discharge would occur far downstream, beyond the Pine River confluence. The latter assertion is based on the understanding of lateral mixing patterns that was developed from the turbidity transects described in Section 11.8.3.4 Lateral Mixing of Tributary Sediment Inputs. The exception to this is the flushing of the diversion channels and tunnels at the start of the river diversion stage; the sediment entrained in this activity would be fully mixed in the confined turbulent flow within the tunnels.

Headpond Shoreline Erosion

Headpond shoreline erosion was estimated on a daily basis using a wave-energy erosion model. The seasonal distribution of sediment input events reflects the distribution of windy days. Autumn and winter are the windiest seasons (averaging 15 and 12 daily events per season, respectively), while spring and summer are the calmest seasons (averaging seven daily events per season each). The range in concentration in each season reflects the variability in erosion event magnitudes and the river discharge into which the sediment inputs would be diluted. The headpond shoreline sediment would be fully mixed with the river discharge as it passes through the diversion tunnels. The computed increases in concentration refer to a location downstream of the tunnel outlets in fully mixed flow.

Expected Changes

The estimated fine sediment input from in-stream construction activities during the eight-year construction phase ranges from approximately 18,000 t to 30,000 t. For comparison, the mean annual suspended sediment load in the Peace River is 1.36 million t/year. Averaged over the eight-year construction phase, the fine sediment inputs related to in-stream construction activities would represent a 0.2% to 0.3% increase above baseline.

The estimated fine sediment input from headpond shoreline erosion during the four-year diversion stage of construction is 56,000 t. For comparison, the estimated mean annual suspended sediment load of the Peace River at the Site C dam site is 1.36 million t/year. Averaged over the four-year diversion stage, the fine sediment inputs related to headpond shoreline erosion would represent a 1% increase above baseline.

The fine sediment inputs from in-stream construction activities and headpond shoreline erosion would occur in an episodic manner, so short-term increases in suspended sediment concentration would be greater than the comparison of annual loads (above) would suggest. These episodic events are described below in chronological order.

Year 1

In Year 1 of the construction phase, in-stream construction activity would consist of haul road construction along the north river bank, and lateral cofferdam and containment dyke construction on the north side of the river to set up the river channelization stage of construction. Seven discrete in-stream activities have been identified, each of which would have a minimum duration of wetted work in the order of a few hours to a few days. The incremental increase in suspended sediment concentration from each activity, considered independently from one another, is estimated to be in the order of 300 to 1,200 mg/L at a location close to the source where the sediment is mixed into 5% of the ambient river flow, and 15 to 60 mg/L further downstream once the sediment is fully mixed into 100% of the river flow. All of the activities would occur on the north side of the river, so the elevated suspended sediment concentrations would occur close to the north shore of the river, with the incremental concentration levels diminishing in a downstream direction as the sediment mixes laterally across the river. Full mixing would occur somewhere downstream of the Pine River confluence.

Years 2–3

No in-stream construction activities are planned for Years 2 or 3. All construction activity would occur onshore and site runoff would be managed according to an Environmental Management Plan (see Volume 5 Chapter 35 Summary of Environmental Management Plans).

Year 4

In Year 4 of the construction phase, the diversion channels at the tunnel inlets and outlets would be excavated in preparation for river diversion. The start of river diversion would then result in a flushing of the diversion channels and tunnels.

- The excavation of each of the two diversion channels would result in elevated suspended sediment concentration for a duration of one to two months. The incremental increases in suspended sediment concentration would be in the order of 10 to 30 mg/L close to the source where the sediment is mixed into 5% of the river flow along the north side of the river, diminishing to around 1 mg/L at a downstream location where the sediment is fully mixed into 100% of the river flow. These values refer to each of the diversion channels (inlet and outlet), so would be additive if the channels were excavated in unison.
- Associated with diversion channel excavation, the construction of an excavation berm in each channel would result in a short (one day) pulse of elevated suspended sediment concentration. The incremental increase in suspended sediment concentration would be in the order of 400 to 1,000 mg/L close to the source where the sediment is mixed into 5% of the river flow along the north side of the river, diminishing to around 20 to 50 mg/L at a downstream location where the sediment is fully mixed into 100% of the river flow. These values refer to each of the diversion channels (inlet and outlet), so would be additive if the excavation berms were excavated in unison.
- The flushing of the diversion tunnels when they are first opened to receive river flow would result in a short (one hour) pulse of increased suspended sediment concentration in the order of 340 to 520 mg/L. This sediment would be fully mixed into 100% of the river flow as it passes through the tunnels.

Years 4–8

The river diversion stage of construction would start when the diversion tunnels start to convey river flow. The tunnels would have a smaller cross-sectional area than the natural river channel, so a headpond would form upstream of the tunnel inlets under high flow conditions. Headpond shoreline erosion is expected to occur in an episodic manner, primarily during windstorm events when the headpond level is high. It is expected that shoreline erosion events of a one-day duration would generate incremental increases in suspended sediment concentration in the order of 1 to 20 mg/L, as observed in fully mixed river flow downstream of the tunnel outlets. These events would be most common in the autumn and winter (averaging 12 and 15 daily events per season, per year), and least common in the spring and summer (averaging seven daily events per season, per year), due to seasonal differences in wind conditions and wave energy in the headpond.

Year 7

Toward the end of Year 7, one final set of in-stream construction activities would take place: the excavation and flushing of the tailrace/discharge channel. These activities would result in moderately elevated suspended sediment concentration for a period of approximately 11 days, followed by a short (one hour) pulse of higher suspended sediment concentration when the channel is opened to river flow.

- The first set of activities (11 days' duration) would generate an incremental increase in suspended sediment concentration in the order of 8 to 25 mg/L close to the source where the sediment is mixed into 5% of the river flow along the south side of the river, diminishing to around 1 mg/L at a downstream location where the sediment is fully mixed into 100% of the river flow
- The short pulse (one hour) of sediment associated with the opening and flushing of the channel would generate an incremental increase in suspended sediment concentration in the order of 500 to 1,200 mg/L close to the source where the sediment is mixed into 5% of the river flow along the south side of the river, diminishing to around 25 to 60 mg/L at a downstream location where the sediment is fully mixed into 100% of the river flow

Uncertainty, Sensitivity, and Reliability

The estimation of fine sediment loading due to in-stream construction activities was computed analytically. The input information and calculation methods contained the following sources of uncertainty.

- Grain-size gradation of construction materials: The in-stream construction materials consist of river gravels and riprap. The river gravels to be excavated and/or placed during construction have a range of grain-size gradations. The fine sediment (less than 200 μm) content of the river gravels ranges from 0% to 10%. The finest gradation curve (10% fines) was used in the analysis to provide an upper bound estimate on the availability of fines for entrainment in the river.
- Fraction of fine sediment eroded from construction berms: All fine sediments were assumed to be eroded from the full thickness of construction berms constructed perpendicular to the river flow. All fine sediments were assumed to be eroded from the riverside slope, but not the full thickness, of construction berms constructed parallel to the river flow. These assumptions likely overestimate the actual fraction of fine sediment that would be eroded.
- River flow conditions: The quantity of construction materials exposed to river flow is dependent on river levels. Three river flow/level conditions were considered for each season (5%, 50%, and 95% exceedance). Therefore, a full range of flow conditions was considered.
- Mitigative measures: No special mitigative measures were considered in the analysis, such as pre-washing the river gravels to reduce fine sediment content or targeting construction activities to avoid certain flow conditions. Opportunities to reduce sediment loading through the application of these or other mitigative measures likely exist.

The estimation of incremental increases in suspended sediment concentration due to in-stream construction activities was computed analytically. The input information and calculation methods contained the following sources of uncertainty.

- Duration of construction activities: The minimum duration of in-stream construction activities was computed from equipment productivity rates. The application of these minimum durations provides an upper bound on concentration estimates for a given sediment load.

- Timing of construction activities: The incremental suspended sediment concentration associated with each in-stream construction activity was computed and presented independently. This is thought to represent the likely reality that individual activities would be conducted asynchronously rather than simultaneously. Unlike most of the other sources of uncertainty, this source can be controlled by the construction team.
- Incremental suspended sediment concentrations were not computed at specific locations, but rather at unspecified locations where the construction sediments would be mixed into 5% and 100% of the river flow. In this case, it was decided to avoid introducing uncertainty by trying to predict where these mixing ratios would occur.

The estimation of fine sediment loading due to wave-driven shoreline erosion in the diversion stage headpond was computed analytically. The input information and calculation methods contained the following sources of uncertainty.

- Wave energy: Wave energy in the headpond was modelled based on historical wind speed and direction data from Fort St. John, adjusted to the Peace River valley according to a comparison of in-valley wind data. Uncertainty in wave energy arises from variability in the relationship between wind speed and direction at Fort St. John and in the Peace River valley. The wave modelling is discussed in Volume 2 Appendix B Geology, Terrain Stability, and Soil Reports, Part 2 Preliminary Reservoir Impact Lines, and a statistical evaluation of the wind relationship is discussed in Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report, Appendix B.
- Characterization of headpond shoreline materials: The grain-size distributions and bulk densities of shoreline materials were estimated based on surficial test pit and drill core samples. Some grain-size bias occurred during sampling. The final grain size curves were estimated. The spatial resolution of the shoreline characterization was limited by site access and sample site density. Where sites were not visited in the field, LiDAR imagery and orthophotos were used for interpretation of shoreline material types exposed at key headpond levels.
- Erodibility of headpond shoreline materials: Erodibility coefficients were estimated with dimensions of volume per unit of wave energy guided by observations of shoreline erosion on Williston Reservoir, Dinosaur Reservoir, and other reservoirs with similar geological conditions.
- Headpond levels: High headpond levels were used in the analysis in order to generate conservative estimates of wave energy and shoreline erosion. The headpond surface elevations used in the analysis were 421 m for the higher flow months of November through February, and 417 m for the remainder of the year. These elevations have exceedance frequencies (the percentage of time the value is equalled or exceeded) of approximately 5% and 40% in the respective periods of year specified. Thus, the winter wave energy and erosion results represent upper bound estimates, whereas the non-winter results are closer to median estimates.

The estimation of incremental increases in suspended sediment concentration due to headpond shoreline erosion was computed analytically. The input information and calculation methods contained the following sources of uncertainty.

- Wave erosion events: Monthly erosion loads were grouped into daily events in which daily wave energy exceeded an arbitrary threshold that was exceeded on approximately 12% of the days. This was done to generate higher incremental increases in concentration than would have resulted using monthly erosion values.
- Timing of events: The wave erosion events were treated as discrete events, asynchronous with the in-stream construction activities.
- Sediment settling in the headpond: All fine sediment (less than 200 µm) was assumed to be entrained into suspension and transported downstream out of the headpond on the day of the erosion event. In reality, the transport process would likely be more complex, with some settling of sand and silt in the headpond under high water level conditions, and subsequent re-entrainment and downstream transport during falling water level conditions.

In summary, the information sources and methods used to estimate fine sediment loads due to in-stream construction activities and headpond shoreline erosion are subject to various sources of uncertainty. Analytical sensitivity was addressed by using a range of information inputs to characterize variability (e.g., river flow/level conditions) or else a single value was selected that contributed to an upper bound estimate of sediment loading. The information sources and methods that were used to estimate incremental increases in suspended sediment concentration also contained sources of uncertainty. Here, values were selected to generate upper bound estimates of incremental concentration, and correspondingly, lower bound estimates of elevated concentration duration. The sediment loading events were treated as individual, asynchronous events, which is a likely scenario but not a certain one. Overall, the results are reliable for characterizing expected changes due to the Project.

11.8.5 Operation

11.8.5.1 Suspended Sediment Dynamics in the Reservoir

Approach and Methods

The following approach was used to assess the changes in fluvial geomorphology and sediment transport due to the Project during the operations phase:

- A three-dimensional hydrodynamic and sediment transport model was developed for the Site C reservoir (described below and in Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report)
- Baseline meteorology, hydrology, and suspended sediment transport data for the period 2000 to 2009 were used as inputs to the model
- A new type of sediment source due to wave erosion on the reservoir shoreline was estimated and input to the model as well

The model was run for the 10-year period to generate:

- Suspended sediment concentrations and turbidity in the reservoir
- Suspended sediment outflux load to the downstream study area
- Sediment deposition patterns on the reservoir bed

The period 2000–2009 was selected as the reference baseline period because it represents recent (current) hydro-climatic conditions, and because this period contains a range of hydrologic conditions, including a large flood event in 2001 and low flow years in 2006 and 2009, so is suitable to characterize the range of conditions that could be expected in the reservoir. However, the mean annual suspended sediment load during that decade was estimated to be 13% lower than the 46-year mean, so a separate longer-term (50 years) modelling exercise was undertaken to characterize cumulative sediment deposition with different tributary sediment input conditions. A five-year period was modelled using low (5^{th} percentile), average, and high (95^{th} percentile) tributary sediment inputs and a morphological scale factor of 10 was applied to “accelerate” the morphological evolution of the reservoir bed. This means that a multiplier of 10 was applied to any resultant scour or deposition at each time step in the model run. The morphological scale factor was used to reduce the model run time required for this type of simulation. The scale factor does not alter the sediment concentrations or the water densities in the model, and consequently the main physical processes are not altered unrealistically. This factor only speeds up the scour and deposition at each time step.

Modelling of reservoir sediment dynamics, using the proprietary model H3D, was used to characterize reservoir temperature, as reported in Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report. This tool has been used in a number of studies. Two of the most relevant studies that involve sediment transport in lakes/reservoirs are:

- Cleveland Dam East Abutment Environmental Impact Assessment Study: The model was used to assess the impacts of proposed remedial operations on reservoir turbidity, sedimentation, sediment production, and water supply. The model investigated turbidity and suspended sediment fate in the reservoir during a 7.6 m drawdown of water level for construction purposes.
- Kelowna Waterfront Sediment Transport Study: The model was used to provide the City of Kelowna with baseline sediment transport characteristics for Lake Okanagan from which waterfront development opportunities could be assessed. The model included tributary delta formation for Mission Creek.

Expected Changes

The estimated annual input of fine sediment to the reservoir due to shoreline erosion is 1.1 million t/year in Year 1 of reservoir operation, dropping to 0.55 million t/year by Year 10 as beach platforms develop, reducing the energy of wave impact. The mean annual fine sediment input from the shorelines in the first 10 years is estimated to be 0.78 million t/year, or approximately 57% of the annual suspended sediment inputs from tributaries.

A typical pattern of reservoir surface turbidity during spring freshet is presented in Figure 11.8.9. This Figure illustrates the dominance of the Halfway River in terms of tributary sediment inputs and shows the spatial distribution of near-surface turbidity during the 2007 freshet. Annual and seasonal concentration duration curves for two locations in the reservoir (indicated in Figure 11.8.9) are provided in Figures 11.8.10 and 11.8.11.

In the first 10 years of reservoir life, the average annual outflow of suspended sediment at the dam site is estimated to be about 30% of the total sediment input into the reservoir from both tributary and shoreline sources. The sediment outflow would comprise 98% clay and 2% silt on average.

The remainder of the tributary and shoreline sediment is predicted to be deposited within the reservoir. The estimated thickness of sediment deposition in the reservoir after 10 years would be variable with more deposition near tributary confluences and highly erodible shoreline segments. It is estimated that the deposition thicknesses would range from about 0.1 m in the main reservoir to over 2 m at the Halfway confluence and adjacent to some shoreline segments.

After 50 years of operation, the estimated thickness of reservoir sediment deposition under average sediment load conditions would range from about 0.3 to about 0.5 m in the main reservoir and 3 m to 4 m near some shoreline sections, as shown in Figure 11.8.12. In the Halfway River embayment, a deposition thickness of 3 m to 4 m is expected throughout the embayment, with up to 8 m near some shoreline segments, as shown in Figure 11.8.13.

The initial volume of the entire reservoir is 2,310 million m^3. The modelled sediment deposition volume for the entire reservoir after the first decade is approximately 12 million m^3, or 0.5% of the initial reservoir volume. The modelled deposition volume for the entire reservoir after 50 years is approximately 58 million m^3, or 2.5% of the initial reservoir volume, assuming average sediment input conditions. For the 5^{th} and 95^{th} percentile sediment input conditions for Halfway River, the 50-year deposition volumes in the reservoir would be 46 million m^3 (2.0% of reservoir volume) and 68 million m^3 (3.0% of reservoir volume), respectively.

The initial water volume of the Halfway River embayment at the start of reservoir operations would be approximately 90 million m^3. The sediment deposition volume after the first decade is estimated at 4 million m^3, or less than 5% of the initial embayment water volume. Depending on the sediment input rate, it is estimated that the Halfway embayment would infill by 22% to 35% after 50 years and would infill completely in 150 to 220 years. Once the embayment had infilled, the Halfway River would likely flow in a gravel-bed channel with a meandering or braided pattern within a valley bottom floodplain, and would have a delta slope extending out into the main body of the reservoir.

Uncertainty, Sensitivity, and Reliability

Suspended sediment modelling in the reservoir was subject to uncertainty in the following areas:

- Estimation of meteorological, hydrological, and tributary sediment load data inputs for the period 2000–2009
    - Meteorological inputs were computed based on historical records from Fort St. John, adjusted to the Peace River valley according to a comparison of in-valley meteorology data. Uncertainty in meteorological inputs arises from variability in the relationship between meteorology at Fort St. John and in the Peace River valley. A statistical evaluation of the wind relationship is discussed in Appendix B of Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report.

- Hydrologic inputs were obtained from the Water Survey of Canada streamflow records on the Peace River and its two main tributaries in the reservoir study area: the Halfway and Moberly Rivers. These data were collected within the reservoir study area according to the highest available standards, so represent the least source of uncertainty.
- Tributary sediment inputs were generated based on suspended sediment samples collected in several different years with varying flow conditions, including sampling during peak runoff events. As such, the samples provide good coverage of sediment transport conditions. The main uncertainty in the estimation of tributary sediment inputs lies in the development of discharge-concentration rating curves for use in computing sediment loads during periods other than those directly sampled. Separate rating curves were developed for rising and falling flow conditions for the seasonal snowmelt freshet and large rainstorm runoff events, but some residual scatter remained around the two curves for each tributary. Standard procedures were followed for this work and the level uncertainty in the results is within the normal range, but has not been explicitly quantified.

- Estimation of reservoir shoreline sediment inputs
  - Wave energy: Wave energy in the reservoir was computed based on historical wind speed and direction data from Fort St. John, adjusted to the Peace River valley according to a comparison of in-valley wind data. Uncertainty in wave energy arises from variability in the relationship between wind speed and direction at Fort St. John and in the Peace River valley. The wave modelling is discussed in Volume 2 Appendix B Geology, Terrain Stability, and Soil Reports, Part 2 Preliminary Reservoir Impact Lines, and a statistical evaluation of the wind relationship is discussed in Appendix B of Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report.
  - Characterization of headpond shoreline materials: The grain-size distributions and bulk densities of shoreline materials were estimated based on surficial test pit and drill core samples. Some grain-size bias occurred during sampling. The final grain-size curves were estimated. The spatial resolution of the shoreline characterization was limited by site access and sample site density. Where sites were not visited in the field, LiDAR imagery and orthophotos were used for interpretation of shoreline material types exposed at the reservoir level. The thickness of colluvial deposits overlying in situ materials was estimated using LiDAR imagery and available local subsurface data.
  - Erodibility of headpond shoreline materials: Erodibility coefficients with dimensions of volume per unit of wave energy were guided by observations of shoreline erosion on Williston Reservoir, Dinosaur Reservoir, and other reservoirs with similar geological conditions
  - Wave erosion events: Annual erosion loads were grouped into daily events in which daily wave energy exceeded an arbitrary threshold that was exceeded approximately 15% of the days. This was done to generate higher incremental increases in concentration than would have resulted using average daily erosion values (i.e., annual erosion values divided by 365).

- Representativeness of the period 2000–2009 relative to longer-term future conditions
  - The period 2000–2009 was selected as the reference baseline period because it represents recent (current) hydro-climatic conditions, and because this period contains a range of hydrologic conditions including a large flood event in 2001 and low flow years in 2006 and 2009, so is suitable to characterize the range of conditions that could be expected in the reservoir
  - The mean annual suspended sediment load during that decade was estimated to be 13% lower than the 46-year mean, so a separate longer-term (50 years) modelling exercise was undertaken to characterize cumulative sediment deposition with different tributary sediment input conditions. A five-year period was modelled using low (5^{th} percentile), average, and high (95^{th} percentile) tributary sediment inputs.
- Accuracy of the reservoir model in representing sediment dynamics in the reservoir
  - Model physics: H3D is a sophisticated 3D model that represents all of the fundamental physical processes relevant to sediment dynamics. The calibration and validation of the hydrodynamic model is detailed in Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report. The model was capable of matching observed temperatures in the existing Dinosaur Reservoir and therefore the uncertainty of the underlying physics in the sediment model is low. A mass balance confirmed that all sediment input to the model was either deposited in or transported out of the reservoir.
  - Representation of sediment: One source of uncertainty in sediment transport modelling is the representation of a near-infinite variety of grain sizes with statistical measures such as the median and 90th percentile grain sizes. For this study, sediment was split into three common size classes: sand, silt, and clay, with specific median grain sizes. This approach was used in a similar study on an existing reservoir and turbidity was predicted with a normalized root-mean-square error of 15%.
  - Model resolution: The model grid size was established to provide a balance between computational efficiency and increased resolution in key areas – primarily near the reservoir surface (in the vertical) and near tributary mouths (in the horizontal). The model resolution is sufficient to predict large-scale trends, but not small-scale features such as the development of beaches, wetlands, or distributary channels on tributary deltas.
  - Model time step: The model time step for the first 10 years (represented by input data for the period 2000–2009) ranged from 20 to 40 seconds, whereas the temporal resolution of the input data ranged from hourly to daily. Therefore, the model time step was sufficiently short to properly distribute the incoming inputs of mass and energy.
  - Model time step: To simulate sediment deposition over a longer time period of 50 years, a morphological scale factor of 10 was applied to "accelerate" the morphological evolution in a separate five-year model run. This was achieved by applying a multiplier of 10 to any resultant scour or deposition for every time step. The morphological scale factor was used to reduce the model run time required for a 50-year simulation. The scale factor did not alter the sediment

concentrations or the water densities in the model, and consequently the main physical processes were not altered unrealistically. This factor only sped up the scour and deposition at each time step. The greatest uncertainty in the accelerated methodology would appear in areas with both scour and deposition, such as the upper tributary embayments. However, most of the reservoir is a depositional environment where the accelerated methodology is appropriate.

In summary, spatial and temporal variability in meteorological, hydrological, and sediment transport processes contributes to uncertainty in the estimation of reservoir inputs. These sources of uncertainty are considered to be far greater than the uncertainties associated with the internal mechanics of the reservoir model. In other words, the reservoir model represents the dynamics of sediment in the reservoir with reasonable accuracy, given a specified set of meteorological, hydrological and sediment inputs. The sensitivity of model results to the period of model inputs was considered and addressed by selecting appropriate periods for specific analyses. Overall, the results provide a reliable characterization of the expected changes due to the Project.

11.8.5.2 Suspended Sediment Regime Downstream of the Site C Dam Site

Approach and Methods

Daily suspended sediment loads and concentrations downstream of the Site C dam site to the Alces River confluence were computed analytically using the daily sediment outflux at the Site C dam site generated by H3D, combined with daily baseline loads for downstream tributaries calculated in the baseline study.

Expected Changes

The estimated mean annual suspended sediment load immediately downstream from the Site C dam site under operational conditions is 620,000 t/year, or 46% of the baseline load (i.e., a 54% reduction compared to baseline conditions). Most of the suspended load reduction would occur in the spring, when baseline loads are greatest. The average seasonal suspended load would actually increase slightly in the autumn and winter, when baseline loads are lowest, due to shoreline erosion in the reservoir.

The differences between baseline and predicted operational suspended sediment concentration immediately downstream of the Site C dam site are illustrated in a series of three figures – a time series Figure (Figure 11.8.14) and annual and seasonal concentration duration figures (Figures 11.8.15 and 11.8.16, respectively). These figures illustrate the relatively large reductions in concentration that would occur during baseline peak transport events, and the relatively small increases in concentration that would occur during baseline non-peak periods (i.e., when reservoir tributary inputs are low).

The expected changes in median daily suspended sediment concentration immediately downstream of the Site C dam site during each season are presented in Table 11.8.5.

Table 11.8.4 Expected Median Daily Suspended Sediment Concentration Immediately Downstream of the Site C Dam Site (Baseline and Operations Phase)

Season	Baseline (mg/l)	Operations (mg/l)
Winter (Jan–Mar)	0.1	0.6
Spring (Apr–Jun)	39.6	14.3
Summer (Jul–Sep)	3.2	11.6
Autumn (Oct–Dec)	0.1	6.9

The relative changes in suspended sediment concentration below the Site C dam site would be most pronounced between the dam site and the Pine River confluence, and would diminish in a downstream direction due to tributary flow and sediment inputs. The downstream diminishment of changes would occur at tributary confluences if the cross-sections were laterally mixed. However, changes in suspended sediment concentration would be expected to persist along the left (north) bank of the Peace River downstream of the Pine River confluence due to the long mixing length of the tributary inflows, which varies depending on relative flows in the two rivers and would not change substantially as a result of the Project.

The mean annual suspended sediment load immediately downstream of the Site C dam site during Years 1–10 of operations would be reduced by 54% compared to the baseline condition. The percentage reductions in mean annual load further downstream are presented in Table 11.8.5.

Table 11.8.5 Expected Changes in Mean Annual Suspended Sediment Load in the Peace River (Operations Phase)

Peace River Location	Change in Annual Load
Site C Dam Site	- 54%
Pine River Confluence	- 21%
Alces River Confluence	- 8%
Dunvegan	- 5%
Town of Peace River	- 2%
Peace Point	- 2%

Uncertainty, Sensitivity, and Reliability

The estimate of suspended sediment inputs from tributaries were summed along the Peace River, and net deposition of suspended sediment along the river channel was assumed to be negligible. The primary sources of uncertainty in this analysis are the accuracy of modelled sediment outflows from the reservoir (see Uncertainty, Sensitivity, and Reliability in Section 11.8.5.1 above), the accuracy of estimated baseline sediment inputs from tributaries downstream of the dam (same as in reservoir tributaries, see Section 11.8.5.1, Uncertainty, Sensitivity and Reliability above), and the potential net deposition of a portion of the suspended sediment load along the river. The net deposition in the river has been shown to represent a negligible fraction of the total load based on the similarity of grain-size distributions in the tributaries and the Peace River mainstem, where suspended sediment deposition would comprise primarily fine sand

and would lead to a reduced sand fraction in the Peace River grain-size distribution. Overall, the results provide a reliable characterization of the expected changes due to the Project.

11.8.5.3 Channel Erosion and Deposition Patterns Downstream of the Site C Dam Site

Approach and Methods

The Peace River flow regime below the Site C dam site would not be substantially altered by the Project during the operations phase (refer to Section 11.4 Surface Water Regime). However, channel hydraulics would be altered locally downstream of the tailrace and spillway, bedload supply from upstream of the dam would be eliminated, and some localized changes due to these combined factors are anticipated.

The following modelling exercises were undertaken to assess the influence of locally modified hydraulic conditions and upstream bedload interception:

- A two-dimensional (2D) hydrodynamic model (River2D) was used to assess flow competence during the operational phase. The model is described in Section 11.4 Surface Water Regime. Flow competence was assessed at 4000 m^3/s.
- A one-dimensional (1D) morphodynamic model (HEC-RAS) was developed to assess the potential extent of channel gradation adjustment below the Site C dam site under an extreme flow scenario of 5,000 m^3/s for one year. This flow condition is similar to the high flows recorded during the summer of 1996, but with approximately eight times longer duration, and was selected to provide an upper bound on potential channel change. The HEC-RAS model was calibrated to match the MIKE 11 model described in Section 11.4 Surface Water Regime.

These two models are freely available and widely used for hydraulic and sediment transport analyses. River2D was developed at the University of Alberta (Steffler and Blackburn 2002), while HEC-RAS was developed by the United States Army Corps of Engineers (USACE 2010).

Expected Changes

The Project would intercept the Moberly River bedload material that has been accumulating in the Peace River channel below the confluence since the onset of regulation.

Bed material in the Peace River is rarely mobilized under the normal range of regulated baseline flow conditions, but was likely mobilized in some areas during the Williston Reservoir drawdown in the summer of 1996, when flows exceeded 4,000 m^3/s for 45 consecutive days at the Site C dam site. Under an operational flow scenario of 5,000 m^3/s for one year (i.e., eight times the duration of the 1996 drawdown event), the Peace River bed would degrade (bed elevation could decrease) by approximately 1 m to 1.5 m in a 2 km stretch below the tailrace (generating station outlet) due to bed material mobilization and lack of bedload replenishment from upstream. Much of the scoured bed material would accumulate in a 2 km aggradation (net deposition) zone downstream of the degradation (net erosion) zone, as shown in Figure 11.8.17.

Elsewhere, the Project is not expected to result in any changes in channel erosion or deposition patterns, which are either natural (i.e., valley wall erosion and landslides along the river), or are driven by the ongoing response of the river channel to upstream flow regulation that started in 1967 (i.e., aggradation below tributary confluences, local bank erosion opposite from tributary confluences, and vegetative encroachment onto gravel bars and into secondary channels).

Uncertainty, Sensitivity, and Reliability

The primary sources of uncertainty in this analysis are the characterization of subsurface riverbed material, characterization of hydraulic conditions in the river, and computing of bedload transport based on the above.

- A large number of bed material grain-size samples were collected on the surfaces of exposed gravel bars and on the wetted channel bed surface. These samples give some indication of the bulk characteristics of the subsurface material, but the latter typically contains a greater component of finer sediment. A smaller number of subsurface bulk samples was used to characterize the subsurface grain-size characteristics. Subsurface sediments tend to be less spatially variable because they tend to be deposited during large flood events and are not exposed to subsequent variable flow conditions at the riverbed surface, so the smaller number of subsurface samples is adequate.
- A one-dimensional (1D) model, HEC-RAS, was used to characterize hydraulic conditions in the river. HEC-RAS is a widely used hydraulic model developed by the US Army Corps of Engineers. A 1D model represents cross-sectional average depth and velocity conditions, but does not capture lateral variability. Such a model was adequate for the intended purpose of estimating average bed degradation depth and longitudinal extent. It was not intended to represent detailed patterns of scour and deposition at scales of less than one channel width.
- The Meyer Peter Muller bedload transport formula was employed to compute transport within the HEC-RAS model. This is one of the most widely used bedload transport formulae used in gravel bed rivers.

The channel erosion analysis contains uncertainty with respect to the spatial variability of bed material composition, the probability of extreme high flow conditions, and the accuracy with which bedload transport can be computed (limited by the state of the science). The analysis used the best estimates of bed material composition and bedload computation methods, and a high estimate for extreme high flow conditions, in order to generate an upper bound estimate of channel change. The results provide a reliable characterization of how much channel change could be expected due to the Project.

11.8.6 Summary of Expected Changes

Construction Phase – Downstream Suspended Sediment

In-stream construction activities would be carried out in Years 1, 4, and 7. Onshore construction activities would be conducted throughout the eight-year construction phase in isolation from the river, with site runoff managed according to an Environmental Management Plan. Headpond shoreline erosion would occur during periods of high flow during the diversion stage of construction.

Over the eight-year construction phase, the fine sediment inputs related to in-stream construction activities would represent an estimated increase of 0.2% to 0.3% above mean annual baseline sediment load immediately downstream of the Site C dam site. Over the four-year diversion stage of construction, the fine sediment inputs related to headpond shoreline erosion would represent an estimated increase of 1% above mean annual baseline sediment load immediately downstream of the Site C dam site. The sediment inputs would likely occur as asynchronous event-type pulses.

The in-stream construction activities are expected to generate elevated suspended sediment concentrations for durations ranging from a few hours to a few months. The incremental increases in suspended sediment concentration would be in the order of 10 to 1000 mg/L at locations close to the source (i.e., mixed into 5% of the river flow), decreasing to lower levels once fully mixed in the river flow at some location downstream of the Pine River confluence. The exception to this is the flushing of the diversion channels and tunnels at the start of the river diversion stage (Year 4), when a brief (one hour) pulse of high concentration would occur: 300 to 500 mg/L in fully mixed flow immediately downstream of the tunnel outlets. The headpond shoreline erosion events are expected to generate incremental increases in suspended sediment concentration in the order of 1 to 20 mg/L in the fully mixed river flow immediately downstream of the tunnel outlets. These events would occur on approximately 12% of the days during the four-year diversion stage of construction, with greater frequency in the autumn and winter and lower frequency in the spring and summer.

Operations Phase – Reservoir

The proposed reservoir would trap a portion of the sediment delivered from tributaries, while the remainder (mostly clay) would be transported out of the reservoir and down the Peace River.

Wind-driven waves in the reservoir would erode the valley slopes and create a new source of sediment in the reservoir/river system. A portion of this sediment would be trapped in the reservoir, while the remainder (mostly clay) would pass through the dam and travel down the Peace River.

After 50 years, the depth of sediment deposition throughout most of the reservoir would range from 0.3 to 0.5 m, while depths of several metres would accumulate near some of the more erodible shoreline sections and in the Halfway River embayment.

Operations Phase – Downstream Suspended Sediment

The mean annual suspended sediment load in the Peace River immediately downstream of the Site C dam site would be reduced by approximately 54% over the first 10 years of reservoir life. The load would further diminish through time as reservoir shoreline erosion rates decline.

The relative reduction in mean annual suspended sediment load during the first 10 years of reservoir life diminishes in a downstream direction, from 54% at the Site C dam site to 2% at the Town of Peace River and 2% at Peace Point.

The reduction in suspended sediment load would occur primarily during baseline peak events (spring snowmelt and summer rainstorms). Due to reservoir attenuation, the median daily concentration downstream of the dam would actually increase in summer, autumn, and winter (by a small amount from low baseline values), and would only decline in the spring (by a larger amount from higher baseline values).

Downstream Channel Erosion and Deposition Patterns

The Site C dam would intercept bedload and locally alter hydraulic conditions in the Peace River. In the event of sustained high flows – similar in magnitude to the summer of 1996 when Williston Reservoir was drawn down, but with eight times the duration – the bed of the Peace River would erode vertically by 1 to 1.5 m over a 2 km length downstream from the dam. Most of the eroded bed material would accumulate in a deposition zone in the next 2 km downstream. This is an extreme high flow scenario that was modelled for the purpose of establishing an upper bound estimate in downstream channel change.

Further downstream, channel erosion and deposition patterns are governed primarily by river flows and tributary bedload inputs. Changes in river flows due to the Project are not expected to influence the erosion and deposition patterns; therefore, no incremental changes to the dynamic baseline patterns are predicted.

All of the expected changes are well contained within the specified study areas.

11.8.7 Climate Change

Baseline conditions in the Peace River are intrinsically linked to the prevailing climate, particularly the magnitude and temporal distribution of seasonal and storm-event runoff volumes in the tributaries that join the Peace River downstream of the two existing hydropower dams.

Suspended and bedload sediment transport are positively related to streamflow discharge, and the relationships are non-linear. Most of the sediment transport occurs during a relatively small fraction of time when flows are the highest. The linkages between climate, runoff, and sediment transport in the Peace River tributaries are described below.

Snowmelt runoff in mountain-headwater tributaries such as the Pine River occurs in the late spring and early summer (typically peaking in June), which coincides with the time of year that is prone to the most intense rainstorms. Therefore, peak flows in these tributaries often result from a combination of rainfall and snowmelt. Snowmelt runoff in plateau tributaries such as the Kiskatinaw River occurs in early to mid-spring (typically peaking in May), and is less synchronized with the timing of the most intense rainstorms. The largest peak flows in these tributaries usually result from summer rainstorms. Streamflows in mountain-headwater and plateau tributaries currently reach their minimum levels in late winter.

Future climate trends in the Peace River watershed (summarized in Volume 2 Appendix T Climate Change Summary Report) suggest that the following changes are likely to occur by the 2050s time period (with the same general patterns for the 2080s time period):

- Increased temperature year-round, with the greatest increases in the winter
- Increased precipitation year-round, with the greatest increases in the winter and spring
- Negligible change in snowpack in the Rocky Mountains (net balance between increased winter precipitation and increased winter temperature)

- Decreased snowpack on the Alberta Plateau (increased winter temperature dominates over increased winter precipitation)
- Increased annual streamflow in Peace River tributaries (mountains and plateau), with the greatest increases in the autumn, winter, and spring, and reduced flows in late summer
- Earlier onset of spring snowmelt freshet in the mountain-headwater tributaries, with a shift in the peak from June to May

Based on the above, the following changes in streamflow patterns relevant to sediment transport regime are hypothesized:

- Increased annual and seasonal precipitation may correspond with increased rainstorm intensity and increased storm runoff
- Larger snowmelt runoff volumes are predicted in the mountain-headwater tributaries, but with potentially less synchronization of snowmelt and rainstorm runoff in these tributaries. The net change in peak flow magnitude in the mountain-headwater tributaries due to increased early spring rainfall, stable snowmelt runoff, increased rainstorm intensity, and reduced synchronization between snowmelt and late spring rainstorms is difficult to predict from the available information. However, the most likely result would seem to be an overall increase in runoff volume, peak flow magnitude, and sediment transport capacity.
- Decreased snowmelt runoff volumes are predicted in the plateau tributaries, but an increase in late spring and summer rainstorm intensity would result in increased peak flows. These peak flows mainly occur in the absence of snowmelt already, so the reduced snowmelt would not be expected to counteract this change. The increased peak flows would result in increased sediment transport capacity.

The most likely changes that can be expected from the available information are for increased suspended sediment and bedload transport loads in mountain-headwater and plateau tributaries of the Peace River. These in turn would result in a greater turbidity and deposition in the proposed reservoir, greater suspended sediment loads and turbidity in the Peace River downstream of the Site C dam site, and greater bedload deposition at tributary mouths downstream of the dam site. Although it is not currently possible to quantify the magnitude of the potential increase in sediment inputs due to climate change, it is thought to be within the range of uncertainty in the baseline data collection and modelling studies of project-related changes, and would not result in a materially different description of sediment dynamics in the reservoir or in the Peace River downstream of the dam site.

11.9 Methylmercury

11.9.1 Objective and Section Structure

This section on methylmercury describes the approach used to: a) describe baseline conditions of mercury (Hg) and methylmercury (MeHg) in the technical study area for methylmercury, b) explore specific factors that influence mercury methylation in general and in the proposed Site C reservoir specifically, c) review the models and other lines of evidence that were used to determine how operation of the Project may change these conditions, and d) predict changes in MeHg concentration in the aquatic food web, with a focus on fish in the Site C reservoir and downstream. This prediction has been used to inform the human health risk assessment (HHRA) for methylmercury (Volume 2 Appendix J Mercury Technical Reports, Part 3 Mercury Reservoir Modeling) and Volume 4 Section 33 Human Health. This section is organized according to the following subsections:

- Reservoir creation and methylmercury dynamics – This subsection explores the relationship between inundation of terrestrial soils during reservoir creation and enhanced methylmercury generation, with a discussion of the general trends that have been observed in other Canadian reservoirs.
- Technical study area – The technical study area includes the Site C reservoir and the Peace River, extending as far downstream as Many Islands, Alberta. Mercury may be transported downstream of the reservoir, adhered to sediment particles and organic material, as well as directly in the tissue of plankton and fish that are discharged or entrained downstream. Fisheries investigations indicate that fish populations within the Peace River move between the Site C dam and Many Islands (Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). Fish that feed on injured or stunned fish entrained from the reservoir that have accumulated MeHg may become distributed within the Peace River, potentially as far as Many Islands.
- Site-specific factors of the Project – Several key physical, chemical, and ecological parameters affect the rates of Hg methylation/demethylation, bioaccumulation and biomagnification of MeHg within aquatic food webs of rivers, lakes, and reservoirs. This subsection summarizes relevant terrestrial (i.e., existing areas forecast to be inundated during reservoir creation) and aquatic baseline information pertinent to establishing baseline conditions for the Site C reservoir. This includes mercury and methylmercury concentrations in terrestrial (soil, vegetation) and aquatic (water, sediment, invertebrates, fish) media.
- Predicting changes in mercury in fish – Three independent lines of evidence were used to determine how mercury in fish would change following creation of the Site C reservoir. These included a simple regression model (Harris and Hutchinson 2012), a complex mechanistic model called RESMERC (Volume 2 Appendix J Mercury Technical Reports, Part 3 Mercury Reservoir Modelling) and a 'weight-of-evidence' or matrix approach, whereby many physical, chemical, and ecological parameters associated with increased methylation rates observed in several Canadian reservoirs were contrasted with baseline and predicted conditions within the Site C reservoir (Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report).

- Integrated assessment of changes to fish mercury concentrations for the Project – Each of the above lines of evidence were integrated together to determine the change in fish methylmercury concentrations within the Site C reservoir and downstream. This is expressed as a multiplier of existing baseline concentrations. Finally, the duration that concentrations in fish are predicted to be elevated before returning to baseline is estimated.

The information underlying the discussion of this section can be found in the following documents: Mercury Technical Synthesis Report (Part 1 of Volume 2 Appendix J Mercury Technical Reports), Reservoir Modelling Report (Part 3 of Volume 2 Appendix J Mercury Technical Reports). This information also informs Volume 4 Section 33 Human Health.

11.9.2 Mercury Terminology

This subsection clarifies terminology used when referring to inorganic mercury (Hg) and organic or methylmercury (MeHg). When referring to ‘total mercury’, this is the sum of all forms of Hg, whether in the inorganic or organic forms, primarily MeHg. Both of these forms of mercury occur naturally in the environment and their concentrations vary widely according to which media (e.g., water, sediment, aquatic insects, fish) is being referred to. For example, the concentration of MeHg in fish is many million times more concentrated than in water. Furthermore, the proportion of the total Hg concentration that comprises MeHg also varies according to media. This is often termed as the methyl: total ratio. For example, in all environmental media (except fish), the ratio of MeHg relative to total Hg is small and difficult to measure, except using sophisticated methods by a small number of specialized laboratories. To illustrate this, the typical percentage of the total Hg concentration that comprises MeHg in various environmental media is as follows:

- In vegetation and soil, MeHg makes up less than 2% of total mercury
- In water, MeHg usually comprises less than 5% of the total mercury
- In vegetation and soil, MeHg makes up less than 2% of the total Hg measured
- In benthic invertebrates, MeHg comprises 30 – 50% of total Hg
- In fish, nearly all of the measured mercury is present as MeHg (Bloom 1992). Also, the absolute concentration of MeHg in fish is much higher in fish than in all other media, especially water, soil, vegetation, and sediment.

Thus, when referring to fish Hg concentrations, although the term Hg is used, it is assumed that it is entirely MeHg. This is why commercial laboratories measure for total Hg in fish, not MeHg, which is more complex and costly.

11.9.3 Reservoir Formation and Methylmercury Dynamics

Under natural conditions, Hg is present in low concentrations in all environmental media including water, soil, sediment, and plants, and in all terrestrial and aquatic animals. As noted above, methylmercury occurs in far lower concentration than does inorganic Hg in all environmental media except fish. In soils, water, and sediment, inorganic Hg is the prevalent form and originates from atmospheric (natural or anthropogenic) and geologic sources. Over time, inorganic Hg captured from the atmosphere by the leaves and needles of plants falls to the ground and accumulates, being sequestered and concentrated into terrestrial soils. Under these conditions, the natural rate of Hg methylation is low. However, when soils are flooded, degradation of the organic material creates favourable and accelerated conditions for sulphate-reducing bacteria that transform or “methylate” some of the inorganic Hg into organic mercury, primarily methylmercury (although there are other forms). The rate of bacterial activity and mercury methylation is governed by many factors such as the amount and quality of organic carbon, pH, and sulphate, not necessarily the mass of inorganic Hg available.

Methylmercury is much more easily absorbed and accumulated by animals than inorganic Hg. Once MeHg is incorporated by bacterial tissue, it becomes part of the food chain. MeHg accumulates at a greater rate than it degrades or is eliminated, accumulating over time within an organism (i.e., bioaccumulation), and becoming more concentrated through successive trophic levels (i.e., biomagnification). Thus, MeHg concentrations are higher in large-bodied, longer-living animals, especially those at the top of the food chain such as predatory fish (Potter et al. 1975; Abernathy and Cumbie 1977; Bodaly and Hecky 1979; Bodaly et al. 1984, 1987; Hall et al. 1997).

Flooding of terrestrial soil and vegetation to form new reservoirs creates conditions favourable for accelerating methylation rates. The degree to which this happens and how long these conditions persist varies among reservoirs. The rate and magnitude of MeHg production is affected by many factors, and the response to inundation and reservoir creation differs among reservoirs. This is explored in detail in the Mercury Technical Synthesis report (Part 1 of Volume 2 Appendix J Mercury Technical Reports). Data from Canadian reservoirs agree in the general pattern of changes in fish Hg concentration over time. Mercury in adults of large, predatory species increases rapidly, with peak concentrations three to eight years after impoundment, after which levels decline to eventually reach pre-impoundment (or baseline) concentrations 15 to 25 years later (Schetagne et al. 2003; Munthe et al. 2007).

Fish-eating species (e.g., lake trout, bull trout) have the highest peak Hg concentrations, take the longest to reach maximum levels, and take longer to return to a baseline level, although there is variability in each of these endpoints (Bodaly et al. 1997, 2007; Schetagne et al. 2003). These differences are related to many reservoir-specific conditions, especially water residence time, ratio of reservoir area to original wetted area, organic carbon in soils, water pH, amount of flooded wetland, and food web complexity. The physical, chemical, and ecological factors that contribute to this are explored below and in detail within the Canadian reservoirs comparison matrix of the Hg Synthesis Report (Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report).

11.9.4 Technical Study Area

The change in MeHg concentration in environmental media will occur primarily within the Site C reservoir, but also downstream in the Peace River, extending as far as Many Islands Alberta (Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report).

Within the reservoir, changes will occur between Peace Canyon Dam to the Site C dam and in the lower reaches of the larger tributaries (Halfway and Moberly). A strong factor influencing the containment of MeHg within a new reservoir is the degree of erosion and export of carbon and MeHg in water, sediment, and biota out of the new reservoir. Some of this might occur during the construction phase, which is not accounted for here, and will make predictions slightly more conservative because it is assumed that no carbon is exported before the reservoir is impounded. The main factors that influence sedimentation rates are reservoir depth, water residence time, and particle settling time. The Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report suggests that there may be considerable erosion of banks and sediment deposition (principally gravel and sand, and some silt) throughout the reservoir, especially during the first 10 years after impoundment. This would have the effect of reducing Hg methylation by burying organic soils under a thin layer of inorganic material. This may also reduce the export of Hg that is adhered to organic matter from being transported out of the reservoir and discharged downstream.

In addition to changes within newly created reservoirs, changes may also extend downstream. For example, downstream export of inorganic Hg adhered to carbon has been observed in some Quebec reservoirs (Schetagne et al. 2000), Southern Indian Lake, Manitoba (Bodaly et al. 1997) and in the Churchill River downstream of Smallwood Reservoir, Labrador (Anderson 2011). Changes to Hg concentrations in fish downstream of reservoirs occurs either when a fish species increases its consumption of fish, or shifts its diet from algae and invertebrates (e.g., longnose sucker or whitefish) to a diet with a higher proportion of fish, such as when targeting fish that have been injured or killed from passage through turbines. An increased diet of fish with elevated Hg may increase Hg in some downstream fish (Brouard et al. 1994). The increase is not related to export of MeHg dissolved in water, as food remains the dominant source of MeHg in fish (Hall et al. 1997). In upstream reservoirs with a long hydraulic residence time and large settling capacity, the implications for accumulation of Hg for downstream fish appear to be reduced. The degree to which an increase of Hg in fish may occur downstream of a new reservoir in some individuals of some species that do not normally consume fish and may be exacerbated in some fish consumers such as bull trout and lake trout is difficult to predict.

The downstream extent of changes in fish Hg for the Project may extend to the area of Many Islands. This is the furthest downstream extent that local fish populations have been shown to migrate upstream from, to as far as the Site C dam site, based on fish tagging studies (Volume 2 Section 12 Fish and Fish Habitat).

11.9.5 Site-Specific Factors Relevant for Predicting Changes in Fish Methylmercury Concentration

Several key physical, chemical, and ecological parameters affect the rates of Hg methylation/demethylation, bioaccumulation, and biomagnification of MeHg within the food web. The most important factors are baseline MeHg concentrations in environmental media, hydraulic residence time, flooded area relative to original area, pH of water/sediment, the amount and chemical composition of the newly flooded soil, and invertebrate and fish community structure (particularly the number of trophic levels). Reservoir-specific differences in these factors are responsible for the substantial variability in the number of years for fish to reach peak mercury concentrations, the magnitude of those peaks, and the return time to pre-flooding conditions that has been observed among reservoirs (Bodaly et al. 2007; Schetagne et al. 2003).

The following subsections summarize relevant terrestrial (i.e., existing terrestrial areas inundated as a result of reservoir creation) and aquatic baseline information pertinent to establishing the starting conditions for the Site C reservoir.

11.9.5.1 Baseline Terrestrial Media

Organic soils in flooded terrestrial habitats are the medium for accelerated bacterially mediated methylation rates and mobilization of MeHg into aquatic food chains in newly created reservoirs. In addition to Hg concentrations (mg/kg) in terrestrial soils and vegetation, inventories or the mass of mercury (kg Hg/ha) and carbon (metric tonnes C/ha) in these environmental media are important drivers of Hg methylation. The most important component is the uppermost organic fraction represented by the litter, fermentation, and humus horizons, within several centimetres (<5 cm) of the surface. Labile (i.e., easily decomposable, bioavailable) carbon and Hg in these horizons also supports mercury methylation.

As described in detail in the Mercury Technical Synthesis Report (Part 1 of Volume 2 Appendix J Mercury Technical Reports), terrestrial ecosystem mapping (TEM) was used to stratify the relative spatial abundance (ha) of different habitat types. Organic soils beneath well-developed deciduous and coniferous forests contain the vast majority of the mass of Hg and organic nutrients to fuel the methylation process. Mercury and carbon pool sizes (i.e., the mass of Hg or carbon stored per m^2 of habitat) were estimated across flooded habitats using organic soil horizon thickness, soil bulk density, and soil total Hg concentrations. Mercury was also measured in vegetation, including leaves and needles from dominant trees (e.g., spruce, balsam, willow, alder), shrubs (e.g., prickly rose, willow, and dogwood), and grasses (e.g., horsetail, sedge, reeds, cattail). However, vegetation is a minor source of Hg relative to soil contribution, and woody debris from trees is not a major contributor to the methylation process.

Total Hg concentration in all plant tissues in the study area was low, in most cases just above the laboratory detection limit of 0.005 mg/kg dw. Methylmercury was not measured, as MeHg comprises a very low proportion (<2%) of total Hg concentration in plants (Rasmussen 1995; Grigal 2003). The most abundant shrub (<0.008 mg/kg dw) and tree species (<0.005 to 0.019 mg/kg) had low and similar Hg concentrations.

The average total Hg concentration of all organic soils within the upper 5 cm (i.e., the zone available for methylation) within the area forecast to be inundated by the Site C reservoir was 0.079 ± 0.03 mg/kg dw, ranging from 0.02 to 0.17 mg/kg dw. This is consistent with the range in Hg concentrations in soils (0.01 to 0.2 mg Hg/kg) measured elsewhere from background non-mineralized areas (e.g., Rasmussen 1994; Lodenius 1994; McKeague and Kloosterman 1974). Soil organic layer thickness, organic content, and Hg concentration were integrated across the inundation area to estimate carbon (kg C/m^2) and mercury (µg Hg/m^2) pools for use in Hg modelling (see the RESMERC report in Volume 2 Appendix J Mercury Technical Reports, Part 3 Mercury Reservoir Modeling). These were estimated at 0.54 – 1.2 kg C/m^2 and 0.16 – 0.36 mg Hg/m^2, respectively.

11.9.5.2 Baseline Aquatic Media

Key parameters in the aquatic environment that influence generation and bioaccumulation of MeHg are hydrology, limnology, and specific water and sediment chemistry parameters (Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report). The current ratio of inorganic to organic mercury in total Hg was measured in aquatic environmental media within the technical study area from Dinosaur Reservoir to downstream of Peace Canyon Dam in the Peace River and, in some cases, as far as Many Islands. The majority (>95%) of Peace River water between the Peace Canyon Dam and the Site C dam is discharged from Williston/Dinosaur reservoirs and is highly influential on the chemistry and ecology of the general area. Water discharged from Williston Reservoir is nutrient poor (ultra-oligotrophic), cold (<14oC) and well oxygenated all year (Stockner et al. 2005), of moderate to slightly basic pH (7.8 – 8.2), low in organic carbon content (<2 mg/L), and with low total suspended solids concentrations (<3 mg/L) during all times of the year (Golder 2009a, b). The only exception is during freshet or flood flows from large tributary streams such as Halfway River.

Water quality baseline conditions are not expected to markedly change, given the influence of Williston Reservoir upstream, which will continue to influence mercury methylation rates in the downstream reservoir. Given the short hydraulic residence time of water in the Site C reservoir (approximately 23 days), water discharged from Williston Reservoir will continue to influence downstream water temperature, oxygen, nutrients, suspended solids inputs, and biota, even during operation of the Site C reservoir (Volume 2 Section 11.4 Surface Water Regime, Section 11.5 Water Quality, and Section 11.7 Thermal and Ice Regime).

11.9.5.2.1 Water Chemistry and Mercury

Key parameters known to influence Hg methylation and total MeHg concentrations in environmental media are summarized here, with further detail in Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report and Volume 2 Appendix E Water Quality Baseline Conditions in the Peace River. The technical study area of the Peace River downstream of Williston Reservoir is slightly alkaline with a mean pH of 8.1 (7.5 to 8.4). Major tributary stream (e.g., Halfway, Moberly, and Pine) pH is slightly higher than mainstem pH values. Total suspended solids (TSS) concentrations vary considerably seasonally, episodically, and annually depending on rainfall and freshet flow volume within the Peace River downstream of Williston Reservoir (Golder 2009a). During most of the year, TSS in the mainstem of Peace River technical study area is below the routine laboratory detection limit of 3 mg/L. Tributary streams, especially Halfway, Moberly, and Pine, contribute high TSS during freshet or high rainfall events, with concentrations ranging in the hundreds of mg/L, which can increase Peace River concentrations (tens of mg/L). Total organic carbon concentrations (TOC) in Dinosaur Reservoir, Peace River between Peace Canyon dam and the Site C dam, Halfway and Moberly rivers were less than 5 mg/L, with dissolved concentrations making up >90% of the TOC. TOC concentrations in excess of 5 mg/L are associated with greater rates of MeHg production.

Total Hg concentrations in water from remote, pristine areas removed from industrial activities and natural sources (i.e., mineralized areas, volcanoes) range from <1 ng/L – 5 ng/L, or parts per trillion (i.e., <0.001 – 0.005 µg/L) (e.g., Hurley et al. 1995; Krabbenhoft et al. 1999, 2007). In the Peace River technical study area, exclusive of high TSS events during freshet, total Hg concentration seldom exceeded 1 ng/L. This low total mercury concentration is a reflection of low Hg water discharged from Williston

Reservoir. Similarly low concentrations were measured from Williston Reservoir in the early 2000s (Baker et al. 2002), and these data suggest that conditions have not changed over the last nearly 15 years.

Methylmercury concentration in Peace River and tributary stream water within the technical study area was consistently below the laboratory detection limit of 0.05 ng/L in nearly all samples. The only exceptions occurred during 2011 in the Moberly River (332 mg/L; 0.13 ng/L MeHg) and Halfway River (1960 mg/L; 0.34 ng/L MeHg) during a high flow event.

11.9.5.2.2 Sediment

Total Hg concentration in sediment along the Peace River in 2007 was either below the laboratory DL (0.05 mg/kg) or in low concentration (0.053 to 0.110 mg/kg dw) when detectable (Golder 2009b; Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report). Total Hg was non-detectable in Halfway and Farrell rivers, except for one sample from Moberly River (0.057 mg/kg dw). These low Hg concentrations are partly due to the sandy grain size of the river sediments (48% to 80% sand) and low TOC content (<1%) of sediment biomass. Subsequent sampling targeted fine sediments (>85% silt/clay) within and beneath the sand/gravel/cobble substrate measured 0.03 – 0.06 mg Hg/kg dw and 0.05 – 0.06 mg Hg/kg in Farrell, Halfway, and Moberly rivers. Methylmercury concentrations in Peace River (0.15 to 1.2 µg/kg) and tributaries (0.6 – 2.5 µg/kg) from the technical study area were similar and comprised <3% of the total concentration. These values are low and similar to or less than sediment Hg concentrations elsewhere in B.C. and elsewhere in Canada.

11.9.5.2.3 Aquatic Invertebrates

The dominant dietary organisms for fish in the Peace River technical study area were epibenthic invertebrates dominated by caddisflies and mayflies, with fewer numbers of stoneflies, water boatmen, snails, mites, clams, and chironomid fly larvae (Volume 2 Appendix P Aquatic Productivity Reports, Part 1 Baseline Aquatic Productivity in the Upper Peace River). The Peace River downstream of Williston Reservoir does not have a resident zooplankton community. Instead, zooplankton within the Peace River upstream of the Site C dam to Peace Canyon Dam is representative of what has been discharged out of Williston Reservoir downstream. Consequently, Hg/MeHg concentrations in zooplankton in the Peace River technical study area are very similar to that in zooplankton from Williston Reservoir. Total Hg in zooplankton in the Peace River downstream of the Peace Canyon Dam to the Site C dam site ranged from 0.004 to 0.009 mg/kg (ww). This concentration in zooplankton is similar to what was observed in Williston Reservoir 12 years earlier (Baker et al. 2002). The MeHg concentration in zooplankton from the technical study area was only 5 – 10% the total Hg concentration (0.0001 – 0.0007 mg/kg ww).

Total mercury concentration in benthic invertebrates collected from the Peace River mainstem of the technical study area (Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report) ranged from 0.010 to 0.082 mg/kg ww. Methylmercury concentrations ranged from 0.003 to 0.030 mg/kg ww, ranging from 20% – 63% of total Hg concentration. There was variation among discrete taxa groups, as chironomid larvae (0.06 mg/kg total and <0.04 mg/kg methylmercury) and water boatmen (Corixidae) had higher Hg concentrations (0.05 mg/kg total and 0.04 methyl) and total to methyl ratios than aquatic insects (e.g., Trichoptera 0.016 mg/kg ww total Hg, 0.005 mg/kg MeHg) (Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report).

These concentrations are comparable to or slightly lower than concentrations observed in reservoirs studies elsewhere in Canada, including La Grande, Quebec (0.013 to 0.026 mg/kg ww; Tremblay et al. 1996), Manitoba (0.02 to 0.21 mg/kg ww; Jackson 1988) and Finland (0.018 to 0.14 mg/kg; Sarkka 1979).

11.9.5.2.4 Fish

The fish community of the Peace River technical study area has been studied extensively (e.g., Aquatic Resources Ltd. 1991; Mainstream Aquatics 2009, 2010, 2011) and Hg concentration data have been collected periodically dating back to the early 1990s (e.g., Pattenden et al. 1991). Tissue Hg analysis has mainly focused on the dominant species observed downstream of Williston Reservoir to the Site C dam site including bull trout, lake trout, Arctic grayling, burbot, lake whitefish, mountain whitefish, rainbow trout, longnose sucker, and redside shiner. Mercury concentration data have also been collected from fish species found downstream of Site C as well, as far as Many Islands (northern pike, walleye, goldeye, burbot) and those whose habitat extends into Alberta.

The main influencing factors of fish Hg concentrations are MeHg in prey, age, and size of fish, growth rates, bioenergetics and reproduction. Because MeHg accumulated by fish is primarily from dietary sources, body burden concentration is highly dependent on concentrations in their food, and trophic status. Invertebrate MeHg concentration data described above were used as baseline values from which changes to invertebrate MeHg and fish Hg concentrations in the Site C reservoir were predicted using the RESMERC model (Volume 2 Appendix J Mercury Technical Reports, Part 3 Mercury Reservoir Modelling).

Table 11.9.1 summarizes recent fish mercury data for Dinosaur Reservoir and the Peace River technical study area as far downstream as Many Islands. Only data from burbot are reported from as far downstream as the Dunvegan project. Despite the diversity of fish species and their dietary habits, differences in mercury concentrations among species were small.

Results of fish Hg concentrations from the technical study area are:

- Bull trout Hg concentration ranged between 0.03 – 0.34 mg/kg, with a mean of 0.08 mg/kg, less than from Dinosaur Reservoir (0.12 mg/kg). It is noteworthy that only one bull trout measured 0.34; all other fish were <0.18 mg/kg.
- Mean Hg concentration in mountain whitefish and rainbow trout from Peace River and Dinosaur Reservoir were low and within a narrow range (0.03 to 0.09 mg/kg)
- Mercury in longnose sucker downstream of Peace Canyon Dam to the Site C dam was 0.05 mg/kg and 0.06 mg/kg downstream to Many Islands, Alberta
- Mean Hg of redside shiner downstream from the Site C dam site was 0.05 mg/kg
- Mercury concentrations in fish found only downstream of Site C dam site into Alberta including walleye (0.08 – 0.33 mg/kg), goldeye (0.13 – 0.31) and burbot (0.02 –

0.14 mg/kg) had higher concentrations than fish residing upstream of the B.C.–Alberta border. No northern pike were captured and there are no Hg data for this fish species.

Mean Hg concentrations of all fish species in the Peace River between the Peace Canyon Dam and the Site C dam were less than 0.10 mg/kg, with concentrations in nearly all fish less than 0.20 mg/kg. These are low concentrations, especially for the large piscivorous species bull trout and lake trout. These concentrations lower than for the same species of a similar size in all other B.C. lakes and reservoirs for which there are Hg data (Rieberger 1992; Baker 2002) (Table 11.9.2) and among the lowest in Canada (Depew et al. 2012).

Table 11.9.1 Recent (2008–2011) Peace River Technical Study Area Fish Mercury Concentrations

Species	Area	Year[1]	Sample Size	Length (mm)		Weight (g)		Hg (mg/kg ww)		Reference
				Range	Mean	Range	Mean	Range	Mean	
Bull trout										
	Peace River – Site C study area	2008	21	248 - 741	484	166 – 5450	1684	0.042 – 0.14	0.08	Mainstream 2009a
	Peace River – Downstream[2]	2008	4	211 - 544	336	100 – 1798	618	0.018 – 0.12	0.07	Mainstream 2009a
	Dinosaur Reservoir	2010/2011	6	285 - 811	476	262 – 7775	2519	0.038 – 0.34	0.12	Volume 2 Appendix J, Part 1
	Peace River – Site C study area	2010/2011	19	292 - 806	470	308 – 7160	1635	0.031 – 0.34	0.07	Volume 2 Appendix J, Part 1
	Peace River – Downstream	2011	2	500 - 558	529	1350 – 1822	1586	0.077 – 0.09	0.08	Volume 2 Appendix J, Part 1
Burbot										
	Peace River – Dunvegan	2008	43	274 – 790	474	132 – 2550	753	0.018 – 0.14	0.06	Mainstream 2009b
Goldeye										
	Peace River – Downstream	2010/2011	10	310 – 410	379	314 – 854	600	0.136 – 0.31	0.24	Volume 2 Appendix J, Part 1
Lake trout										
	Dinosaur Reservoir	2010/2011	28	304 – 630	414	262 – 2676	865	0.029 – 0.14	0.09	Volume 2 Appendix J, Part 1
	Peace River – Site C study area	2010	1	—	391	—	570	—	0.07	Volume 2 Appendix J, Part 1
Longnose sucker										
	Dinosaur Reservoir	2010/2011	12	268 – 434	393	240 – 1074	755	0.063 – 0.36	0.20	Volume 2 Appendix J, Part 1
	Peace River – Site C study area	2010/2011	31	295 – 442	388	362 – 1172	770	0.017 – 0.17	0.05	Volume 2 Appendix J, Part 1
	Peace River – Downstream	2011	10	373 – 442	403	654 – 990	779	0.019 – 0.10	0.06	Volume 2 Appendix J, Part 1
Mountain whitefish										
	Peace River – Site C study area	2008	30	209 – 466	340	94 – 1180	483	0.018 – 0.09	0.04	Mainstream 2009a
	Peace River – Downstream	2008	31	202 – 512	355	74 – 1526	570	0.014 – 0.09	0.04	Mainstream 2009a
	Dinosaur Reservoir	2010/2011	21	246 – 395	317	192 – 692	364	0.022 – 0.07	0.05	Volume 2 Appendix J, Part 1
	Peace River – Site C study area	2010/2011	39	211 – 480	345	108 – 1252	498	0.010 – 0.17	0.04	Volume 2 Appendix J, Part 1
	Peace River – Downstream	2010/2011	10	237 – 396	319	158 – 622	366	0.016 – 0.07	0.04	Volume 2 Appendix J, Part 1
Rainbow trout										
	Dinosaur Reservoir	2010/2011	10	265 – 313	292	178 – 286	242	0.036 – 0.06	0.05	Volume 2 Appendix J, Part 1
	Peace River – Site C study area	2011	10	215 – 440	330	128 – 984	433	0.022 – 0.09	0.04	Volume 2 Appendix J, Part 1
Redside shiner										
	Peace River – Downstream	2011	11	85 – 119	99	6 – 26	14	0.034 – 0.07	0.05	Volume 2 Appendix J, Part 1
Walleye										
	Peace River – Downstream	2011	16	399 – 479	431	630 – 1204	885	0.085 – 0.33	0.18	Volume 2 Appendix J, Part 1

Table 11.9.2 Fish Mercury Concentrations in Select BC Hydro Reservoirs and Lakes

Species	Area	Year	Sample Size	Length (mm)		Sample Size	Weight (g)		Sample Size	Hg (mg/kg ww)		Reference[1]
				Range	Mean		Range	Mean		Range	Mean	
Bull trout												
	Arrow Reservoir	1987	23	410 – 790	628	23	740 – 7000	3163	23	0.14 – 1.40	0.43	Baker 2002
	Arrow Reservoir	1995	16	430 – 760	588	16	800 – 5300	2488	16	0.10 – 0.28	0.17	Foster and Gadbois 1998
	Kinbaset Reservoir	1987	7	285 – 530	362	7	200 – 640	381	7	0.23 – 0.92	0.41	Baker 2002
	Kinbaset Reservoir	1995	11	580 – 860	736	11	2000 – 7300	5509	11	0.23 – 0.41	0.39	Foster and Gadbois 1998
	Revelstoke Reservoir	1987	25	260 – 565	365	25	160 – 2025	572	25	0.14 – 0.82	0.41	Baker 2002
	Revelstoke Reservoir	1995	17	510 – 890	670	17	1400 - 10300	4282	17	0.12 – 0.64	0.30	Foster and Gadbois 1998
Lake trout												
	Babine Lake	1979	28	480 – 710	589	28	500 – 4200	1991	28	0.10 – 0.50	0.25	Baker 2002
	Stuart Lake	2000	21	351 – 829	566	21	500 – 6050	2271	21	0.10 – 1.0	0.31	Baker 2001
	Trembleur Lake	2000	13	498 – 765	621	13	1325 – 6000	2927	13	0.11 – 0.72	0.32	Baker 2001
Lake whitefish												
	Stuart Lake	2000	31	161 – 515	312	31	50 – 1450	454	31	0.04 – 0.22	0.09	Baker 2001
	Trembleur Lake	2000	31	122 – 450	255	31	25 – 1175	286	31	0.02 – 0.26	0.08	Baker 2001
Mountain whitefish												
	Carpenter Reservoir	2000	11	182 – 275	228	11	75 – 275	145	11	0.09 – 0.19	0.13	Baker 2001
Rainbow trout												
	Arrow Reservoir	1986	13	335 – 650	442	13	410 – 4200	1187	13	0.07 – 0.31	0.14	Baker 2002
	Kinbaset Reservoir	1985-1987	13	310 – 440	395	13	390 – 830	715	13	0.05 – 0.27	0.14	Baker 2002
	Revelstoke Reservoir	1987	11	270 – 500	406	11	270 – 1100	754	11	0.12 – 0.57	0.23	Baker 2002

11.9.6 Predicting Changes in Fish Mercury Concentrations at Site C

The accumulated knowledge gained over the last 30–40 years of research and monitoring of Hg dynamics in new reservoirs provides a foundation upon which predictions regarding changes to fish mercury concentrations can be made, from the time of first impoundment to a return to baseline Hg concentrations. However, each reservoir has unique physical, chemical, and ecological conditions, and there is no single accepted tool or method to forecast what will happen within different reservoirs. For this reason, several lines of evidence were used to determine the most likely magnitude of change in MeHg concentrations in environmental media within the Site C reservoir. The three predictive tools were integrated together to derive a single, most likely estimate of change. The three tools employed at Site C were:

- Harris-Hutchinson (2012) Regression Model – This is a linear regression model that uses simple input parameters including original and flooded area (ha) and hydraulic residence time (or flow) to predict the relative degree to which fish mercury concentrations will increase and peak, relative to baseline values. Results of this exercise are presented as an Appendix within the RESMERC model report (Volume 2 Appendix J Mercury Technical Reports, Part 3 Mercury Reservoir Modelling).
- RESMERC Model – The RESMERC model (Volume 2 Appendix J Mercury Technical Reports, Part 3 Mercury Reservoir Modelling) is a complex, quantitative, mechanistic model that includes the latest understanding from scientific studies on methylmercury dynamics in aquatic systems. RESMERC mimics the production, destruction, and bioaccumulation of MeHg in various environmental media in reservoirs using mass balance calculations over time. The key outputs of this model are predictions of Hg and MeHg concentrations in water and biota (e.g., invertebrates, insects, fish) at any point in time, in this case, within the Site C reservoir.
- Canadian Reservoir Comparison Matrix – Chapter 5 of the Mercury Technical Synthesis Report (Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report) undertook a comprehensive review of many key physical, chemical, and ecological factors that are associated with creating conditions that enhance mercury methylation in reservoirs. Fifteen large reservoirs from Manitoba, Quebec, B.C. and Labrador were evaluated. Baseline and predicted values for these parameters from the Site C technical study area were contrasted against what has been observed elsewhere in Canada, to put the Site C Project in perspective with other large Canadian hydroelectric projects, with a focus on changes in fish Hg concentrations over time.

11.9.6.1 Harris-Hutchinson Regression Model

The Harris-Hutchinson regression model (Harris and Hutchinson 2012; Volume 2 Appendix J Mercury Technical Reports, Part 3 Mercury Reservoir Modelling) predicts the relative increase in fish Hg concentration over baseline for a new reservoir, using only three input parameters: flooded area, total area, and mean annual hydraulic residence time (Equation 1). The outcome is a peak increase factor (e.g., 3x or 5x). This is the number that is used to multiply baseline fish Hg concentrations in order to predict peak Hg concentrations for a particular species or size class in a new reservoir. However, the model only predicts peak concentrations, and does not predict the timing of the response, nor the return period back to a baseline condition.

This approach assumes that the primary source of MeHg in a new reservoir is the flooded terrain (numerator in Equation 1), while MeHg removal (denominator in Equation 1) is more efficient in reservoirs with a short replacement or residence time. When hydraulic residence times are longer, outflow is less effective at removing MeHg and other mechanisms become more important, including bacterial demethylation, photochemical degradation, and sedimentation.

$$\text{Peak Increase factor} = k_1\left(\frac{A_{Flooded}}{(Q + k_2 A_{total})}\right) + k3 \qquad \text{(Equation 1)}$$

Where:

Peak increase factor	=	peak increase factor in fish MeHg
$A_{flooded}$	=	flooded area (km^2)
A_{total}	=	Total reservoir area (km^2)
Q	=	mean annual flow (km^3/year); or removal rate
k_1 and k_2	=	regression coefficients (km/year)
k_3	=	regression coefficient (dimensionless)

The calibrated version of Equation 1 is as follows:

Peak increase factor = 0.427 * (Af/(Q+0.075At)) + 1.77

No long-term monitoring data were available to calibrate the model for conditions in British Columbia for bull trout or other fish species. Consequently, the regression developed for northern pike was used as a surrogate for bull trout, as bull trout and northern pike are both large predatory fish species. To account for potential long-term variation in discharge from Williston Reservoir, the 5^{th} percentile (sustained low discharge), the 95^{th} percentile (sustained high discharge), and the long-term mean discharge were used to depict the possible range in change in fish Hg concentration under these different discharge scenarios. Results are shown in Figure 11.9.1.

Predicted peak increase factors for the Site C reservoir ranged from 2.1 to 2.8, depending on 2000–2010 discharge rates from Williston. Assuming that long-term mean discharge patterns from Williston Reservoir are similar moving forward (Volume 2 Appendix D Surface Water Regime Technical Memos), the model predicts a 2.3x increase in fish Hg concentration above current baseline. That is, assuming a mean baseline concentration of 0.08 mg/kg concentration for a 50 cm bull trout from the Site C technical study area, the predicted mean Hg concentration for a similar size bull trout within the reservoir would peak at 0.20 mg/kg.

11.9.6.2 Summary of Findings from RESMERC

RESMERC is a process-based simulation model that was designed to predict changes in Hg and MeHg concentrations in environmental media in new reservoirs over time (Harris et al. 2009). The model was originally developed and calibrated from experimental reservoirs at the Experimental Lakes Area, Ontario (Bodaly et al. 2004; St. Louis et al. 2004). Model compartments include the water column, sediments, and a simplified food web of phytoplankton, zooplankton, benthos, and several fish species

(Figure 11.9.2). Fish Hg concentrations are followed in different size classes and the model predicts Hg and MeHg concentrations over time. RESMERC processes include atmospheric deposition, inflows and outflows, particulate settling, re-suspension, burial, in situ transformations (methylation, demethylation, photodegradation) and MeHg uptake kinetics in plankton and partitioning in benthos and fish. Additional information on RESMERC is available in Volume 2 Appendix J Mercury Technical Reports, Part 3 Mercury Reservoir Modelling.

The approach used to apply RESMERC to the Project was as follows:

- The model calibration was updated by applying it to two full-scale reservoirs created in the 1970s that had long-term fish Hg datasets: Robert Bourassa Reservoir (LG2), Quebec, and Notigi Reservoir, Manitoba
- The model was then applied to pre-flood conditions in the Peace River between the Peace Canyon Dam downstream to the Site C dam location, using data from baseline studies. This step was necessary to establish that RESMERC could predict baseline conditions prior to predicting conditions within the Site C reservoir. Simulated pre-flood or baseline concentrations of MeHg in mountain whitefish and bull trout are shown in Figure 11.9.3.
- RESMERC was then applied to the Site C reservoir to predict changes in Hg concentrations in water, sediments, and the food web, including key fish species

Once calibrated and run to simulate baseline conditions, RESMERC was used to predict changes in MeHg concentrations in water, flooded soils, and biota in the Site C reservoir during the operating phase. Construction phase effects during operations were not simulated because there is currently insufficient information on potential physical changes brought about by fluctuating water levels upstream of the Site C cofferdam prior to operations. The effect of construction-related fluctuations in water levels and periodic inundation of soils may cause erosion and transport or organic material downstream and/or burial of organic sediments within the reservoir. By not accounting for this, RESMERC may be conservative in terms of predicting peak fish Hg concentrations, as Hg methylation may be extended over a slightly longer period of time and would produce lower peak fish Hg concentrations on a reservoir-wide basis.

The Site C reservoir is predicted to thermally stratify during summer at the lower end of the reservoir (Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report). Two reaches of the reservoir were therefore simulated. The upper reach (25 km in length) would not stratify, while the lower 58 km was predicted to thermally stratify for a portion of the ice-free season. Simulations were carried out for both reaches; however, given the likelihood of fish moving between the modeled reaches in the reservoir, predictions for the two reaches were combined into an overall reservoir-wide prediction for fish, using an area-weighted approach.

RESMERC predictions for Hg in water, sediment (stratified by reach), and fish (combined) for the Site C reservoir are shown in Figure 11.9.4**.** MeHg concentrations in the water column are predicted to roughly double during the first decade after flooding to reach 0.04 ng/L (annual average), with short term peaks up to 0.06 ng/L. While these concentrations represent increases due to reservoir inundation, they remain within the typical range of background concentrations for natural water bodies (St. Louis et al. 1995; Bodaly et al.; 2004; Volume 2 Appendix P Aquatic Productivity Reports, Part 1

Baseline Aquatic Productivity in the Upper Peace River). MeHg concentration in newly flooded soils would increase by a factor of up to 10x above baseline in the range of 0.02 µg/g (20 µg /kg).

Mercury concentrations for lower trophic level fish species, redside shiner (0.12 mg/kg), mountain whitefish (0.15 mg/kg; 30 cm fish) and longnose sucker (0.14 mg/kg; 30 cm fish) are predicted to reach peak levels between four and six years after full impoundment of the Site C reservoir. Mercury concentrations are predicted to be higher for larger fish. Rainbow trout are predicted to reach 0.16 mg/kg six years after inundation. Bull trout will take longer (eight years) and peak at a higher level (0.45 mg/kg for a large 60 cm fish) because of their slower growth rate and highly piscivorous diet (Figure 11.9.4). This increase above baseline is greater than what was predicted by the regression model and relative to what would be expected when compared to many other Canadian reservoirs.

RESMERC predicts that fish Hg concentrations will return to background concentrations after approximately 18–25 years or more, depending on the species. Small forage species like redside shiner will return more quickly, while long-lived species like bull trout may take longer. Note that the timing of return to a ‘baseline condition’ does not necessarily mean pre-impoundment concentrations. Given long-term global increases in atmospheric mercury emission and deposition, it is reasonable to expect that fish mercury concentrations may be higher than the present day. Furthermore, RESMERC may overestimate the return period for some species because it does not account for the influence of Williston Reservoir, just upstream. This reservoir will continue to rapidly flush the Site C reservoir with oligotrophic water that is very low in mercury and biota, which may result in a more rapid return to a new baseline than RESMERC predicts.

The increases in fish Hg concentrations within the Site C reservoir as predicted by RESMERC are conservative because of the following two reasons. First, with the exception of bank erosion and slumping events that are episodic and transitory, Volume 2 Appendix I Sediment Transport Technical Report predicts that, during the first 10 years following impoundment, a substantial increase and settling of inorganic solids is predicted to occur throughout the new reservoir. In most areas, the depth of material exceeds 3–5 cm and is up to 30 cm in some areas. Deposition of inorganic material over top of organic sediment at the rates predicted would depress methylation rates to such an extent that methylation would nearly cease within the reservoir. However, given that a depression in methylation to this degree has not been observed in other newly formed reservoirs, the full influence of sedimentation within the Site C reservoir was not taken into account. The effect of not considering sedimentation is that increases in fish Hg concentrations would be lower than predicted by RESMERC.

Secondly, it was assumed that increases in benthic and epibenthic invertebrate tissue MeHg concentrations were more closely linked to increases in MeHg concentrations in sediments than the overlying water column. This would result in higher predicted fish Hg concentrations than if dietary items for fish were linked less to MeHg in sediment and more to the water column. This might be true for most important dietary items such as mayflies and caddisflies, which are some of the most important dietary organisms in Peace River technical study area fish (Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). While the future conditions report (Volume 2 Appendix P Aquatic Productivity Reports, Part 3 Future Conditions in the Peace River) predicts benthic organisms to be an important component of the post-flood food web in the reservoir, it is not known whether the MeHg in these organisms may be more closely linked to MeHg in the sediments or overlying waters. RESMERC conservatively linked benthos more closely to exposure to MeHg generated in sediment than from the water column. This assumption may over-predict fish Hg concentrations.

11.9.6.3 Findings of the Canadian Reservoirs Comparison Matrix

The Canadian reservoirs comparison matrix (Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report) reviews the physical, chemical, and ecological parameters that are positively associated with increases in mercury and methylation rates, based on what was observed in 15 Canadian reservoirs (Manitoba, Quebec, Labrador, and Williston Reservoir in B.C.). How these parameters ultimately influence fish mercury concentrations were contrasted against baseline and predicted conditions within the Site C reservoir. Comparing and contrasting results from many other reservoirs to the Site C reservoir provides insights into where Site C fits within the spectrum of reservoir types – as it relates to MeHg magnification in environmental media. An advantage of this approach is that it relies on real data from a range of reservoir types across Canada, to provide insights into what factors drive fish Hg concentrations.

A series of matrices were developed to compare a large number of physical, chemical, and ecological factors across many reservoirs. The reservoirs comparison matrices are large and complex, and full details are presented in Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report.

Key factors were identified from seven Manitoba reservoirs (Keeyask, Limestone, Long Spruce, Notigi, Southern Indian Lake, Stephens, and Wuskwatim), five Quebec reservoirs (Caniapiscau, LG1, LG2 [Robert Bourassa], LG3, and Opinaca), two Labrador reservoirs (Gull and Muskrat) and Williston Reservoir (B.C.). Among the large number of factors considered, both as important input parameters to RESMERC as well as the contributors to methylation potential at the Site C Project, the most important physical factors associated with enhanced mercury methylation were:

- Total reservoir area – Larger reservoirs have fish with higher Hg concentrations and take longer to return to baseline or background (relative to nearby lakes)
- Ratio of total reservoir area (original area) – The higher the ratio, the greater amount of MeHg that is generated
- Water residence time – Fish from longer residence time reservoirs have higher Hg concentrations that persist for a longer period

The most important chemical factors were:

- Slightly acidic pH (<6.5) water and sediment is associated with higher Hg concentrations in fish
- Higher total or dissolved organic carbon (TOC/DOC) concentrations in water (>5 mg/L) are weakly but positively correlated with the magnitude of increase in fish Hg

- Labile or easily degradable carbon, best represented by the amount (% of total and/or hectares) of wetland within the reservoir has been found to be a key contributor to elevated mercury methylation rates

The most important ecological factors are:

- Lower trophic level Hg concentration – Lakes/rivers with higher baseline MeHg concentrations in benthos result in higher MeHg increases post-flood and contribute to higher rates of bioaccumulation and biomagnification by fish
- Reservoir productivity – Larger reservoirs with more in situ nutrients, and nutrient inputs from upstream and/or tributaries, have greater biomass production and higher Hg methylation potential and, consequently, higher MeHg concentrations in biota

Each of the reservoirs evaluated was placed into one of two categories, either ‘low’ or ‘high’, based on the magnitude of increase in fish Hg concentration relative to baseline, or reference data (i.e., nearby water bodies not influenced by flooding). A value of less than 3x above baseline was defined as producing a ‘low’ increase in fish Hg concentration, while an increase of more than 3x baseline was defined as a producing a ‘high’ increase in fish Hg concentration. The value of 3x baseline was chosen as a cutoff value, which is approximately half the increase in what is seen in most ‘worst-case’ scenario increase reservoirs (an increase of 6–7x baseline). A 3x increase factor is conservative, yet high enough that it is statistically distinguishable from baseline, and the return to baseline can be measured with greater precision (Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report).

A summary matrix (Table 11.9.3) illustrates where the Site C reservoir would fit within the range of either a ‘low’ increase (<3x baseline) or ‘high’ increase (>3x baseline) for each of the physical, chemical, and ecological parameters evaluated from the reservoirs considered.

1 **Table 11.9.3 Canadian Reservoirs Comparison Matrix Summary**

Reservoir Characteristics	Low Magnitude Increase Reservoirs (Fish Mercury <3x Baseline)	High Magnitude Increase Reservoirs (Fish Mercury >3x Baseline)	Predicted Site C Result
Magnitude of Fish Mercury Increase above Baseline	Muskrat Falls, Gull Island (Nfld/Lab); Limestone, Long Spruce, Wuskwatim, Southern Indian Lake (MB) for some fish species	LG-1, LG-2, LG-3, Opinaca, Caniapiscau Quebec; Southern Indian Lake, MB (for some species) Williston, B.C.	
Physical Parameters			
Total Reservoir Area	Less than 200 km^2, ranging from 28 (Limestone) – 200 km^2 (Gull Island) for all reservoirs	Very large, with most exceeding 2,000 km^2 except Opinaca (1,040 km^2), Williston (1,779 km^2)	Site C predicted area = 9.3 km^2 and falls into LOW increase category
Original: Flooded Area	Less than 2 at Muskrat (1.5) and Gull (1.7) Nfld/Lab and Limestone (1.3), Long Spruce (1.9), and Wuskwatim, MB (1.5)	A ratio well in excess of 2 at LG1 (2.3), LG2 (13.8), LG3 (9.9), Opinaca (3.5), Caniapiscau (5), Williston (22), with a lower ratio at SIL (1.2)	Site C predicted ratio is 2.3 and would fall into the upper end of the LOW increase category; although similar to LG1, the influence of LG2 on Hg in LG1 fish was anomalous
Water Residence Time	In the order of days and typically less than one month in Muskrat (7d), Gull (26d), Limestone (5d), and Long Spruce (10 d)	Residence time much longer, typically greater than 5 months including LG2 (7m), LG3 (11m), Opinaca (3.8m), Caniapiscau (26m), and SIL (8m)	With a water residence time of 23 d, Site C falls into the LOW category
Chemical Parameters			
pH	Usually pH of 7.5 or greater, especially in Manitoba reservoirs (7.5 – 8.5) and Williston (8.5); approximately pH 7 in Gull/Muskrat	A pH of <6.5 for all reservoirs including LG1 (6.5), LG2 (6.2), LG3 (<6.5), Caniapiscau (5.8 – 6.4) and Opinaca (5.9 – 6.3)	Peace River has pH of 7.8 – 8.6 and not predicted to change, clearly placing Site C in the LOW increase category
TOC/DOC	TOC/DOC concentrations are 2.6 – 4.6 mg/L in Muskrat/Gull; 8 – 12 mg/L in MB; 2 – 3 mg/L in Williston	TOC tends to be slightly higher, averaging 6.4 mg/L in LG1, 9 – 29 mg/L in LG2, 7 – 10 mg/L in LG3, 4 – 6 mg/L in Caniapiscau and 7 – 10 mg/L in Opinaca	TOC/DOC slightly higher in high increase reservoirs. Influence of low TOC water from upstream will likely place Site C in LOW increase category, with some uncertainty

Reservoir Characteristics	Low Magnitude Increase Reservoirs (Fish Mercury <3x Baseline)	High Magnitude Increase Reservoirs (Fish Mercury >3x Baseline)	Predicted Site C Result
Labile Carbon/ %Wetland	There are few good data for most reservoirs. However, the trend is for % wetland to be 3% or less including Williston (<1%) and Site C (<2%); Few data on labile carbon or biomass except for Nfld/Lab (2.7 kg/m2) and Site C (5 kg/m^2)	PQ reservoirs have a high percentage of flooded wetland: LG1 and LG2 (5%), LG3 (10%), Caniapiscau (7%) and Opinaca (16%); No data for Williston; SIL in MB was also high >5%. Carbon pool was also high with 16 – 23 kg/m^2 in peat soils, 9 – 42 kg/m^2 in wetlands and 7 kg/m^2 in forest soil	Site C has a low carbon biomass relative to other reservoirs for which this is known and a low percentage of wetland (<2%), placing Site C in the LOW increase category
Ecological Parameters			
THg/MeHg in Lower Trophic Level Biota	Pre-impoundment THg in Gull/Muskrat Nfld zooplankton 0.07 – 0.26 ppm THg and 0.002 – 0.07 ppm MeHg. At Williston post-impoundment (2000, 2001) THg in zooplankton is 0.06 – 0.18 and 0.03 – 0.05 ppm of which 35% is MeHg; In benthos THg is 0.2 – 0.57 and 0.15 – 0.28 ppm of which 20% is MeHg. Peace River (2011) baseline benthos is 0.07 ppm THg in zooplankton and 0.016 ppm THg in benthos of which approximately 10% is MeHg	The best data sets are for PQ reservoirs; values are on a dw basis. THg in zooplankton (baseline) is 0.03 – 0.57 ppm; 0.03 – 0.51 MeHg; Post-flood range 0.45 – 0.67 THg and 0.45 – 0.82 MeHg. In benthos, baseline THg ranges from 0.28 – 0.45 ppm and 0.25 – 0.8 ppm depending on taxa; MeHg 0.2 – 0.6 and 0.02 – 0.15 ppm post-flood; In SIL post-flood zooplankton was 0.3 – 3.0 and benthos 0.1 – 3.5 depending on taxa and organism size	Peace River baseline THg and MeHg fall into lower range of zooplankton and benthos concentrations. Percentage MeHg of THg is also low (<15%). Low baseline lower trophic level Hg concentrations are consistent with a low magnitude increase in fish Hg and place Site C in the LOW increase category
Reservoir Productivity Features	Tend to be run-of-river, have upstream reservoirs that limit nutrient/biota introductions, limited tributary/river inflow, lower carbon biomass and limited connectivity with larger waterbodies. Lack of nutrients and high turnover limit reservoir productivity and thus Hg bioaccumulation.	Tend to be spatially large, have higher nutrient inputs, greater connectivity to tributaries and lakes, longer residence time (lower nutrient export), and are more productive, even supporting commercial fisheries (e.g., SIL)	Site C is a run-of-river reservoir receiving very low nutrient water from upstream with limited connectivity and small tributary stream and nutrient inputs. Its low productivity status is consistent with LOW magnitude fish Hg increases.

NOTES:

THg = total mercury; MeHg = methylmercury; dw = dry weight; MB = Manitoba, PQ = Quebec; SIL = Southern Indian Lake (MB)

None of the parameters that are associated with increases in fish Hg concentrations of greater than 3x baseline are projected to be present within the Site C reservoir based on data from 13 large Canadian reservoirs (Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report). In particular, these include presence of an upstream oligotrophic reservoir, low TOC and nutrients in water, alkaline pH, low temperature and high oxygen, low baseline MeHg concentrations in water and biota, small increase in reservoir area relative to river area, small area of flooded wetland, and short hydraulic residence time. In summary, among the physical, chemical, and ecological factors primarily responsible for mercury methylation in new reservoirs, the Site C reservoir was clearly classified as having a strong likelihood of producing a less than 3x increase in fish mercury concentrations above baseline for all parameters evaluated.

11.9.7 Predicted Changes in Fish Methylmercury Concentration Within the Site C Technical Study Area

11.9.7.1 Site C Reservoir

Results of the three lines of evidence (i.e., Harris-Hutchinson (2012) regression model, RESMERC model, and Canadian reservoirs comparison matrix) were integrated to determine the most likely relative increase factor to predict changes to fish Hg concentrations within the Site C reservoir following inundation relative to baseline conditions. Key results from each line of evidence are:

- Harris-Hutchinson regression model – Fish Hg concentrations in the Site C reservoir were predicted to increase by 2.3x above baseline at peak levels. The model does not provide information regarding the timing of the peak concentration, nor the duration of elevated fish Hg concentrations.
- RESMERC – Fish Hg concentrations are predicted to increase by up to 4 to 6x above baseline at peak levels, depending on the species, five to eight years after impoundment. Following the peak, fish Hg concentrations are expected to decline to ‘baseline’ over a 15- to >20-year period. The magnitude and duration of elevated Hg concentrations depends on fish species and fish size. Larger, older fish will ultimately achieve higher concentrations.
- Canadian reservoirs comparison matrix – Fish Hg concentrations are predicted to increase by less than 3x baseline concentrations, based on a large suite of physical, chemical, and ecological features from 15 Canadian reservoirs

It is important to note here that baseline fish Hg concentrations in the Peace River are lower than reported anywhere else in British Columbia (Baker 2002) and are among the lowest reported for their size in Canada (Depew et al. 2012). This is an unusual situation, as no reservoir has been created starting with such low baseline fish Hg concentrations. Given that most of our understanding of Hg dynamics has been generated from eastern and central Canadian reservoirs (i.e., all three prediction methods were developed based on reservoirs from other Canadian regions), there is some uncertainty in the application of these tools at the Site C reservoir. Nevertheless, taken together, these diverse approaches provide a robust characterization of potential increases in fish mercury concentrations within the reservoir.

An integrated approach was taken to harmonize and reconcile the three lines of evidence to determine the most likely magnitude of increase in fish Hg concentration with the Site C reservoir. These approaches provide lower and upper bound estimates of increase in fish mercury. Two of the three lines of evidence suggest a low magnitude of increase – 2.3x based on the Harris and Hutchinson model, and less than 3x based on the Canadian reservoirs comparison matrix. Although RESMERC predicts a maximum increase of 4 to 6x above baseline (depending on species), there is inherent conservatism in the model (e.g., assumption of negligible sedimentation during the construction phase) that would suggest a lower increase than what is predicted using this method. Consequently, based on the available information, the harmonized peak increase factor for all species is likely to be approximately 3x. This value retains some conservatism relative to the results of the empirical evidence of the regression and matrix approaches, but also some uncertainty relative to RESMERC. Given that uncertainty, it is less likely, but possible, that the peak increase factor could reach 4x, but is unlikely to be higher. For the purposes of assessing the potential effect on humans of mercury-related changes to fish associated with Site C, it is recommended that a peak increase factor of 4x be used to reduce the possibility of underestimating fish mercury concentrations. This value was used to inform the HHRA (Volume 2 Appendix J Mercury Technical Reports, Part 2 Mercury Human Health Risk Assessment).

As Figure 11.9.4 illustrates, the peak increase factor and the magnitude of mercury concentration will vary according to fish species and by size for most species. This phenomenon has been observed in all other reservoirs, and RESMERC accurately predicts the relative difference in fish mercury concentrations across species and across size ranges.

Table 11.9.4 compares predicted peak (applying both the 3x and 4x factors) and baseline mercury concentrations for five fish species for the Site C reservoir. Given that fish mercury concentrations are often correlated to size, the results are reported for the size most commonly captured and targeted by sport fishers (e.g., bull trout, rainbow trout; Volume 2 Appendix J Mercury Technical Reports, Part 2 Mercury Human Health Risk Assessment). For food web species such as mountain whitefish, longnose sucker, and redside shiner, where there is a weak or no relationship between mercury concentration and fish size, the mean size for a large or adult fish was used.

The mean mercury concentration value was used for adult bull trout, not the maximum concentration. Although smaller fish will have a lower absolute mercury increase and larger fish may have a higher concentration, use of the mean better approximates typical exposure to humans. For example, although the maximum mercury concentration of the 50 bull trout measured from the Site C technical study area since 2008 was 0.34 mg/kg, the next highest value was 0.17 mg/kg. All other fish had lower concentrations than 0.17 mg/kg (Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report).

Table 11.9.4 Predicted Changes in Fish Mercury for Site C Fish Relative to Baseline Conditions

Fish Species/Size	Mercury concentration (mg/kg ww)				
	Bull trout	Rainbow trout	Mountain whitefish	Longnose sucker	Redside shiner
	50 cm; 1.6 kg	40 cm; 0.5 kg	35 cm; 0.5 kg	30 cm; 0.6 kg	10 cm; 14 g
Baseline Concentration	0.067[1]	0.050[1]	0.036[1]	0.052[2]	0.054[2]
3x Increase Factor	0.20	0.15	0.11	0.16	0.16
4x Increase Factor	0.27	0.20	0.14	0.21	0.22

NOTES:

[1] Baseline concentration estimated for standardized fish using Hg-size relationships (Volume 2 Appendix J Mercury Technical Reports, Part 1 Mercury Technical Synthesis Report; Azimuth 2011)

[2] Baseline concentration estimated based on mean of fish caught

11.9.7.2 Downstream Changes to Fish Mercury

Monitoring programs for boreal reservoirs have demonstrated that some fish have increased mercury concentrations as far downstream as 275 km in Quebec (Schetagne and Verdon 1999a, 1999b), Manitoba (Bodaly et al. 2007) and Labrador (Anderson 2011). The extent and duration of downstream changes to fish Hg levels vary from system to system, depending on the hydrological and biological characteristics of the rivers and reservoirs. For example, the extent of dilution from tributaries below the reservoir and the presence of large deep lakes (Schetagne and Verdon 1999b) may affect mercury concentrations in water. In addition, mercury concentrations may increase in some fish in the event an individual shifts its dietary preference from lower trophic level organisms (algae, benthos) to fish (e.g., easy prey that are injured or killed from passage through the turbines). Downstream of the Smallwood Reservoir in Labrador, for example, mercury concentrations in lake whitefish increased by 5x above baseline, higher than the reservoir itself; brook trout increased by 3x, the same magnitude as within the reservoir (Anderson 2011).

The degree to which this may occur downstream of the Site C reservoir is uncertain and difficult to predict. As described in Section 11.9.4, the downstream extent of exposure to fish with elevated MeHg concentrations from the Site C Project may extend as far as Many Islands. As described above, mercury may be exported from the Site C reservoir via water (i.e., inorganic Hg adhered to sediment particles or MeHg dissolved in water) or directly, in biota (e.g., tissue Hg in invertebrates or fish). These two pathways generally result in different patterns of change in fish tissue concentrations in the downstream environment. Water-borne Hg may lead to low magnitude changes across a broad spatial extent, while biota-based mercury exports may lead to higher magnitude changes in a more localized area, such as the tailrace area of a dam. While water-borne mercury exports may lead to minor changes in downstream fish mercury concentrations, the importance of this pathway was considered secondary, relative to biota-related mercury exports, and was not pursued further.

The degree to which mercury concentrations in individual fish may increase downstream of the Site C reservoir will vary by species, fish size, the biomass and mercury concentration of fish entrained out of the reservoir, and the dietary preference of individual fish. For non-piscivorous species, tissue mercury concentrations are unlikely to change substantially relative to baseline. For normally piscivorous species feeding in the tailrace area, the magnitude of increase may match what is observed within Site C. For normally non-piscivorous species that switch to a predominantly fish-based diet, their tissue mercury concentrations may increase more than what is seen within the Site C reservoir. This has been observed in Quebec (Schetagne et al. 2003) and Labrador (Anderson 2011), where downstream lake whitefish mercury concentrations were 1.5–2x higher than what was observed in the upstream reservoir.

From a population perspective, only a small portion of fish may potentially be affected downstream of the Site C dam to Many Islands. This is mainly because the mass of Hg contained within fish entrained out of Site C reservoir is likely insufficient to result in a widespread increase in Hg in most fish, combined with the small number of fish within the greater population that may switch to a piscivorous diet. Changes of the magnitudes seen in other Canadian reservoirs would be limited largely to those few piscivorous fish feeding predominantly in the tailrace area.

Nevertheless, if it is conservatively assumed that the general fish population downstream of the Site C reservoir was to double in concentration for key species presented in Table 11.9.4, this would result in mean mercury concentration for local populations of less than 0.10 mg/kg. The only exception is bull trout, with a mean of 0.16 mg/kg. Despite this increase, these are very low concentrations relative to other fish populations in B.C. (Baker 2002) and elsewhere in Canada (Depew et al. 2012).

11.9.7.3 Timing of Return to Baseline

The timing of a return of reservoir fish Hg concentrations to baseline can be inferred from the Canadian reservoirs comparison matrix as well as from RESMERC. Based on information from other Canadian reservoirs, those with a short hydraulic residence time, small reservoir to original basin ratio, minimal flooded wetland, and a large upstream oligotrophic lake or reservoir will have shorter return periods, depending on the species, in the order of 15–20 years following impoundment (Table 11.9.3). RESMERC predicts a return time of between 20 and 25 or more years, depending on the species. Redside shiner, sucker, and rainbow trout that consume lower mercury dietary items will return to a baseline more quickly than omnivorous whitefish and piscivorous bull trout.

Given the above two estimates, a return to baseline is likely closer to 20 years after impoundment than >25, because of the weight of evidence presented by the Canadian reservoirs comparison matrix and the presence of a large, oligotrophic, low-Hg reservoir upstream that will continue to dominate water chemistry in a post-Site C environment. Furthermore, the effects of sedimentation, which were not considered by RESMERC, would result in lower peak concentrations and reduced time required to return to baseline.

With respect to downstream fish, it is acknowledged that the return to baseline is much shorter. For example, lake whitefish in the Caniapisco River in northern Quebec returned to background levels within 2–4 years, while concentrations in lake trout remained high for 4–8 years (Schetagne and Verdon 1999b). Downstream of the Smallwood Reservoir in Labrador, fish mercury concentrations had returned to baseline within 7–8 years after impoundment.

Based on the weight of evidence from other Canadian reservoirs and the presence of a large, oligotrophic upstream reservoir, the return to baseline mercury concentrations within the Peace River technical study area is predicted to be on the shorter end of what has been observed elsewhere, likely 4–6 years after impoundment of the Site C dam occurs.

11.10 Microclimate

11.10.1 Introduction

The existing and predicted future microclimatic conditions in the Peace River valley and at the North Peace Regional airport are described in the following section. Both current conditions and potential changes as a result of the Project are described. Predicted microclimate was modelled to quantitatively evaluate how the construction of the proposed Site C dam and the formation of the reservoir might influence the local and regional climate.

Details of the microclimate analyses are presented in the Volume 2 Appendix K Microclimate Technical Data Report. Predicted changes in microclimate were used to assess the potential effects of the Project on agriculture (Volume 3 Section 20 Agriculture), navigation (Volume 3 Section 26 Navigation), and transportation (Volume 4 Section 31 Transportation).

Weather is defined as the state of the atmosphere at a given time and place with respect to variables such as temperature, moisture, wind velocity, and barometric pressure. Climate is the long-term average of weather. In this context, the term average refers not only to the simple arithmetic average, such as the average temperature for an area, but also to the average occurrence of extreme weather, for example, the average summertime extreme temperature or the average number of storms per year. Common atmospheric state variables, such as temperature or wind speed, are applicable to both meteorological and climatological studies. As such, the terms atmospheric measurements or climatological measurements may refer to the same quantities, and only differ by the context in which they are examined.

The term microclimate has been adopted as the term for the climate of the section of the Peace River valley where the proposed Site C reservoir would lie. However, the term microclimate more properly refers to climates on horizontal scale of tens to hundreds of metres (Oke 1987). As such, there is no one single microclimate, but rather a collection of microclimates. The technical term for climate on the scale of the Peace River valley would be mesoclimate.

11.10.2 Methodology

The microclimate study comprised the following elements:

- Review of baseline climatic data
- Application of a mesoscale meteorological model with land cover and terrain set to reflect current conditions
- Application of the same model to include topographical changes resulting from reservoir formation
- Description of changes in microclimate inferred by the difference between the two model runs
- Statistical analysis to determine significance of results

The technical study area, which encompassed the entire reservoir, is 108 km east to west, by 68 km north to south, corresponding to a 108 by 68 one-kilometre modelling grid. This area covers the reservoir with a rectangular model grid with a large enough buffer around the reservoir edges to encompass the expected extent of changes from the proposed reservoir. The technical study area is shown in Figure 11.10.1.

To quantify potential changes in microclimate induced by the potential Site C reservoir formation, two model scenarios were examined, the existing Baseline Case and the Future Case with the Project, using the Weather Research and Forecasting (WRF) numerical meteorological model.

The WRF model combines large-scale weather information and the geophysical description of the Earth's surface to simulate local-scale meteorology. By running the model for periods of a year or longer, monthly, seasonal, and annual average estimates of the average meteorological conditions and, hence, the climate of a given region may be developed. The longer term average climate was estimated by selecting a model study year that was typical of the most recent 30-year climate record.

Along these lines, each grid cell of the WRF model results may be considered to be the solution for the microclimate of the topographical area represented by that grid cell. Therefore, by examining the model results for different model grid cells, changes to the microclimate of various locations within the technical study area may be examined.

Changes in microclimate were examined in terms of the following meteorological parameters:

- Temperature
- Wind speed
- Humidity (Mixing Ratio)
- Precipitation
- Fog and visibility

Humidity is the amount of moisture in the atmosphere. It may be described in relative or absolute terms. Relative humidity presents atmospheric water content as a percentage of the total that the atmosphere could possibly hold at that time. It depends on the temperature and pressure as well as the actual amount of water present. Absolute humidity is the actual amount of water regardless of atmospheric capacity and is usually expressed as a mixing ratio, giving the mass of water vapour compared to the mass of dry air in a known volume of moist air. Historical measurements are typically given in relative humidity, but modelling studies are typically conducted using mixing ratio. As a result, both quantities are used in the context where most appropriate.

Visibility is defined as the greatest distance (expressed in kilometres) at which a black object of suitable dimensions can be seen and recognized. During the hours of darkness, it can also be seen if under the same daylight conditions. Fog refers to conditions where visibility is less than 1 km. Visibility in meteorological records is recorded either by an observer or by an instrument called a nephelometer. In either case, the same quantity cannot be directly reproduced by the WRF model or calculated from its outputs. Therefore, changes in visibility were estimated using a formula for calculating light extinction that can use WRF outputs. Although this means that model results are not directly comparable to the historical record, they can be used to determine relative changes between the Baseline Case and the Future Case with the Project.

A single year that is characteristic of the long-term climate record for purposes of modelling may be selected by comparing a sample year to the long-term mean and standard deviation, to ensure that the sample year is within the bounds of normal year-to-year variation and does not represent a non-typical year. Differences between model runs for this typical single year would then provide a representative estimate of differences that would result for the long-term mean.

To support an evaluation of the microclimate of the study area, BC Hydro installed a network of climate stations in the Peace River valley. The locations of the stations within the Peace River valley are shown in Figure 11.10.2, along with other meteorological stations in the area. The locations and monitoring periods are summarized in Table 11.10.1. The stations were installed across a number of different geographical settings. The first full year of climate measurements at all stations was completed in January 2012.

Other meteorological stations inside the technical study area are North Peace Regional airport (Environment Canada), Taylor South Hill (MOE), Taylor Townsite (BCMOE), PMD (BC Hydro), and Hudson's Hope (BCMOF). North Peace Regional airport is located 12 km east of the proposed Site C reservoir and is the closest station with a long measurement record (several decades); Taylor South Hill and Taylor Townsite are about 15 km downstream of the proposed Site C reservoir.

The BC Hydro stations measure a range of meteorological parameters, including wind speed and direction, temperature, and precipitation. A selection of the stations also measure barometric pressure, humidity, solar radiation, and heat influx. Though these extra parameters provide additional information for describing the climate of a location, they are not commonly associated with studies of climate and there are no long-term measurements to compare them with. These extra parameters are, therefore, not included in the current analysis, but constitute part of future monitoring and reporting.

The influence of global climate change on the local microclimate was determined by examining previous studies of global climate change and extracting results for the Peace River valley. For the purposes of this study, the influences of global and local climate change were considered additive. That is, the influence of the two combined would be equal to the sum of the two acting separately. The estimate of future climate change does not include any other anthropogenic changes to land use in the study area.

Table 11.10.1 BC Hydro Climate Station Locations and Monitoring Periods

Station	Location UTM NAD 83 (m)	Type	Measurement Period[a]
Station 1 – Attachie Flat Upper Terrace	597983 Easting 6232938 Northing	Climate	January 15, 2011 to present
Station 2 – Attachie Flat Lower Terrace	597721 Easting 6231898 Northing	Climate	January 13, 2011 to present
Station 3 – Attachie Flat Plateau	595065 Easting 6233032 Northing	Climate	November 4, 2010 to present
Station 4 – Bear Flat	610669 Easting 6238135 Northing	Climate	December 1, 2010 to present
Station 5 – Hudson's Hope	570577 Easting 6213303 Northing	Climate	December 12, 2010 to present
Station 6 – Farrell Creek	580779 Easting 6220238 Northing	Wind	April 1, 2009 to present
Station 7 – Site C Dam	629517 Easting 6230875 Northing	Climate	November 27, 2010 to present

NOTE:
[a] All stations were originally installed in 2009 as measuring wind only. All except Station 6 – Farrell Creek have been upgraded to measure additional parameters. Where applicable, installation date refers to date of upgrade.

11.10.3 Baseline Climate

The region around Fort St. John experiences a continental subarctic climate characterized by long, cold, and dry winters with short, mild summers. Normal daily average temperatures range from -14.2°C in January to 15.7°C in July, with normal total annual precipitation totalling 465 mm, of which 65% falls between May and September.

North Peace Regional airport is the only location close to the study area where long-term climate information is available. This station has been in operation since 1942 and is run by Environment Canada. Climate normals from 1971 through 2000, the most recent 30-year period for which Environment Canada has published them, were reviewed. In addition, the standard deviations of the parameters that were used to evaluate the performance of the WRF model – temperature, wind speed, and precipitation – were calculated to evaluate annual and monthly climate variability. Over the length of record, there was a 1.5°C increase in mean annual temperature. The trend for wind speed shows a decrease over the period of record of approximately 6 km/h. The record shows no change in mean annual total precipitation.

Climate normals from North Peace Regional airport for the parameters that were examined in the microclimate study are listed in Table 11.10.2. The full climate normal listing for North Peace Regional airport is provided in the Microclimate Technical Data Report (Volume 2 Appendix K). Note that, for completeness, the long-term visibility observations are shown; however, as stated above, these are measured using a different method than what was used to estimate visibility from the WRF model results. Per the definition, the occurrence of fog in Table 11.10.2 is given by visibility of less than 1 km.

The results for the first year of observations at the BC Hydro climate stations are summarized in Table 11.10.3. This first year of record was warmer and wetter, and had higher wind speeds than a normal year, as measured at North Peace Regional airport. There were small differences in temperature between the BC Hydro stations, and wind speed and direction were influenced by local topography. Spatial differences in precipitation exist, but may be due to differences in instruments across the network. For ongoing monitoring, the performance of the precipitation gauges would need to be examined and the instruments upgraded or replaced as necessary.

Although there are relatively small differences in measured climate parameters between stations in the first year of observation, the differences that are present demonstrate that each station exists in its own microclimate. Differences in factors such as elevation, moisture availability, surface cover, and topography all contribute to the differences seen between stations. Until the record of measurement becomes longer, it is not known if these differences in measured parameters observed during the first year are reflective of long-term trends.

1 **Table 11.10.2 Selected Climate Normals for Fort St. John**

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily average (°C)	-14.2	-10.5	-4.4	4	10	13.8	15.7	14.6	9.9	3.9	-6.7	-12.1	2
Daily maximum (°C)	-9.9	-6	0.3	9.3	15.7	19.2	21.2	20.2	15.1	8.2	-2.9	-8	6.9
Daily minimum (°C)	-18.4	-15	-9.1	-1.3	4.1	8.2	10.2	8.9	4.6	-0.4	-10.4	-16.2	-2.9
Extreme maximum (°C)	11.6	12.8	18	27.9	31.8	31.7	33.3	33.6	30	25.6	18.3	11.4	N/A
Extreme minimum (°C)	-47.2	-42.2	-36.7	-28.9	-10.6	-0.6	0.7	-2.9	-12.8	-25	-39.2	-44.6	N/A
Precipitation													
Rainfall (mm)	0.4	0.5	0.7	8.8	35.5	70.9	83.2	56.1	41.1	11.5	3.4	0.6	312.6
Snowfall (cm)	32.2	28.3	25.3	10.6	4.1	0.4	0	0.8	4.8	16.5	30.3	32.4	185.6
Precipitation (mm)	26	21.9	21.4	18.8	39.7	71.4	83.2	56.9	45.7	25.8	28.5	26.5	465.6
Wind													
Speed (km/h)	13.7	14.3	13.8	14.4	14.3	13.6	12.3	11.9	13	15.4	13.8	13.7	13.7
Maximum hourly speed (km/h)	89	84	68	77	77	64	80	58	64	80	74	97	N/A
Humidity													
Average vapour pressure (kPa)	0.2	0.2	0.3	0.4	0.6	0.9	1.2	1.1	0.8	0.6	0.3	0.2	0.6
Average relative humidity – 0600LST (%)	73	73.4	73.8	69.3	69	75.6	81.2	84.9	84.1	77.3	78.9	74.4	76.2
Average relative humidity – 1500LST (%)	69.1	63.8	55	42.6	40.6	47.3	51.3	52.7	53.6	56.9	71.8	71.6	56.4
Visibility (hours with)													
< 1 km	14.5	6.5	5.2	2.7	3.3	3.9	7.6	13	14	15.4	25.7	18.5	130.3
1 to 9 km	92.4	76.6	59	25.5	16	20.4	18.8	29	31.3	39	82.1	92.5	582.7
> 9 km	637.1	595.1	679.7	691.8	724.7	695.7	717.6	702	674.8	689.6	612.2	633	8053.2

Table 11.10.3 Summary of Measured Climate Parameters

Station	Mean Temperature (°C)	Maximum Temperature (°C)	Minimum Temperature (°C)	Total Precipitation (mm)	Mean wind speed (m/s)
Station 1 – Attachie Flat Upper Terrace	3.1	29.9	-33.5	447	2.5
Station 2 – Attachie Flat Lower Terrace	3.1	30.6	-35.6	415	2.3
Station 3 – Attachie Flat Plateau	3.3	28.6	-34.2	509	2.8
Station 4 – Bear Flat	2.9	29.3	-35.4	414	1.6
Station 5 – Hudson's Hope	3.7	30.8	-36.3	521	1.9
Station 6 – Farrell Creek	—	—	—	—	1.8
Station 7 – Site C Dam	3.9	29.2	-33.1	541	2.8
North Peace Regional airport	2.9	27.7	-32.9	626	4.3
Max. difference in values	1.0	3.1	3.4	212	2.7

NOTES:
— indicates no data collected

11.10.3.1 Weather Research and Forecasting (WRF) Model

The purpose of the microclimate modelling study was to evaluate quantitatively how the construction of the proposed Site C dam and the formation of the reservoir might influence the local and regional climate. Modelling was conducted because historical measurements by themselves are not sufficient to predict future local climate changes. Past monitoring establishes current baseline conditions, and future monitoring would capture actual changes in climate as they occur, but historical data only permit a subjective and/or qualitative estimate of future changes. Modelling is the only means of objective and quantitative prediction of future changes before the Project is built. The results of the model study allow site-specific estimates of changes in local microclimate well in advance of actual construction.

Potential future microclimate changes were estimated using the WRF model version 3.2.1, released August 2010. This was the most recent model release at the time the study commenced, and the model version was kept the same for the duration of the model study.

The WRF model solves the fundamental equations of atmospheric motion on a three-dimensional (3-D) grid. It may be used to forecast future weather events or to investigate historical weather occurrences. In either mode, WRF makes use of terrain data and land-cover characteristic information. When applied to examine historical events, WRF also makes use of actual observations of meteorology. The model incorporates parameters that influence atmospheric conditions, such as turbulence, convection and cloud formation, precipitation, radiation, surface heat transfer, and moisture. Thus, WRF is able to simulate various weather conditions, including wind shears, mountain and valley drainage flows, and other topographically induced wind flow patterns.

In simpler terms, WRF provides a 3-D estimate of the wind, temperature, humidity, and several other variables for each hour throughout the period modelled. The model output provides hourly estimates of weather conditions at any 3-D point within the model domain. By contrast, a meteorological station, although it is a direct measurement of actual meteorology, can only provide information for a single point in space. Furthermore, when applied over a period of a year or longer, WRF can supply an estimate of long-term average meteorological conditions, i.e., the climate of an area.

The main inputs to WRF are the historical data used to set the starting meteorology and to set the meteorology of the model edges as it runs (referred to as the initial and boundary conditions, respectively), and the geophysical data used to define the earth surface in the model. This is shown schematically in Figure 11.10.3. If either of the input streams is changed to reflect future rather than current conditions, then the model can be used to predict the resulting future local microclimate.

The initial and boundary conditions for the WRF model were set using the North American Regional Reanalysis (National Centers for Environmental Prediction 2011). This consists of results from large-scale weather models that are adjusted, or reanalyzed, using surface, upper air, and satellite observation to give a more accurate historical snapshot of past weather conditions. The geophysical data are derived from global databases compiled by the United States Geological Survey that are provided with the WRF model codes for use with the model preprocessors. For the Future Case with the Project, the geophysical data was supplemented with outputs from a lake surface model, described below, to set the temperature and ice cover of the proposed reservoir surface.

The model was applied in a nested configuration with an outer domain simulating meteorological parameters every 12 km over much of western Canada, an intermediate domain with 4 km spacing, and finally a 1 km resolution model domain of 108 by 68 grid cells covering the proposed reservoir and the surrounding valley, including Fort St. John. The 1 km resolution model domain corresponds to the technical study area for the microclimate study. The nested domain configuration is shown in Figure 11.10.4. The innermost domain in Figure 11.10.4 corresponds to the technical study area as shown in Figure 11.10.1.

The model was run for a one-year period, from October 2004 through September 2005. This model year was chosen by selecting a recent consecutive 12-month period that was hydrologically normal in terms of water flows, and was also typical of 30-year climate normals from the Fort St. John station. A statistical comparison of the model period to the historical record of meteorological observations at North Peace Regional airport confirmed that the model year was representative of typical meteorological conditions within the area.

The 1 km domain was run in two configurations: a Baseline Case to reflect the existing Peace River valley and the Future Case with the Project to estimate meteorological conditions in the technical study area when the proposed Site C reservoir is filled to capacity. The Future Case with the Project was constructed by editing the terrain elevation and land cover classification data used by the model to reflect changes as a result of creating the reservoir. For both cases, boundary and initial conditions for the WRF model runs were set using North American Regional Reanalysis (National Centers for Environmental Prediction 2011). For the Future Case with the Project, the temperature and ice cover of the proposed reservoir surface were included in the evaluation by incorporating outputs from the Hydrodynamics in Three Dimensions (H3D) model (Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report). The incorporation of the H3D results is illustrated in Figure 11.10.3, showing the WRF model inputs streams.

The differences between the two model runs were used to investigate changes in meteorology and microclimate that might result from creating the Site C reservoir.

11.10.4 Statistical Significance of Model Predictions

In addition to calculating absolute difference between the Baseline Case and the Future Case with the Project, a statistical analysis of the predicted changes was conducted to quantify the probability that the model predictions represent a statistically significant change. This analysis was conducted using Bayesian two-sample comparisons. This method compares the mean and variance of two samples to determine if there is a statistically significant difference between them. In this application, the two samples being tested are the Baseline Case and the Future Case with the Project model results for a particular meteorological parameter. The statistical significance is described in terms of a confidence interval. The terms likely and extremely likely correspond to 90% and 95% confidence intervals, respectively.

11.10.5 Weather Research and Forecasting Model Performance Evaluation

To be sure that the WRF model was providing results that are representative of actual conditions in the technical study area, numerical WRF model output for the October 2004 through September 2005 model year was compared statistically against observations at North Peace Regional airport for the same period. The model was deemed capable of predicting observed temperature at the BC Hydro climate stations. The model produced wind speeds and directions similar to those observed at North Peace Regional airport. Predicted precipitation during the 2004–2005 model year was closer to the long-term climate mean at North Peace Regional airport than the typical year-to-year variability observed in the long-term climate record. The WRF model is not sensitive enough to predict these small differences among the BC Hydro climate stations, but the results indicate that model predictions for precipitation were within historic norms.

To further confirm model performance, WRF was also run using the Baseline Case terrain elevation and land-cover characteristic inputs (no reservoir) for one year from January 2011 through January 2012, corresponding to the first full year of observations from the BC Hydro climate station network for the six stations that recorded wind temperature and precipitation. The meteorological observations collected during the first year at these six field stations, which were located along or near the proposed reservoir, were similar to the observations at the North Peace Regional airport for the same period.

The model evaluation shows that WRF reproduced the monthly, seasonal, and annual observations at the BC Hydro climate stations well enough that differences between the Baseline Case and the Future Case with the Project for the model study year would be indicative of changes in local meteorology and climate resulting from creation of the proposed Site C reservoir.

11.10.6 Predicted Changes to Microclimate

The differences between the Baseline Case and the Future Case with the Project WRF runs were examined to evaluate local meteorological changes after the Site C reservoir is filled.

Meteorological parameters of interest were examined in terms of annual and seasonal averages as well as daily maxima and minima for the model year. Detailed results over all periods are provided in the Microclimate Technical Data Report (Volume 2 Appendix K). It was predicted that there would be no changes more than 1 km from the proposed reservoir that are statistically distinguishable from year-to-year variations. Statistically significant changes were predicted only in some sections within 1 km of the proposed reservoir for parts of the year for temperature, wind, and mixing ratio. These changes are described in more detail in the next subsections.

11.10.7 Temperature

The analysis of model results for temperature examined annual average, extreme minimum and maximum, and daily average, as well as minimum and maximum by month.

For areas within 1 km of the reservoir, annual average temperatures were predicted to increase by a maximum of 1°C. Extreme temperatures were predicted to be moderated, with warmer minimum temperatures in winter and cooler maximum temperatures in summer. Largest short-term changes in temperature were predicted in winter during periods when H3D predicted that a portion of the water surface would be ice-free.

Predicted changes in monthly temperature are shown in Figure 11.10.5, with statistical significance of predictions plotted in Figure 11.10.6. All 12 months were analyzed separately. A characteristic month for each season is shown for simplicity. There are no statistically significant changes predicted beyond 1 km from the reservoir. The largest changes are seen all along the edge of the reservoir in fall, where the open water surface is warmer than the cooler ambient air, and in the southwest during winter, when this area of the reservoir remains ice-free.

Figure 11.10.7 shows the daily change in average temperature at the climate station locations. The largest short-term variations, up to 6°C, are predicted during winter near areas where there is no ice cover. Predicted changes are decreased for stations further away.

11.10.8 Wind Speed

There is an approximately 10% change in annual average and maximum over water wind speed. This is due to the reduced roughness of the proposed reservoir water surface compared with the existing river valley. Figure 11.10.8 shows changes in monthly average wind speed. All 12 months were analyzed separately. A characteristic month is shown for simplicity. The largest absolute changes are seen in fall and winter. However, the existing wind speed is also highest during these times. The largest relative changes are predicted in spring and summer. During these times, the synoptic winds from large-scale weather patterns are the weakest, so the winds influenced by local topography dominate.

Figure 11.10.9 shows the statistical significance of the predicted changes shown in Figure 11.10.8. No statistically significant changes beyond 1 km of the proposed reservoir are predicted.

A wind rose for the Baseline Case and the Future Case with the Project at Station 1 Attachie Flat Upper Terrace is shown in Figure 11.10.10. The Future Case with the Project at this location shows a shift in wind direction to the southwest. This is due to the reservoir surface changing the configuration of the valley bottom and thus the manner in which winds are channelled. The change in wind direction experienced by a given location depends on the specific terrain geometry before and after formation of the reservoir. The wind rose for Attachie Flat Upper Terrace shows the largest shift among the climate stations.

The predicted change in maximum hourly wind speed for the Site C climate station locations is given in Table 11.10.4. Monthly results have been compiled into seasons to simplify the table. The maximum hourly wind speeds reported for each season is the highest hourly wind speed predicted in that season. Hudson’s Hope was predicted to experience the greatest change, with an increase of 3.4 km per hour in spring and summer, 7.5 km per hour in the fall, and 8.7 km per hour in winter. At some locations and times, the maximum wind speed is predicted to decrease. In these instances, the reduced surface roughness of the water (which tends to increase wind speeds) is probably dominated by reduced topographic forcing (which decreases influence of local wind systems) from the reservoir filling the valley.

Table 11.10.4 Seasonal Change in Maximum Hourly Wind Speed

Difference (Future Case with the Project – Baseline Case)	Spring	Summer	Fall	Winter	Year
North Peace Regional airport	-0.7 (43.3)	-0.2 (44.7)	0.4 (44.7)	0.4 (43.0)	0.4 (44.7)
Station 1 – Attachie Flat Upper Terrace	5.5 (38.0)	1.0 (39.0)	4.4 (42.8)	5.8 (35.6)	4.4 (42.8)
Station 2 – Attachie Flat Lower Terrace	2.6 (39.2)	4.7 (38.1)	6.9 (42.7)	6.3 (39.0)	6.9 (42.7)
Station 3 – Attachie Flat Plateau	1.2 (37.8)	1.7 (41.3)	4.9 (51.1)	4.4 (43.8)	4.9 (51.1)
Station 4 – Bear Flat	-5.0 (41.4)	-2.4 (37.6)	1.3 (49.6)	-1.0 (41.2)	1.3 (49.6)
Station 5 – Hudson's Hope	3.4 (35.3)	3.4 (46.2)	7.5 (53.7)	8.7 (55.5)	8.7 (55.5)
Station 6 – Farrell Creek	3.6 (35.6)	-0.6 (42.5)	5.2 (47.7)	5.5 (42.3)	5.2 (47.7)
Station 7 – Site C Dam	2.6 (38.9)	-2.1 (37.4)	1.0 (52.4)	3.6 (42.4)	1.0 (52.4)

NOTE:
All values in kilometres per hour. Baseline maximum wind speed for same period is shown in parentheses.

11.10.9 Mixing Ratio

Model results for humidity were analyzed in terms of monthly and annual averages. The WRF model provides outputs of humidity in terms of mixing ratio.

Water vapour mixing ratio shows increases at all locations adjacent to the reservoir, as would be expected close to a large water body. Predicted changes in seasonal mixing ratio are shown in Figure 11.10.11. All 12 months were analyzed separately. A characteristic month for each season is shown for simplicity. The greatest changes are seen in fall and summer. This is due to the open water surface providing a source of moisture and the increased overall capacity of the air to hold water caused by the increased daily minimum (i.e., warmer nights) from the influence of the reservoir. The smallest changes are seen in winter, due to the frozen reservoir surface that is very similar to snow-covered conditions that currently occur. Areas where the reservoir remains open in winter show larger differences.

Figure 11.10.12 shows the statistical significance of the predicted changes shown in Figure 11.10.11. No statistically significant changes are predicted beyond 1 km of proposed reservoir.

The mixing ratio at elevations above ground level was also examined, as this may be of concern to some transportation activities. At all levels extracted, increases or decreases predicted by the WRF model are less than 0.04 grams of water per kilogram of dry air, which is less than 1% of the saturated mixing ratio and, at most, a few per cent of typical mixing ratios at these levels. Such a difference would be unobservable in measurement and therefore should not represent any meaningful change in mixing ratio. As an illustration, Figure 11.10.13 shows the change in monthly average mixing ratio at approximately 800 m above sea level, or about 110 m above the ground at North Peace Regional airport.

The change in seasonal and annual mixing ratio for the Site C climate station locations is given in Table 11.10.5. Monthly results have been compiled into seasons to simplify the table.

Atmospheric moisture was predicted to increase at all locations adjacent to the proposed Site C reservoir. This result was expected, as moisture would be more readily available with the presence of the proposed Site C reservoir. Evaporation is expected to increase at the surface and increase atmospheric moisture near the reservoir. Typical mixing ratios in the technical study area are on the order of less than 1.0 g/ kg of dry air in winter and over 10 g/ kg of dry air on a hot humid summer day.

The greatest changes are predicted to occur in the summer at the Bear Flat and proposed Site C dam station locations where changes were found to be statistically significant. The largest change in humidity is predicted to occur in summer at the proposed Site C dam with an increase of 0.98 g/kg of dry air or about a 15% increase in atmospheric moisture. Stations closest to the reservoir show the highest changes.

Table 11.10.5 Seasonal Change in Water Vapour Mixing Ratio

Difference (Future Case with the Project – Baseline Case)	Spring	Summer	Fall	Winter	Year
North Peace Regional airport	0.00	0.03	0.02	0.00	0.01
Station 1 – Attachie Flat Upper Terrace	0.41	0.86	0.81	0.03	0.53
Station 2 – Attachie Flat Lower Terrace	0.41	0.83	0.85	0.02	0.53
Station 3 – Attachie Flat Plateau	0.00	0.06	0.09	0.00	0.04
Station 4 – Bear Flat	0.38	0.90	0.79	0.02	0.52
Station 5 – Hudson's Hope	-0.02	0.03	0.12	0.04	0.04
Station 6 – Farrell Creek	0.00	0.03	0.10	0.02	0.04
Station 7 – Site C Dam	0.41	0.98	0.77	0.02	0.55

NOTE:

All values in grams of water vapour per kilogram of dry air.

11.10.10 Precipitation

The model results for precipitation were examined in terms of monthly and annual totals.

Predicted changes in monthly precipitation are shown in Figure 11.10.14. All 12 months were analyzed separately. A characteristic month for each season is shown for simplicity. All seasons show changes of less than 20 mm. Changes are smallest for fall and winter. This period is easier to model because it is dominated by synoptic effects that are well captured in large-scale inputs. Also, the proposed reservoir ice cover at this time of year is not much different than the snow-covered Baseline Case. There is more variation across the domain in the summer, but this is due to the convective nature of precipitation that is more randomly distributed than in winter.

Table 11.10.6 shows predicted changes in precipitation in the study area. Monthly results have been compiled into seasons to simplify the table. Changes at Farrell Creek are greatest, with a decrease in total annual precipitation of 18 mm. Attachie Flat Upper Terrace, Attachie Flat Lower Terrace, and the proposed Site C dam site are predicted to have a decrease of greater than 10 mm of total annual precipitation. All other locations are predicted to have a change less than 10 mm of total precipitation on an annual basis, while measured precipitation at the station locations ranges from around 400 mm to 600 mm per year. The predicted changes are statistically indistinguishable from the large inter-annual and intra-annual variability of precipitation for all of the stations.

Table 11.10.6 Seasonal Change in Total Precipitation

Difference (Future Case with the Project – Baseline Case)	Spring	Summer	Fall	Winter	Year
North Peace Regional airport	2.7	-10.5	-0.2	0.3	-7.7
Station 1 – Attachie Flat Upper Terrace	-12.2	-0.1	-2.8	-0.5	-15.6
Station 2 – Attachie Flat Lower Terrace	-3.6	-2.2	-3.2	-2.6	-11.6

Difference (Future Case with the Project – Baseline Case)	Spring	Summer	Fall	Winter	Year
Station 3 – Attachie Flat Plateau	-7.0	0.9	-1.4	2.4	-5.1
Station 4 – Bear Flat	-19.3	13.0	-1.8	2.0	-6.2
Station 5 – Hudson's Hope	1.4	3.3	-1.7	0.2	3.2
Station 6 – Farrell Creek	-10.4	-6.3	-1.1	-0.2	-18.0
Station 7 – Site C Dam	-5.0	-8.4	-0.4	2.5	-11.3

NOTE:

All values in millimetre water equivalent.

11.10.11 Fog and Visibility

The model-derived visibility changes were examined in terms of monthly and annual number of hours of fog occurrence. Fog frequency and density were evaluated at the locations of the seven BC Hydro climate stations close to the proposed Site C reservoir, at North Peace Regional airport and at Taylor Bridge (see Table 11.10.7 and Table 11.10.8). Fog hours have been compiled into seasonal and annual totals for presentation in the tables. The number of normal fog hours, defined as visibility less than 1 km, is predicted to decrease at five out of nine locations, but increase at the North Peace Regional airport (seven hours per year), Taylor Bridge (eight hours per year), Hudson's Hope (one hour per year), and Attachie Flat Lower Terrace (nine hours per year) locations. The number of heavy fog hours, defined as visibility less than 500 m, decreases at most locations except North Peace Regional airport, where an increase of six hours per year is predicted, and Taylor Bridge, where an increase of 118 hours is predicted.

Table 11.10.7 Predicted Change in Fog from Baseline Case to Future Case with the Project

Station	Spring		Summer		Fall		Winter		Year	
North Peace Regional airport	-6	(208)	4	(177)	16	(484)	-7	(692)	7	(1561)
Station 1 – Attachie Flat Upper Terrace	-7	(199)	-10	(177)	11	(359)	2	(437)	-4	(1172)
Station 2 – Attachie Flat Lower Terrace	4	(200)	-2	(179)	10	(353)	-3	(443)	9	(1175)
Station 3 – Attachie Flat Plateau	-10	(229)	-14	(195)	3	(365)	-4	(462)	-25	(1251)
Station 4 – Bear Flat	-18	(227)	2	(155)	-7	(393)	-7	(520)	-30	(1295)
Station 5 – Hudson's Hope	-8	(210)	0	(172)	9	(350)	0	(353)	1	(1085)
Station 6 – Farrell Creek	-4	(210)	6	(178)	-14	(365)	-1	(492)	-13	(1245)
Station 7 – Site C Dam	-8	(216)	-7	(171)	-7	(427)	4	(560)	-18	(1374)
Taylor Bridge	7	(151)	5	(136)	-3	(350)	-1	(496)	8	(1133)

NOTE:

Shown are changes in normal fog hours, with baseline hours in brackets

Table 11.10.8 Predicted Change in Heavy Fog from Baseline Case to Future Case with the Project

Station	Spring		Summer		Fall		Winter		Year	
North Peace Regional airport	-4	(188)	1	(155)	14	(468)	-5	(678)	6	(1489)
Station 1 – Attachie Flat Upper Terrace	-9	(171)	-11	(156)	9	(338)	-4	(432)	-15	(1097)
Station 2 – Attachie Flat Lower Terrace	-5	(174)	-5	(151)	1	(336)	-5	(429)	-14	(1090)
Station 3 – Attachie Flat Plateau	1	(197)	-6	(166)	0	(351)	-4	(453)	-9	(1167)
Station 4 – Bear Flat	-16	(192)	-1	(133)	-6	(376)	-10	(508)	-33	(1209)
Station 5 – Hudson's Hope	-10	(187)	-4	(153)	9	(341)	1	(521)	-4	(1202)
Station 6 – Farrell Creek	-3	(183)	6	(158)	-13	(354)	-1	(481)	-11	(1176)
Station 7 – Site C Dam	-14	(182)	-4	(142)	-7	(401)	5	(547)	-20	(1272)
Taylor Bridge	46	(130)	8	(124)	41	(329)	23	(475)	118	(1058)

NOTE:

Shown are changes in heavy fog hours, with baseline hours in brackets.

Visibility, as classed into various ranges from less than 500 m to greater than 20 km, was examined to determine the potential for change at the North Peace Regional airport as a result of the proposed Site C reservoir (see Table 11.10.9). The combined total number of clear hours with visibility greater than 20 km and hours with visibility 10 km to 20 km was predicted to be reduced by 15 hours over the year, while the number of hours with visibility in the range of 1 km to 10 km was predicted to increase by eight hours over the year. The number of hours of poor visibility (less than 500 m) was predicted to increase by six hours per year with the addition of the reservoir.

Due to the nature of the calculation, a statistical significance test was not possible. Both visibility and fog calculation give results that are placed into class ranges, as opposed to other parameters such as temperature, which gives a continuous hourly time series result. This classification makes developments of a robust statistical test difficult. However, the occurrence of fog and atmospheric visibility are both determined by the base quantities of temperature and moisture, for which statistically significant changes were limited to within 1 km of the reservoir. It is reasonable to conclude that any quantity derived from temperature and moisture would provide similar results.

Table 11.10.9 Predicted Changes in Visibility at North Peace Regional Airport

Seasons	Visibility					
	Clear		Moderate		Poor	
	> 20 km	10–20 km	5–10 km	1–5 km	0.5–1 km	< 0.5 km
Spring						
Baseline Case	1,914	9	16	37	20	188
Future Case with the Project	1,919 (-5)	9 (0)	9 (-7)	45 (8)	18 (-2)	184 (-4)
Summer						
Baseline Case	1,980	8	10	33	22	155
Future Case with the Project	1,977 (-3)	5 (-3)	14 (4)	31 (-2)	25 (3)	156 (1)
Fall						
Baseline Case	1,689	9	7	19	16	468
Future Case with the Project	1,674 (-5)	7 (-2)	6 (-1)	21 (2)	18 (2)	482 (14)
Winter						
Baseline Case	1,441	2	8	17	14	684
Future Case with the Project	1,444 (3)	2 (0)	7 (-1)	22 (5)	12 (2)	679 (-5)
Year						
Baseline Case	7,024	28	41	106	72	1,495
Future Case with the Project	7,014 (-10)	23 (-5)	36 (-5)	119 (13)	73 (1)	1,501 (6)

NOTE:
Shown are hours per year within each visibility class. The change is given in brackets.

11.10.12 Global Climate Change

WRF model predictions for changes in temperature and precipitation within the technical study area were compared to projections of the influence of global climate changes in the technical study area as calculated by several global circulation models. The lower bounds for estimates of the influence of global climate change are for increases of about 2°C for temperature and approximately 15% for precipitation.

As seen in the plots and tables of WRF model results for changes in temperature, for some sections along the proposed reservoir, in the fall and winter, mean-temperature changes from the proposed reservoir and regional mean-temperature increases caused by global climate change were predicted to be of similar strength. At other times and elsewhere, predicted changes due to the reservoir were smaller and sometimes partly cancel regional temperature increases. For most of the technical study area, the magnitude of predicted changes in microclimate would be statistically insignificant when compared to global climate change. Changes in precipitation due to the reservoir were found to be statistically insignificant everywhere in the technical study area; therefore, they would by definition be dominated by any statistically significant influence of global climate change.

11.11 Air Quality

11.11.1 Introduction

Construction and operation of the Project have the potential to change local and regional air quality.

During construction, activities that would contribute to combustion and fugitive dust emissions include operating construction vehicles and equipment, clearing and burning vegetation and debris, and extracting and transporting construction materials. These activities would take place at the dam, generating station, and spillways; in quarries, gravel pits and borrow pits; and along roads, the railway, and the transmission corridor.

During operations, the Site C reservoir could potentially influence local air quality during dry periods of the year when the reservoir water level is lower than normal. Exposed reservoir shorelines have been sources of fugitive dust emissions when wind speeds are high enough to move and entrain dry sediments. However, wind erosion is not expected to pose an air quality issue, given the reservoir configuration, steep reservoir banks, and the small reservoir level operating range. Other potential emission sources during operation are combustion emissions from maintenance vehicles and vessels. Emissions during operations would be much lower than during construction.

This section of the EIS provides an overview and summary of the air quality study. Details regarding the approach and findings are provided in Volume 2 Appendix L Air Quality Technical Data Report. Information obtained in the air quality study was used in evaluating potential effects of the Project on human health (Volume 4 Section 33 Human Health).

11.11.2 Objectives and Scope

The objectives of the Air Quality study were to:

- Characterize the existing baseline air quality in terms of measured ambient air quality and emissions of criteria air contaminants
- Estimate emissions due to Project construction and operation
- Predict changes to ambient air quality in the dam site area due to Project construction
- Discuss potential changes to ambient air quality during Project operation

This study focuses on criteria air contaminants, i.e., contaminants for which there are either ambient air quality objectives or Canada-wide standards (see Section 11.11.3), including particulate matter (PM), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and carbon monoxide (CO).

11.11.3 Ambient Air Quality Criteria

To provide context for baseline ambient air quality conditions and for predicted changes to ambient air quality in the dam site area during Project construction, existing and predicted concentrations of criteria air contaminants are compared to ambient air quality criteria, which are developed by environment and health authorities. British Columbia ambient air quality objectives and Canada-wide standards for the criteria air contaminants included in the Air Quality study are listed in Table 11.11.1.

There are provincial ambient air quality objectives for all criteria air contaminants except NO_2. For the purposes of this study, federal ambient air quality objectives were used in place of provincial objectives for NO_2. Provincial ambient air quality objectives are divided into three categories designated as Levels A, B, and C, with Level A being the most stringent. These three levels correspond roughly to federal levels, as defined below:

- Level A is equivalent to the federal maximum desirable objective, which is a long-term goal for air quality and provides a basis for an anti-degradation policy for unpolluted areas, and for continuing development of control technology
- Level B is equivalent to the federal maximum acceptable objective, which is intended to provide adequate protection against effects on soil, water, vegetation, materials, visibility, personal comfort, and well-being
- Level C is equivalent to the federal maximum tolerable objective, which denotes time-based concentrations of air contaminants beyond which, due to a diminishing margin of safety, appropriate action is required without delay to protect the health of the general public

Canada-wide standards have been developed for $PM_{2.5}$ and ozone. Canada-wide standards are established by the Canadian Council of Ministers of the Environment as a step towards the long-term goal of minimizing risks to human health and the environment. They represent a balance between the desire to achieve the best health and environmental protection possible in the relative near term, and the feasibility and costs of reducing the pollutant emissions that contribute to elevated ambient concentrations.

Table 11.11.1 B.C. Ambient Air Quality Objectives and Canada-wide Standards

Contaminant	Averaging Period	Objectives/Standards ($\mu g/m^3$)			Canada-Wide Standard
		British Columbia			
		Level A	Level B	Level C	
Total suspended particulate	24-hour	150	200	260	—
	Annual	60	70	75	
Particulate matter less than 10 µm (PM_{10})	24-hour	50			—
	Annual	—			—
Particulate matter less than 2.5 µm ($PM_{2.5}$)	24-hour	25[a]			27 to 30[b]
	Annual	8[c]			8.8 to 10[d]
Dustfall[e]	24-hour	1.75 $mg/dm^2/d$ residential, 2.9 $mg/dm^2/d$ non-residential			—
Nitrogen dioxide[f]	1-hour	—	400	1,000	—
	24-hour	—	200	300	
	Annual	60	100	—	
Sulphur dioxide	1-hour	450	900	900-1,300	—
	24-hour	160	260	360	
	Annual	25	50	80	
Carbon monoxide	1-hour	14,300	28,000	35,000	—
	8-hour	5,500	11,000	14,300	
Ozone	8-hour	—			62 to 65 ppb[g]

NOTES:

[a] Compliance based on annual 98th percentile value

[b] Current objective of 30 $\mu g/m^3$ is proposed to change to 28 $\mu g/m^3$ in 2015 and 27 $\mu g/m^3$ in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years

[c] B.C. also has a planning goal for annual $PM_{2.5}$ of 6 $\mu g/m^3$

[d] There are currently no annual Canada-wide standards for annual $PM_{2.5}$, but there is a proposed objective of 10.0 $\mu g/m^3$ for 2015 and 8.8 $\mu g/m^3$ for 2020

[e] 24-hour average based on 30-day sample

[f] B.C. does not have ambient air quality objectives for NO_2 and therefore, the federal maximum acceptable (Level A), desirable (Level B), and tolerable (Level C) objectives are presented

[g] Current objective of 65 ppb is proposed to change to 63 ppb in 2015 and 62 ppb in 2020; compliance based on fourth highest annual value, averaged over three consecutive years

— not collected

SOURCES:

BCMOE 2009; Canadian Council of Ministers of the Environment 2006, 2012

11.11.4 Approach and Methods

11.11.4.1 Technical Study Areas

Two study areas were used to analyze air quality including: (a) a technical study area and (b) a dispersion modelling study area. These two study areas are illustrated in Figure 11.11.1.

The technical study area is a 138 km by 102 km area that encompasses the Project activity zone, including the West Pine Quarry as well as the City of Fort St. John and the

District of Taylor. Emissions from all Project components during construction and operation were estimated for the technical study area.

Due to the extent of construction activities at the Site C dam site and its proximity to the City of Fort St. John, dispersion modelling was conducted for the dam site area and surroundings to predict ambient air quality concentrations resulting from Project construction emissions. The dispersion modelling study area is a 26 km by 27 km rectangle specified to include a minimum 5 km buffer around the dam site area, Wuthrich Quarry, and Area E (a potential source of granular material), and extended north and east to include the community of Charlie Lake and the District of Taylor, respectively.

Sub-areas within the technical study area were defined around the construction material source areas (Wuthrich Quarry, West Pine Quarry, 85th Avenue Industrial Lands, Portage Mountain and Del Rio Pit) and Hudson's Hope Shoreline Protection to further characterize baseline settings and Project emissions in these areas. These sub-areas are 12 km by 12 km squares, specified to include a minimum 5 km buffer around each Project component.

11.11.4.2 Field Surveys

Field surveys consisted of operating two ambient air quality monitoring stations and a BC Hydro network of meteorological stations. The ambient air quality monitoring stations, located at Attachie Flat and Old Fort, were installed to collect baseline particulate matter data and to provide ongoing monitoring during all phases of the Project. The six meteorological stations located between Taylor and Hudson's Hope, and one wind station located in Farrell Creek, were installed to collect data for the microclimate study (Volume 2 Appendix K Microclimate Technical Data Report) and dispersion modelling. Details on the ambient air quality and meteorological stations, including station co-ordinates and operating time periods, are provided in Volume 2 Appendix L Air Quality Technical Data Report.

11.11.4.3 Baseline Air Quality

Baseline air quality conditions were determined based on existing provincial and national emission inventories and on historical ambient air quality monitoring data.

Baseline emissions were determined by extracting information from provincial and national emission inventories. Emission estimates of criteria air contaminants for area and mobile sources were obtained from the B.C. Ministry of Environment (McCormick 2012, pers. comm.), based on their most recent provincial emission inventory in 2000. Emissions from point sources were determined from Environment Canada's National Pollutant Release Inventory (Environment Canada 2012) for the year 2010.

Baseline ambient concentrations were determined by reviewing air quality monitoring data collected primarily from field surveys and from the BCMOE network of monitoring stations in the province (BCMOE 2012). Additional information was obtained from the Clean Air Strategic Alliance Data Warehouse (2012) where necessary. Dustfall monitoring data from the Quintette and Bullmoose mines, now closed, and the existing Brule, Dillon, and Willow Creek coal mines were obtained from public reports on the Environmental Assessment Office website and reviewed for baseline air quality characterization.

11.11.4.4 Emission Estimation

Project construction emissions were estimated for every year of the expected eight-year construction period. The emission inventory was subdivided by Project component (i.e., dam, generating station, and spillways; quarried and excavated construction material; road and rail access; and transmission line). Project operation emissions were estimated for ongoing Site C dam site operations, including maintenance activities at the generating station.

The scope of the emission inventory included the following emission sources, where applicable:

- Clearing activities
- Open burning and incineration of clearing debris
- Extraction, processing, movement, and placement of construction and waste materials
- Drilling
- Explosives detonation and blasting
- Material handling and transfers
- Concrete batch plant operations
- Material processing
- Stockpile wind erosion
- Grading and scraping
- Fugitive emissions of road dust on paved and unpaved access roads
- Mobile vehicle exhaust
- Diesel-fuelled equipment and generators
- Boats
- Aircraft
- Asphalt production

Project emissions were estimated using published emission factors obtained primarily from the United States Environmental Protection Agency (US EPA) Compilation of Air Pollutant Emission Factors known as AP-42 (US EPA 1995–2011) and US EPA emission models. Other sources of emission information include Environment Canada's Criteria Air Contaminants Emission Inventory 2002 Guidebook (Environment Canada 2006), the Air and Waste Management Association's Air Pollution Engineering Manual (AWMA 2000), the Western Regional Air Partnership's Fugitive Dust Handbook (WRAP 2006), and The Chamber of Shipping's Ocean-Going Vessels Emissions Inventory Report (Chamber of Shipping 2007).

11.11.4.5 Dispersion Modelling

The dispersion modelling methodology was based on the Guidelines for Air Quality Dispersion Modelling in British Columbia (BCMOE 2008). A conceptual model plan was submitted to and agreed upon by the BCMOE. Technical options were selected based on the Guidelines for Air Quality Dispersion Modelling in British Columbia or set to model defaults. Details are provided in the Air Quality Technical Data Report (Volume 2 Appendix L).

Dispersion modelling was conducted using the CALPUFF model in full three-dimensional CALMET mode, as is appropriate for the complex terrain and wind patterns in the Peace River Valley. CALMET is a meteorological preprocessor that develops hourly three-dimensional meteorological fields of wind and temperature used to drive pollutant transport within CALPUFF. CALPUFF is a multi-layer, multi-species, non-steady-state puff dispersion model. It simulates the influences of time- and space-varying meteorological conditions on pollutant transport, transformation, and deposition.

Project construction emissions within the dispersion modelling study area, including emissions from the dam, generating station and spillways, Wuthrich Quarry, 85th Avenue Industrial Lands, and Area E, were entered in a dispersion model to predict maximum ambient concentrations of criteria air contaminants and dustfall deposition rates. All estimated emissions were included in the modelling except road dust and emissions from clearing activities, including burning vegetation. Volume 2 Appendix L Air Quality Technical Data Report provides the rationale for excluding these emissions from the dispersion modelling.

To assess the cumulative air quality changes of the Project, background concentrations were added to ambient concentrations predicted from dispersion modelling. These background concentrations, which are single values applied to every hour and every location in the dispersion modelling study area, are used as a simplified approach to represent the contribution from all other natural and human-caused sources (i.e., the baseline setting). Representative background concentrations were calculated based on the Guidelines for Air Quality Dispersion Modelling in British Columbia (BCMOE 2008) or developed based on discussions with the BCMOE.

11.11.4.6 Study Limitations

A number of limitations are inherent in the air quality study. These include limitations in emissions estimation and limitations in dispersion modelling.

Emissions have been estimated based on Project-specific activity data where available, and default activity data from the US EPA where Project-specific information are not available. Default activity data are based on the average of conditions observed at a limited number of project sites, mainly in the Unites States, which may not be representative of the Project. The use of published emission factors is associated with inherent limitations in that such factors are based on averages of available data, which may not be sufficient to extrapolate for Project-specific activity parameters (e.g. vehicle speed, material silt content, etc.) outside the observed range of these parameters. Furthermore, these published emission factors are typically representative of long-term averages and the use of such emission factors for estimating short-term emission rates for dispersion modelling are associated with uncertainties.

By definition, air quality dispersion models can only approximate atmospheric processes. Many assumptions and simplifications are required to describe real phenomena in mathematical equations. Model uncertainties can result from:

- Simplifications and accuracy limitations related to source data
- Extrapolation of meteorological data from selected locations to a larger region
- Simplifications of model physics to replicate the random nature of atmospheric dispersion processes

Models are reasonable and reliable in estimating the maximum concentrations occurring on an average basis. That is, the maximum predicted concentration that may occur at some time somewhere within the model domain, as opposed to the exact concentration at a point at a given time, will usually be within the ±10% to ±40% range (US EPA 2003) of the observed maximum concentration. Typically, a model is viewed as replicating dispersion processes if it can predict within a factor of two (from one-half to double the actual value), and if it can replicate the temporal and meteorological variations associated with monitoring data. Model predictions at a specific site and for a specific hour, however, may correlate poorly with the associated observations, due to the above-indicated uncertainties. For example, an uncertainty of 5 to 10 degrees in the measured wind direction can result in concentration errors of 20% to 70% for an individual event (US EPA 2003).

This uncertainty in the model is dealt with in air quality studies by selecting inputs that attempt to ensure that the model will err on the conservative side of the uncertainty, which is to say that they will typically over-predict changes to air quality.

11.11.5 Baseline Air Quality Description

The technical and dispersion modelling study areas are characterized by mostly low population densities in rural settings. Forestry, agriculture, oil and gas, mining, and power generation are the main industries and emission sources in the region. The City of Fort St. John is the largest population centre, with a population of over 19,000. Within population centres, emissions from vehicle traffic and residential wood heating are important factors to local air quality, as are emissions from vehicle traffic along major roads, in particular Highway 97 (i.e., the Alaska Highway).

11.11.5.1 Baseline Emissions

Baseline emissions in the technical study area are illustrated in Figure 11.11.2. Point sources contribute 17% to $PM_{2.5}$ and between 40% and 64% to the other five criteria air contaminants. Area sources contribute 49% to $PM_{2.5}$ and between 11% and 31% to the other criteria air contaminants except SO_x, to which they contribute less than 1%. Mobile sources contribute between 23% and 43% to all six criteria air contaminants.

Of the three source categories, point sources emit the most total suspended particulate and PM_{10}, while area sources emit the most $PM_{2.5}$. Agriculture is an important source of particulate matter emissions, contributing from 15% of $PM_{2.5}$ to 19% of total suspended particulate emissions. Off-road vehicles emit almost all of the $PM_{2.5}$, PM_{10}, and total suspended particulate from mobile sources.

The main sources of NO_x, SO_x and CO emissions are point sources and mobile sources. This is particularly true for SO_x, for which the area source category emits less than 1% of total emissions. Area sources emit 11% of NO_x (mainly agriculture) and 16% of CO.

Baseline emissions in the dispersion modelling study area are illustrated in Figure 11.11.3. In the dispersion modelling study area, point source contributions to NO_x and SO_x are 62% and 51%, respectively. The contribution of point sources to other criteria air contaminants is less than 23%. Area sources contribute between 43% and 56% to all particulate matter emissions, 19% to total CO, 5% to total NO_x, and less than 1% to total SO_x. Mobile sources contribute between 33% and 58% to all six criteria air contaminants.

The contribution of point sources to particulate matter emissions is less in the dispersion modelling study area than in the technical study area; the largest industrial contributor to particulate matter emissions in the technical study area (i.e., Willow Creek Mine) is located outside the dispersion modelling study area. Area and mobile sources contribute most to all size fractions of particulate matter. Similar to the technical study area, agriculture is an important area source of particulate matter emissions in the dispersion modelling study area, contributing from 10% of $PM_{2.5}$ to 25% of total suspended particulate emissions. Residential wood heating contributes a larger fraction of particulate matter emissions in the dispersion modelling study area than in the technical study area, contributing from 10% of total suspended particulate to 28% of $PM_{2.5}$ emissions.

Point sources dominate NO_x emissions in the dispersion modelling study area, followed by mobile sources. The industrial and mobile source categories emit roughly 50% each to total SO_x emissions. The majority of the CO emissions are emitted by mobile sources, particularly off-road sources.

11.11.5.2 Baseline Ambient Air Quality

Historical monitoring data were reviewed to characterize baseline air quality. Overall, observed concentrations were less than the relevant ambient air quality objectives for all criteria air contaminants. Some exceedances of the provincial objectives for dustfall were observed near the mine sites. Details are provided in Volume 2 Appendix L Air Quality Technical Data Report.

Representative background concentrations used for assessing cumulative changes are summarized in Table 11.11.2. The rationale for selecting these background concentrations is discussed in Volume 2 Appendix L Air Quality Technical Data Report.

Table 11.11.2 Representative Background Concentrations

Pollutant	Averaging Period	Background Value ($\mu g/m^3$)	Data Source for Value
TSP	24-Hour	26	Old Fort PM_{10} monitoring data
	Annual	5.4	
PM_{10}	24-Hour	26	Old Fort monitoring data
$PM_{2.5}$	24-Hour	15	
	Annual	5.0	
Dustfall[a]	24-Hour	0.8 $mg/dm^2/d$	Willow Creek Mine monitoring data
NO_2	1-Hour	0.0	BCMOE recommendation
	24-Hour		
	Annual		
SO_2	1-Hour	0.0	BCMOE recommendation
	24-Hour		
	Annual		
CO	1-Hour	229	BCMOE recommendation
	8-Hour[b]	160	
Ozone	1-Hour	64 ppb	Taylor Townsite monitoring data
	24-Hour	19 ppb	
	Annual	19 ppb	

NOTES:

[a] 24-hour average based on 30-day sample

[b] The eight-hour average concentration is calculated by applying a scaling factor of 0.7 (BCMOE 2008) to the specified one-hour average concentration

11.11.6 Project Emissions

The emission estimates associated with Project construction are presented in Section 11.11.6.1 and the emission estimates from Project operation and maintenance are presented in Section 11.11.6.2.

11.11.6.1 Construction

Detailed estimates are provided in Volume 2 Appendix L Air Quality Technical Data Report. For summary purposes, only selected estimates are provided in this section.

Total annual Project construction emissions are shown in Table 11.11.3 and compared to baseline emissions in the technical study area. Estimated emissions of total suspended particulate are greatest in Year 5, estimated emissions of PM_{10} are greatest in Year 2, estimated emissions of $PM_{2.5}$ and CO are greatest in Year 1 and estimated emissions of NO_X and SO_X are greatest in Year 4.

The largest sources of Project construction emissions are the construction of the dam, generating station and spillways, construction of infrastructure for road and rail access, and burning and incineration.

Table 11.11.3 Estimate of Total Annual Project Construction Emissions (in Tonnes)

Pollutant	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Baseline 2000/2010
TSP	9,012	10,161	10,801	10,529	11,270	10,012	8,736	2,080	13,200
PM_{10}	3,210	3,463	3,403	3,200	3,444	2,876	2,476	589	6,570
$PM_{2.5}$	1,456	1,373	827	634	650	326	287	65	2,250
NO_X	916	1,028	1,067	1,413	1,397	301	256	43	13,800
SO_X	18.6	251	555	1,015	1,015	1.23	0.938	0.1	21,600
CO	15,009	13,036	5,463	2,571	2,568	238	190	49	38,100

Emissions included in the dispersion modelling are summarized in Table 11.11.4. These represent Project construction emissions for components located inside the dispersion modelling study area for a select year, as discussed below. As explained in Volume 2 Appendix L Air Quality Technical Data Report, emissions from road dust entrainment and from burning and incineration are excluded from dispersion modelling, and therefore are not included in the totals shown in Table 11.11.4.

Table 11.11.4 Total Annual Emissions Used in Dispersion Modelling (in Tonnes)

Pollutant	TSP	PM_{10}	$PM_{2.5}$	NO_X	SO_X	CO
Dam, generating station, and spillways	573	197	66	334	0.7	193
Wuthrich Quarry	16	5.3	2.0	7.2	0.1	7.6
85th Avenue Industrial Lands	30	10	3.4	7.8	0.01	4.3
Area E	25	9.7	2.0	6.1	0.01	2.9
Vehicles in transit	0.2	0.2	0.2	1.3	0.08	4.5

The largest source of total suspended particulate and PM_{10} emissions from the construction of the dam, generating station and spillways is estimated to be the movement and placement of construction and waste materials via bulldozers; the largest source of $PM_{2.5}$, NO_x and CO emissions is estimated to be diesel-fuelled equipment; and the largest source of SO_x emissions is estimated to be explosives detonation. Modelling of dam site area construction emissions was based on Year 3, for which particulate matter and NO_x emissions were the highest.

The largest sources of particulate matter emissions at Wuthrich Quarry include bulldozing, drilling, blasting, and diesel-fuelled equipment. The largest source of NO_x emissions is estimated to be diesel-fuelled equipment and the largest source of SO_x and CO emissions is estimated to be explosives detonation. Modelling of Wuthrich Quarry was based on Year 2, as this represents the year in which the most material is expected to be extracted, resulting in the highest emissions.

The largest sources of particulate matter emissions at the 85th Avenue Industrial Lands are estimated to be grading, scraping, and bulldozing. For NO_x, SO_x, and CO, the largest source of emissions is estimated to be diesel-fuelled equipment. Modelling of the 85th

Avenue Industrial Lands was based on Year 5, corresponding to the year when emissions are expected to be greatest.

Area E, a potential source of granular material in Year 7 in the event that Zone 3 in the dam site area does not have sufficient material, was conservatively included in the dispersion modelling, but was not included in the Project construction emissions presented in Table 11.11.3.

Emissions from vehicles in transit are tabulated separately in Table 11.11.4 and represent travel on public roads outside of dam construction boundaries. The modelled year for vehicles in transit was dependent on activity. Vehicles in transit from Wuthrich Quarry were based on Year 2, and vehicles in transit from Area E were based on Year 7. Vehicles in transit to/from the City of Fort St. John and the District of Taylor comprise worker transportation and service vehicles, for which vehicle travel is expected to be relatively constant throughout the duration of Site C dam site construction. As a result, modelling for these vehicles was based on Year 1, when regulatory tailpipe emission standards that are integrated into the emission estimates are the least stringent, and therefore estimated emissions are greatest. Vehicles in transit to/from West Pine Quarry, Hudson’s Hope, and Chetwynd were not included in dispersion modelling, since the length of road associated with these routes that lies within the dispersion modelling study area is small.

11.11.6.2 Operation and Maintenance

Estimated emissions from ongoing operation and maintenance at the Site C dam site are shown in Table 11.11.5. The largest source of total suspended particulate and PM_{10} emissions is estimated to be the entrainment of road dust from paved roads (88.8% and 60.4%, respectively) and diesel-fuelled heavy equipment is estimated to be the largest source of $PM_{2.5}$ (51.5%) and CO (44.4%) emissions. Boats account for 64.3% of NO_X emissions and 91.5% of SO_X emissions. Emissions from the switch yard and microwave station account for less than 1% of total emissions from operation and maintenance activities.

Table 11.11.5 Total Annual Emissions from Project Operation and Maintenance (in Tonnes)

Activity	TSP	PM_{10}	$PM_{2.5}$	NO_X	SO_X	CO
Road dust	0.4	0.08	0.02	—	—	—
Vehicle exhaust	0.002	0.002	0.001	0.02	0.0001	0.1
Diesel equipment	0.04	0.04	0.03	0.3	0.0005	0.1
Diesel generators	0.003	0.003	0.003	0.09	0.0001	0.02
Boats	0.01	0.01	0.01	0.6	0.008	0.04
Total	0.5	0.1	0.07	1.0	0.009	0.3

The potential for fugitive dust emissions from shoreline exposures in the proposed reservoir was investigated by Nickling Environmental Ltd., and described in their Project Memorandum dated August 14, 2012 (Nickling 2012). The Nickling report concludes that it is unlikely that dust emissions would be a major problem at the proposed Site C Reservoir. This is attributed to:

- The small annual drawdown and the associated small area of exposed shoreline

- The relatively coarse texture of a large proportion of the sediments
- The amount of bedrock exposure at the shoreline that would reduce sediment input

11.11.7 Dispersion Modelling Results

Selected dispersion modelling results for Project construction are presented in this section. Detailed results are provided in Volume 2 Appendix L Air Quality Technical Data Report.

Maximum predicted concentrations for particulate matter with background included are presented in Table 11.11.6 and illustrated in Figure 11.11.4 through Figure 11.11.9. The highest predicted concentrations that exceed relevant objectives were predicted in the vicinity of Wuthrich Quarry, in an area for which there are no known sensitive receptors. Some exceedances of the objectives were also predicted along the construction boundary for Area E and by the river close to the construction boundary for the dam site area.

At sensitive receptors, exceedances of the B.C. Level A and B objectives for 24-hour total suspended particulate (Figure 11.11.4), the 24-hour PM_{10} (Figure 11.11.6), and both the 24-hour and annual $PM_{2.5}$ objectives (Figure 11.11.7 and Figure 11.11.8, respectively) were predicted at the north camp site, located within the dam site area. Exceedances of PM_{10} were also predicted at one residence located within the dam site area and at several non-residences in the vicinity of the Site C dam site. Exceedances of $PM_{2.5}$ were also predicted at the south camp site located within the dam site area for the 24-hour averaging period and at several non-residences in the vicinity of the Site C dam site for both the 24-hour and annual averaging periods. No exceedances for dustfall were predicted at any sensitive receptors.

Table 11.11.6 Maximum Predicted Concentrations for Particulate Matter including Background (in µg/m³)

Contaminant	TSP		PM_{10}	$PM_{2.5}$		Dustfall[a]
Averaging Period	**24-hour**	**Annual**	**24-hour**	**24-hour**	**Annual**	**24-hour**
Overall max (outside dam site area)	**644**	**136**	**278**	**84**	**25**	**3.3**
Fort St. John	45	8.5	32	18	5.8	0.9
Taylor	32	6.4	28	16	5.2	0.8
Ground-truthed residence	109	17	**51**	24	7.3	1.2
Ground-truthed non-residence	115	37	**67**	**37**	**11**	1.4
Unknown building	32	6.3	28	16	5.3	0.8
North camp site	**210**	45	**90**	**45**	**13**	1.6
South camp site	74	16	47	**26**	7.6	1.0
Schools	35	6.7	29	16	5.3	0.8
Child care facilities	35	6.8	29	17	5.3	0.8
Health care facilities	35	6.1	29	16	5.2	0.8
Senior care facilities	33	6.3	29	16	5.2	0.8
Objective	*150 to 260*	*60 to 75*	*50*	*25*	*8*	*1.75 or 2.9*[b]

NOTES:

Values in bold and shaded exceed relevant objectives

[a] 24-hour average based on 30-day sample, expressed in mg/dm²-d

[b] Provincial objective is 1.75 mg/dm²/d for residential areas and 2.9 mg/dm²-d for non-residential areas

Similar to particulate matter, the highest concentrations for NO_2, SO_2, and CO were predicted in the vicinity of Wuthrich Quarry. Maximum predicted concentrations for these contaminants were well below relevant objectives as shown in Table 11.11.7.

Table 11.11.7 Maximum Predicted Concentrations for NO2, SO2 and CO Including Background (in µg/m3)

Contaminant	NO_2			SO_2			CO	
Averaging Period	1-hour	24-hour	Annual	1-hour	24-hour	Annual	1-hour	8-hour
Overall max (outside dam site area)	306	78	45	75	21	1.6	2,962	2,078
Fort St. John	145	27	3.3	1.6	0.1	0.01	325	191
Taylor	63	8.0	1.0	0.2	0.05	0.003	258	170
Ground-truthed residence	170	44	8.2	3.3	0.4	0.03	422	240
Ground-truthed non-residence	182	49	24	4.5	0.5	0.06	571	280
Unknown building	81	10	1.4	0.5	0.06	0.004	274	173
North camp site	194	54	26	14	1.5	0.1	783	326
South camp site	165	45	13	1.1	0.2	0.03	421	241
Schools	106	12	1.3	0.7	0.1	0.005	277	177
Child care facilities	109	13	1.4	0.7	0.1	0.01	278	178
Health care facilities	87	10	0.9	0.5	0.05	0.003	268	174
Senior care facilities	73	10	1.0	0.3	0.04	0.004	261	171
Objective	400 to 1,000	200 to 300	60 to 100	450 to 1,300	160 to 360	25 to 80	14,300 to 35,000	5,500 to 14,300

11.12 Noise and Vibration

11.12.1 Introduction

This section describes the baseline and potential future noise and vibration levels in the Project activity zone. Current levels and potential changes as a result of Project activities are described.

The purpose of the noise and vibration study was to:

- Characterize the baseline noise environment
- Evaluate the potential for construction and operation of the Project to change the baseline noise environment
- Evaluate the amount of blasting noise or airborne vibration that may occur due to blasting during construction
- Provide a description of potential changes in local noise levels at human receptors
- Provide a spatial description of potential noise levels in support of the wildlife assessment

Details of the noise and vibration analyses are presented in Volume 2 Appendix M Noise and Vibration Technical Data Report. Predicted changes in noise and vibration levels are directly used to assess the potential effects of the Project on human health in Volume 4 Section 33 Human Health. Spatial results of the noise and vibration study are used in the wildlife assessment in Volume 2 Section 14 Wildlife Resources.

11.12.2 Methods

11.12.2.1 Approach

There are no British Columbia province-wide regulations regarding noise. The noise evaluation for construction was based on the methods and criteria outlined in the B.C. Oil and Gas Commission (BCOGC) Noise Control Best Practices Guideline (BCOGC 2009). The BCOGC Guideline outlines the expectations for evaluating noise levels, provides guidance on how to define noise sensitive receptors and study areas, and defines relevant criteria for identified receptors. However, this Guideline does not directly address wildlife, traffic noise, or vibration.

B.C. Ministry of Transportation and Infrastructure (BCMOT) guidance for highway noise mitigation was reviewed as potential sound level guidance for Highway 29 traffic noise (BCMOT 1993). However, the BCMOT guidance is intended as a controlled access highway design document and was not developed with environmental or human health effect criteria. Therefore, Highway 29 traffic noise was evaluated against the overall change in noise levels based on changes in traffic volumes predicted in the Project Traffic Analyses Report (Volume 4 Appendix B).

The evaluation of blasting noise or airborne vibration included review of guidance from the US Office of Surface Mining (USOSM 1986) and the Ontario Ministry of Environment (ONMOE No date). The Ontario guidance was found to be more stringent; therefore, it was used to compare against the calculations of airborne vibration from blasting for the Project.

11.12.2.2 Technical Study Area

The BCOGC Guideline characterizes noise levels at human receptors, which are defined as any permanent or seasonally occupied dwelling. In areas where there are no nearby residents, the guideline sets a limit on the noise levels at a distance of 1.5 km from the "facility fence line". For the purpose of the Project noise study, the facility fence line, and thus the technical study area for noise, has been defined as 1.5 km from the Project activity zone. This includes the local boundaries for individual activities such as quarries or highway construction. The technical study area was then used to identify potentially affected dwellings as noise sensitive receptors. Project-related changes in noise levels were predicted for residences within 1.5 km of project activities.

While the BCOGC Guideline does not apply to blasting noise or airborne vibration, this distance is appropriate to the evaluation of airborne vibration changes. The residences that may be most affected by blast noise or airborne vibration are expected to be those within 1.5 km of Project activities. Where residences were not present within 1.5 km, the effects at the technical study area boundary were considered.

For the baseline noise survey, locations representative of the receptors, particularly of the various densities of residential development and proximities to existing noise sources, were selected for the measurement program. The technical study area is shown in Figure 11.12.1. Complete lists of receptors analyzed are available in Volume 2 Appendix M Noise and Vibration Technical Data Report.

11.12.2.3 Criteria

The BCOGC Guideline outlines a specific process for determining the sound level criteria for each identified receptor on the basis of the level of local development and proximity to heavily travelled transportation routes. The process considers the time of day, the duration of the activity, and existing or baseline sound levels. Section 2 of the BCOGC Guideline provides the specific method for determining the criteria, which is called a permissible sound level (PSL).

Environmental noise levels typically vary with time. To account for the time varying nature of environmental noise, the PSL uses a single number descriptor: an 'average' sound level-known as energy equivalent sound level or L_{eq}, the energy-averaged A-weighted sound level for a specified time period. It is the steady, continuous sound level over a specified time period that has the same acoustic energy as the actual varying sound levels occurring over the same time period. The L_{eq} values are based on A-weighted sound levels expressed in units of dBA (A-weighted decibels). The A-weightings are assigned to reflect the response of the human ear to different frequencies of sound. The human ear is more sensitive to higher frequency sound than lower-frequency sound; this is reflected in the A-weighting scale.

The L_{eq} is a single-number representation of naturally variable sound energy measured over a time interval. The time intervals used for the noise study are as follows:

- Night: the nighttime period $L_{eq(9)}$, a 9-hour L_{eq} determined for the hours of 22:00 through 07:00

- Day: the daytime period $L_{eq(15)}$, a 15-hr L_{eq} determined for the hours of 07:00 through 22:00

Noise criteria were established at each receptor based on the BCOGC Guideline values outlined in Table 11.2.1 (BCOGC 2009). The values are based on land use categories and reflect the expected variation in ambient sound level associated with the different degrees of area development. The daytime PSL includes a +10 dBA adjustment as defined in the BCOGC Guideline.

Table 11.12.1 B.C. Oil and Gas Commission Guideline Table 1: Base Permissible Sound Levels by Land Use Category

Proximity to Transportation	Dwelling Unit Density Per Quarter Section of Land		
	1 – 8 dwellings; 22:00 – 07:00 (nighttime) (dBA L_{eq})	9 – 160 dwellings; 22:00 – 07:00 (nighttime) (dBA L_{eq})	>160 dwellings; 22:00 – 07:00 (nighttime) (dBA L_{eq})
Category 1	40	43	46
Category 2	45	48	51
Category 3	50	53	56

NOTES:

Category 1 – dwelling units more than 500 m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers

Category 2 – dwelling units more than 30 m but less than 500 m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers

Category 3 – dwelling units less than 30 m from heavily travelled roads and/or rail lines and/or subject to frequent aircraft flyovers

Density per quarter section – refers to a quarter section with the affected dwelling at the centre (a 451 m radius). For quarter sections with various land uses or with mixed densities, the density chosen is then averaged for the area under consideration.

Conformance with the BCOGC Guideline is achieved when the cumulative noise level at a receptor, comprising the Project sound level contribution plus the ambient sound level, is equal to or less than the PSL.

The BCOGC Guideline defines the natural ambient sound level (ASL) as 5 dBA less than the base PSL. As no specific influences on local sound levels were identified, other than domestic and traffic activity already accounted for in Table 11.12.1, no ambient noise level adjustments were applied and the calculated ambient sound levels were determined using the 5 dBA less rule.

According to the BCOGC Guideline, compliance with the PSL guidance is achieved when the cumulative noise level at a receptor, comprising the Project sound level contribution plus the ambient sound level, is equal to or less than the PSL (BCOGC 2009).

In addition to using noise guidelines established using BCOGC, the change in ambient sound levels was analyzed. A 3 dBA change in L_{eq} noise level is considered to be the “Just Noticeable Difference” for human perception (Crocker 2007). Changes in noise levels at receptors were reviewed to identify locations where changes in noise levels greater than 3 dBA may occur. As the BCOGC Guideline specifically excludes traffic noise (traffic noise is considered part of ambient – not a potential effect), Highway 29 traffic noise was evaluated against the overall change in noise levels only.

Blasting activities are identified as a potential source for airborne vibration, or blasting noise. The level of airborne vibration experienced by receptors is evaluated using the peak pressure level or L_{peak} measured in linear (unweighted) decibels (dBL). The criteria from the US Office of Surface Mining (USOSM 1986) was reviewed and compared with available Canadian guidance. The Cautionary Limit from the Noise Pollution Control Publication 119 by Ontario Ministry of the Environment was found to be more stringent. Therefore, the NPC-119 Cautionary Limit was used as the criterion for airborne vibration at any receptor (ONMOE No date). This guideline is provided in Table 11.12.2.

Table 11.12.2 Ontario Noise Pollution Control Publication 119 Guideline for Blasting Activity

Vibration Type	Unit	Guideline[a]
Blasting Noise	Peak pressure level L_{peak} (dBL)	120

NOTES:

dBL – linear decibel.

[a] Cautionary Limit as published in Noise Pollution Control Publication 119 by the Ontario Ministry of the Environment (ONMMOE No date)

11.12.2.4 Baseline Field Program

A baseline field program was completed in May and June 2011 to determine representative environmental noise levels and to identify existing sources of sound that may not be accounted for in the BCOGC approach. A blasting noise baseline survey was not necessary, as airborne vibrations are event based, so typically are not part of normal background.

The noise measurement equipment consisted of Brüel and Kjær model 2250 and Larson Davis model 831 Type 1 precision integrating sound level meters with audio recording capability. The noise monitors were calibrated before and after each noise measurement period to verify that the sound meter variance was within 0.5 dB. The noise meters were programmed to continuously measure the parameters identified and to make a continuous audio recording of measured noise events.

For this survey, wind speed and precipitation data reported in the Microclimate Technical Data Report (Volume 2 Appendix K Microclimate Technical Data Report) or from the North Peace Regional airport Environment Canada weather station were used.

The noise recordings were reviewed to identify sources of noise from the sound recordings and to filter out data that indicated interference with the microphone or abnormal sound sources such as technician activities, excessive wind, rain, vehicles that are close to the microphone, and low-flying aircraft noise. Local traffic is a major source of noise for most locations, and is, therefore, included in the hourly calculations. Hourly values were then calculated from the continuous measurements. Daily and nightly values were calculated per the BCOGC Guidance as described in Volume 2 Appendix M Noise and Vibration Technical Data Report.

11.12.2.5 Prediction and Characterization

The noise modelling for all activities except helicopter usage and airborne vibrations was conducted using CadnaA (Version 4.2.139) noise prediction software. This software uses the environmental sound propagation calculation methods prescribed by the

International Organization for Standardization (ISO) Standard 9613 (ISO 1993, 1996). The ISO 9613 sound propagation method predicts noise levels under moderately developed temperature inversion and downwind conditions that enhance sound propagation to the receptor. Model parameters were selected to reflect the propagation of sound during a summertime condition where attenuation due to weather conditions was minimized, such as during evening temperature inversions or mild downwind conditions. Summer is considered the most sensitive period for changes in outdoor noise levels, as it is the time of year when windows are open at night when people are trying to sleep.

Sound emission data for the various sources were established using measurements from similar equipment, vendor data, or theoretical formulae. Details on settings for the predictive modelling are found in the Volume 2 Appendix M Noise and Vibration Technical Data Report.

The noise from helicopter usage for the Project was analyzed using the SELCal version 1.0.2 flyover noise software from the United States Air Force (USAF 2002). This software was designed to analyze the amount of sound at specific locations due to a single aircraft flying, landing, taking off, or hovering. Aircraft sound emission data are integral to the software and were selected within the software based on the expected aircraft used by the Project.

For blasting noise, the L_{peak} values were calculated to determine the instantaneous maximum noise level during a blast event. Blasting noise levels were calculated in linear decibel levels (dBL) to assure that low-frequency energy, typically associated with blasting, is accounted for. The standard formulae used from the International Society of Explosives Engineers (Stiehr 2011) are detailed in Volume 2 Appendix M Noise and Vibration Technical Data Report.

The project activities evaluated varied in the amount of detail with which predictions were performed. Details on each scenario evaluated are provided in Volume 2 Appendix M Noise and Vibration Technical Data Report. The project components where construction or operation activities were evaluated for noise, and the level of detail in the analysis, are as follows:

- Construction
    - Dam site, including Site C dam and 85th Avenue Industrial Lands (site-specific modelling)
    - Quarries and pits (representative modelling)
    - Reservoir (representative modelling)
    - Highway 29 realignment (representative modelling)
    - Transmission line (representative modelling)
    - Hudson’s Hope berm (site-specific modelling)
- Operation
    - Dam site (qualitative discussion)
    - Reservoir (qualitative discussion)

- o Highway 29 realignment (site-specific modelling)
- o Transmission line (qualitative discussion)

11.12.2.6 Data Quality and Prediction Uncertainty

The methods and predictive modelling used in the analysis of environmental noise and airborne vibration has a level of uncertainty that is dependent on three factors: the accuracy of the source data, the precision of the noise propagation model, and the accuracy of locations and quantities of noise sources.

The accuracy or degree of uncertainty with individual measurements or pieces of data cannot be quantified due to the number of variables that influence the measurement or calculation of sound emissions. As uncertainties in sound emissions or model inputs increase, so does the amount of conservatism in the predictions.

The ISO 9613 propagation algorithms utilized by the CadnaA model software used for most of the modelling have a published accuracy of +/-3 dBA over source-receiver distances between 100 and 1,000 m. A similar degree of accuracy would be expected over the distances considered in this evaluation. The accuracy would be less at larger distances.

In addition, the ISO 9613 model produces results that are representative of meteorological conditions favouring sound propagation (e.g., downwind and/or inversion conditions). These conditions do not occur all the time and, therefore, the model predictions are expected to be conservative, and actual sound levels at the receptors may be less than predicted for much of the time.

Locations for equipment or specific blasts were not available at the time of this study. In order to add further conservatism to the predictions, the equipment in some areas has been modelled as area sources to represent the greatest spatial extent of noise during the activity.

Based on the above, there is a high level of confidence that the predicted noise levels at receptors can be considered to be ‘worst case’.

11.12.3 Baseline Conditions

11.12.3.1 Measurement Survey

The results of the baseline noise monitoring for the representative measurement locations are summarized in Table 11.12.3.

Table 11.12.3 Summary of Baseline Noise Levels

Noise Measurement Location	Calculated A-Weighted (dBA) Noise Levels (L_{eq})			
	Daytime Noise Level (L_{day}) (07:00 to 22:00)	Daytime L_{eq} Averaging Duration (hh:mm)	Nighttime Noise Level (L_{night}) (22:00 to 07:00)	Nighttime L_{eq} Averaging Duration (hh:mm)
Lynx Creek 1	45.3	9:39	40.4	8:48
Lynx Creek 2	44.6	13:15	35.9	7:55
Hudson Hope	43.5	12:26	43.3	9:00
Halfway Creek 1	46.1	12:10	39.0	9:00
Halfway Creek 2	53.0	13:05	48.9	9:00
Farrell Creek	42.1	10:51	39.8	8:52
Bear Flat 1	48.8	9:44	42.8	8:54
Bear Flat 2	42.0	12:50	36.4	8:49
Bear Flat 3	54.0	11:42	48.2	9:00
Dam Site 1	40.3	9:40	40.6	8:19
Dam Site 2	37.1	8:24	34.1	8:58
85th Avenue Industrial Lands 1	48.0	12:55	40.9	8:45
85th Avenue Industrial Lands 2	49.6	12:51	42.4	9:00

11.12.3.2 Baseline Summary

The evaluation method for environmental noise compared the measured baseline with the BCOGC-calculated ambient sound levels to estimate where there is evidence of existing noise sources influencing the background noise levels. Baseline noise level measurements were conducted at locations representative of the residential noise receptors within the technical study area based on relative location and proximity to existing sound sources.

The comparison of BCOGC ambient sound levels and representative baseline noise levels indicates that the nighttime ambient levels, adjusted according to BCOGC procedure for this time period, are within 1 to 5 dBA of representative measured values. Based on the sound recordings and observations, this difference is consistent with the natural variability that occurs in environmental sound. Therefore, the BCOGC calculated ambient sound levels (ASLs) were used for the evaluation of changes in noise levels at specific receptors. Detailed ASL values for each receptor and the above analysis are found in Volume 2 Appendix M Noise and Vibration Technical Data Report.

For blasting noise, existing L_{peak} values are zero at the dam site and quarries, as the L_{peak} is event based. No existing activities near the Project were noted as being a possible source of blasting noise.

11.12.3.3 Baseline Traffic Noise Levels

Sound generated by traffic is dependent on the volume of traffic, which fluctuates with time of day, week, or season. Therefore, existing sound levels from traffic on

Highway 29 were modelled using the CadnaA software to establish a base level for comparison with modelled results of Project construction related traffic on Highway 29.

Traffic analysis data from Volume 4 Appendix B Project Traffic Analyses Report were used to model the current traffic noise levels based on annual data. The results of the model for receptors of interest are provided in Table 11.12.4.

Table 11.12.4 Baseline Traffic Noise Levels

Noise Receptor	Existing Highway Sound Level	
	(daytime)	(nighttime)
	(dBA L_{eq})	(dBA L_{eq})
HWY_19	26	19
HWY_20	27	20
HWY_21	30	23

11.12.4 Predicted Construction Noise Levels

The following summarizes the results of the detailed analysis of construction activities. Only those receptors where noise levels are predicted to be higher than the BCOGC Guideline or to change by more than 3 dBA are reported within the EIS. For detailed results for all scenarios, please see the Volume 2 Appendix M Noise and Vibration Technical Data Report.

11.12.4.1 Dam Site

For the purposes of the noise study, the dam site includes the following components: the dam and generating station facilities, related construction site facilities, and the 85th Avenue Industrial Lands. Activity on the dam site is described in Volume 1 Section 4 Project Description.

Two periods with the most scheduled activity on the site were selected for the noise analysis, based on the construction schedule described in Volume 1 Section 4 Project Description. These were Year 3 and Year 5. These periods of activity also defined the placement of noise sources in the model, as they vary from year to year. The number and type of sound emission sources were established using available Project design data for the appropriate years.

The results of the analysis indicate that changes in noise level greater than 3 dBA and levels higher than the BCOGC Guideline criteria are possible during both Year 3 and 5. Results for those receptors that may be affected are shown in Table 11.12.5.

Table 11.12.5 Predicted Changes in Noise Levels from Dam Site Activities

Noise Receptor	Predicted Sound Level at Receptor	Ambient Sound Level	Cumulative Sound Level	Change in Sound Level	Guideline Sound Level	Meets Guideline
	(dBA)	(dBA)	(dBA)	(dBA)	(dBA)	(Y/N)
Year 3 – Day						
DS_NR2	50	48	52	4	53	Y
DS_NR3	53	48	55	7	53	N
DS_NR4	48	48	51	3	53	Y
DS_NR5	50	48	52	4	53	Y
Year 5 – Day						
DS_NR2	54	48	55	7	53	N
DS_NR3	51	48	53	5	53	Y
DS_NR4	51	48	53	5	53	Y
DS_NR5	52	48	53	5	53	N
DS_NR8	49	48	51	3	53	Y
Year 5 – Night						
DS_NR2	44	38	45	7	43	N
DS_NR3	46	38	47	9	43	N
DS_NR4	46	38	47	9	43	N
DS_NR5	43	38	44	6	43	N
DS_NR8	41	38	43	5	43	Y
DS_NR9	41	38	42	4	43	Y
DS_NR10	38	38	41	3	43	Y

The highest predicted change in noise level is expected in Year 5, particularly at night. Sound level contours for the dam site scenario in Year 5 are provided in Figure 11.12.2 and Figure 11.12.3.

As shown in Table 11.2.5, the results indicate that changes in noise level at some receptors could result in daytime and nighttime noise levels higher than the BCOGC Guideline in Year 3 and 5. The primary source of sound at the receptors affected by the dam site scenario would be caused by extraction of materials from the 85th Avenue Industrial Lands.

Blasting is also planned within the dam site construction area. The airborne vibration calculations indicate that L_{peak} levels would be below the 120 dBL NPC-119 Cautionary Limit (ONMOE No date) within 16 m of the blast and would reduce to 82 dBL at the boundary of the technical study area. No receptors would experience airborne vibration above the NPC-119 Cautionary Limit. Blasting noise (airborne vibration) may be distinguishable from background inside and outside the technical study area due to the nature of airborne vibration.

11.12.4.2 Quarries and Pits

Rock and aggregate materials would be acquired from a number of areas remote to the dam site for the construction of the dam. No dwelling receptors were identified within the technical study area for any of the quarry or borrow areas. The Wuthrich Quarry was modelled to represent the spatial extent of changes in noise level for all quarries. The 1.5 km technical study area boundary was used as the receptor point in the absence of dwelling receptors.

Results from modelling earth moving equipment at Wuthrich Quarry indicate that noise from this activity would diminish to below 35 dBA at between 1,000 m and 1,500 m from the activity. Access road noise would diminish to below 35 dBA at 300 m to 500 m from the road. The 35 dBA value is the BCOGC nighttime ambient sound level for rural areas. Predictions equal to or less than 35 dBA mean that the BCOGC Guideline at 1.5 km from activity are met and changes to ambient sound levels would be 3 dBA or less.

For quarries where blasting would be required, the blast noise analysis indicates that airborne vibration would be below the 120 dBL ONMOE criteria within 13 m of the blast and would be reduced to 76 dBL at 1.5 km from the activity (the technical study area boundary).

11.12.4.3 Clearing

Tree and brush clearing during the construction phase would be a source of sound over the entire clearing areas. The nature of clearing work means that the activities would occur in a number of small areas, anywhere within the Project activity zone and at any particular time. Given the transient nature of the sound associated with clearing, a general approach to identify potential setbacks or zones where noise from clearing activity may result in changes in noise level at receptors was used. A CadnaA model was constructed to determine the amount of noise generated by the activities based on distance. Activities included in the analysis are brush and tree cutting, skidding/moving of material, and loading logs onto highway trucks. All activities were modelled as occurring simultaneously, over a 2 km by 500 m area.

The results in Table 11.12.6 indicate that clearing activity may result in noise levels that exceed the BCOGC Guideline criteria at 500 m from the activity. Clearing activity would be within a 500 m proximity of any affected receptor for a period of a few days, and would then progress to the next area to be cleared. These distances would apply wherever clearing was required for Project construction.

Table 11.12.6 Predicted Noise Levels for Clearing

	Distance from Clearing Boundary (m)					
Day (dBA)	50	100	200	500	1000	1500
East	56.4	54.9	52.6	48.1	43.2	39.5
North	57.8	56.1	53.7	48.8	43.7	39.9
South	67.5	63.6	59.3	52.3	46.1	41.8
West	44.0	42.6	41.1	38.1	34.9	32.2

11.12.4.4 Highway 29 Realignment

Similar to the clearing noise analysis, highway construction work would occur in a limited area, progressing along the planned alignment, with roadbed preparation and material movements occurring along varying portions of the highway alignment at a particular time. Therefore, a general approach was used to identify potential setbacks where highway construction activity may result in changes in noise level at receptors of greater than 3 dBA or noise levels higher than the BCOGC Guideline. A CadnaA model was constructed to determine the amount of noise generated by the activities based on distance. Activities included in the analysis included roadbed grading or preparation, paving and bridge construction.

The results in Table 11.12.7 indicate that predicted noise levels from roadbed preparation (grading, and cut and fill activity) would attenuate to less than the BCOGC Guideline levels within 500 m of the activity. Roadbed preparation could occur within 500 m of any particular section of alignment for several months. For bridge construction, noise is below the criteria within 200 m of activity; however, the activity could occur for a period of over a year.

Table 11.12.7 Predicted Noise Levels from Highway Construction Activities

	Distance from Construction Boundary (m)					
Day (dBA)	50	100	200	500	1000	1500
Grading/cut/fill	61.4	42.9	55.6	49.4	58.7	38.5
Bridge Construction	56.6	53.8	50.3	44.1	38.9	35.2

Highway 29 traffic noise looks at the period where the most expected traffic would occur based on Volume 4 Appendix B Project Traffic Analyses Report. The period with the most traffic is predicted to occur during the dam site construction period rather than in future years, so construction data were used to evaluate potential changes in receptor noise levels due to Project related traffic. Traffic analysis data from Volume 4 Appendix B were used to model the current traffic noise levels based on annual data, and then Project traffic noise levels were modelled and compared to estimate potential for noticeable changes for both the daytime and nighttime periods.

The results of the traffic modelling for the construction year 7, the year with the highest amount of traffic predicted, are provided in Table 11.12.8. The results indicate that a just noticeable change in noise level (approximately 3 dBA) may occur for three receptors during daytime hours, due to construction traffic volumes. Receptors are shown in Figure 11.12.4.

Table 11.12.8 Existing and Predicted Noise Levels at Receptors for Highway Operations

Noise Receptor	Existing Highway Sound Level		Highway Operation Sound Level		Changes in Sound Levels	
	(daytime)	(nighttime)	(daytime)	(nighttime)	(daytime)	(nighttime)
	(dBA L_{eq})	(dBA L_{eq})	(dBA L_{eq})	(dBA L_{eq})	(dBA L_{eq})	(dBA L_{eq})
HWY_19	26	19	30	22	3	3
HWY_20	27	20	30	22	3	3
HWY_21	30	23	33	25	3	3

11.12.4.5 Transmission Line

Clearing noise for the transmission line would be similar to the activity evaluated for the reservoir, in Section 11.12.4.3. Equipment from construction of the tower foundations is not expected to change noise levels at receptors, as described in Volume 2 Appendix M Noise and Vibration Technical Data Report.

Helicopter use for tower erection was also identified as a key activity. Helicopter usage creates short-term noise events of five to 30 minutes in duration. These events could occur several times a day. Results of the helicopter modelling indicate that helicopters in flight (passing by) that are lower than 120 m altitude when within 100 lateral metres of a receptor, may result in noise levels higher than the BCOGC Guideline at the time of the pass-by event. Table 11.12.9 indicates that helicopters landing or hovering may generate noise levels higher than the BCOGC Guideline at 400 lateral metres and 100 lateral metres respectively.

Table 11.12.9 Predicted Noise Levels from Helicopter Activities

Distance to Noise Receptor	Predicted Levels for Landing (L_{eq})	Predicted Levels for Hovering (L_{eq}) (23 m height)
50	71.3	55.3
100	66.9	50.9
200	61.5	45.5
400	54.8	38.8
800	45.2	31.2
1000	41.5	25.5

11.12.4.6 Hudson's Hope Shoreline Protection

Operation of earth-moving equipment and truck traffic are the primary sources of sound during construction of the shoreline protection at Hudson's Hope.

There are a number of residences in the technical study area near the proposed berm. Four receptors representative of all the homes within 1.5 km of the berm were used to evaluate noise levels. Results of the modelling are provided in Table 11.12.10. Receptors, contours from equipment on the berm, and the access road are in Figure 11.12.5.

Table 11.12.10 Daytime Predicted Noise Levels at Receptors near Hudson's Hope Shoreline Protection during Construction

Noise Receptor	Predicted Sound Level at Receptor (dBA)	Ambient Sound Level (dBA)	Cumulative Sound Level (dBA)	Changes in Sound Level (dBA)	PSL Guideline (dBA)	Meets Guideline (Y/N)
HH_1	58.8	53	59.8	6.8	58	N
HH_2	58.9	53	59.9	6.9	58	N
HH_3	65.5	53	65.7	12.7	58	N
HH_4	67.4	53	67.6	14.6	58	N

The receptor results indicate that the nearest residences to this activity may experience noise levels that exceed the BCOGC daytime criteria during the active construction periods.

11.12.5 Operation

11.12.5.1 Dam Site

During operation of the Project, sounds would be expected from the generating station, the spillway, and the substation; and from maintenance activities on the reservoir near the dam. The sound generated from these operations or activities may be noticed as a change in the environment near the sources, but the sound emissions are lower from this equipment when compared to the volume of equipment used for construction; therefore, changes at receptors are expected to be less than 3 dBA.

The sound from water movement in the river downstream of the dam, or over the spillway, is expected to be similar to the current sound from the river. It is also expected to be the dominant sound from the site, when it occurs. Sound from the substation transformers may be noticeable at the fence line of the substation (within the Project activity zone), but would not affect the nearest residence, over 3 km away.

11.12.5.2 Reservoir

During the operation phase, the reservoir may be used for more recreational activities than currently occur on the river. River or water movement sounds would diminish. Human sounds such as recreational boats may increase, but would be intermittent. These sounds reflect a change in the acoustic environment, but would not be under BC Hydro direct control.

For sound from reservoir maintenance, occasional short-term noise events at receptors may occur when small motor boats travel the reservoir checking on debris or shoreline conditions. These events would occur during the daytime and no more than once a day. Single events would not affect the 15-hour daytime L_{eq} noise levels.

Helicopters may also be used to conduct inspections or aid with debris removal. Noise from helicopter usage, as described in Section 11.12.4.5, would apply to usage for maintenance activities, assuming that similar aircraft are used for maintenance as for construction.

11.12.5.3 Transmission Line

During operation, there is no expectation of major noise contribution from the transmission line. Corona noise, commonly described as “line hum”, may be audible within close proximity (typically within the right-of-way) of the transmission line. The corona noise from the existing transmission line has been estimated at the edge of the existing right-of-way as 38.2 dBA. Corona noise from the proposed 500 kV configuration is estimated at 51.1 dBA at the edge of the right-of-way. These values would diminish with distance from the right of way, with the 500 kV corona noise diminishing to below 40 dBA at 200 m to 250 m from the right-of-way, well within the 1.5 km technical study area. The receptors near the transmission line are more than 1 km from the right-of-way, so no changes in noise levels at those receptors are expected, as BCOGC Guidance is met within 250 m.

11.12.6 Summary of Predicted Changes

The analysis of noise at receptors due to sound from construction activities in the technical study area indicates that exceedances of the BCOGC guidelines or increases of more than 3 dBA may occur. Specifically, construction activities in the following areas show increased noise levels: the dam site near the 85th Avenue Industrial Lands, during clearing activity within 500 m of receptors, during Highway 29 realignment within 500 m of receptors, and during construction of the Hudson’s Hope shoreline protection.

Blasting noise (airborne vibration) may be distinguishable from background inside and outside the technical study Area, but the blast designs would comply with the NPC-119 guidance for blasting noise.

Volume 4 Section 33 Human Health evaluates whether the predicted changes would have an effect on human health. Potential for Project noise to affect wildlife is discussed in Volume 2 Section 14 Wildlife Resources.

11.13 Electric and Magnetic Fields

11.13.1 Introduction

This section details the electric and magnetic field (EMF) profiles for the existing 138 kV lines (circuits 1L374 and 1L360) and the proposed two 500 kV lines that would replace the existing 138 kV lines. These profiles were calculated using the Corona and Field Effects Program Version 3 (Bonneville Power Authority 1991), which is used throughout the industry for calculating electric and magnetic fields. Potential human health effects of project-induced electric and magnetic field levels are assessed and evaluated in Volume 4 Section 33 Human Health.

EMF is found wherever electricity is generated, delivered, or used, including power transmission and distribution lines, wiring in homes, workplace equipment, electrical appliances, power tools, and electric motors. Transmission lines produce both electric and magnetic fields. Electric fields are measured in kilovolts per metre (kV/m) and magnetic fields in milligauss (mG) or microteslas (μT). Electric fields are the result of voltages applied to electrical conductors and equipment. Most objects, including fences, shrubbery, and buildings easily block electric fields. Magnetic fields are produced by the flow of electric currents; however, unlike electric fields, most materials do not readily block magnetic fields. The intensity of both electric and magnetic fields diminishes with increasing distance from the source.

Electric fields are mainly influenced by the line voltage, tower head dimensions, and configuration and the height of the conductors above the ground. Magnetic fields are influenced by the line current, the phase-to-phase spacing, the tower head configuration, and the height of the conductors above ground.

Electric and magnetic field levels were calculated based on the maximum load for which the line is built. This provides a conservative basis for calculating EMF.

11.13.2 Baseline Conditions

Structural drawings, plans, and profiles for the existing 138 kV lines were used in determining the line configuration and the average conductor height above ground. The right-of-way width varies along the current 138 kV lines due to the placement of the existing lines within the right-of-way. For the purposes of this study, the average right-of-way width of 29 m was used. With the two 138 kV lines side by side, each line in a wishbone configuration, the distance from the circuit centreline to the right-of-way edge is 9 m. Figure 11.13.1 shows the line configuration and right-of-way width for the existing 138 kV lines.

Electric field profiles were calculated for the existing 138 kV lines using the operating voltage of 144.9 kV. Table 11.13.1 below summarizes the calculated electric fields.

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Table 11.13.1 Electric Field Calculations for the Existing 138 kV Lines

Distance from Edge of Right-of-Way	Electric Field
Highest peak on right-of-way	0.721 kV/m
Edge of right-of-way	0.53 kV/m
Edge of right-of-way + 25 m	0.137 kV/m
Edge of right-of-way + 50 m	0.048 kV/m

Figure 11.13.2 shows the electric field profile for the existing 138 kV lines at 1 m above ground.

Magnetic field profiles were calculated for the maximum loading during normal operation of the lines using an average conductor height of 11 m and a loading of 295 A and 300 A.

Table 11.13.2 Magnetic Field Calculations for the Existing 138 kV Lines

Distance from Edge of Right-of-Way	Magnetic Field
Highest peak right-of-way	23.88 mG
Edge of right-of-way	16.91 mG
Edge of right-of-way + 25 m	3.35 mG
Edge of right-of-way + 50 m	1.29 mG

Figure 11.13.3 shows the magnetic field profile for the existing 138 kV lines at 1 m above ground.

11.13.3 Future Levels

The existing 138 kV lines would be replaced with two 500 kV lines. Electric and magnetic fields were calculated for the new lines. Final right-of-way width had not been determined when this analysis was done. A width of 111 m was selected for the analysis, which provides a conservative estimate of the EMF profiles at the actual right-of-way edge. The actual EMF profile would be lower at the edge because the actual right-of-way would be 118 m, and EMF decreases with distance. The right-of-way width of 111 m results in a 32 m distance from the circuit centreline to the right-of-way edge. For the proposed 500 kV circuits, a typical four-conductor bundle with a conductor diameter of 25.4 mm and a bundle spacing of 0.45 m would be used. Phase spacing was 12 m and an average conductor to ground height was taken at 16 m.

Figure 11.13.4 shows the line configuration and right-of-way width for two new 500 kV lines.

Electric field profiles were produced for the proposed two 500 kV lines using the 500 kV line operating voltage of 525 kV. Table 11.13.3 below summarizes the electric fields.

Table 11.13.3 Electric Field Calculations for Two New 500 kV Lines

Distance from Edge of Right-of-Way	Electric Field
Highest peak on right-of-way	5.391 kV/m
Edge of right-of-way	2.228 kV/m
Edge of right-of-way + 25 m	0.523 kV/m
Edge of right-of-way + 50 m	0.195 kV/m

Figure 11.13.5 shows the electric field profile for two new 500 kV lines at 1 m above ground.

Magnetic field profiles were produced for the maximum loading during normal operation of the lines with an average conductor height of 16 m and a loading of 700 A each.

Table 11.13.4 Magnetic Field Calculations for 1L374 and 1L360

Distance from Edge of Right-of-Way	Magnetic Field
Highest peak on right-of-way	73.40 mG
Edge of right-of-way	29.67 mG
Edge of right-of-way + 25 m	11.41 mG
Edge of right-of-way + 50 m	6.03 mG

Figure 11.13.6 shows the magnetic field profile for two 500 kV lines at 1 m above ground.

11.13.4 Summary of Expected Changes

The expected changes to the electric and magnetic field levels would arise once the new lines are constructed and put into service. The maximum electric field on the right-of-way would be 5.391 kV/m and 2.228 kV/m at the edge of the right-of-way. The maximum magnetic field on the right-of-way would be 73.40 mG and 29.67 mG at the edge of the right-of-way. Potential public health effects of electric and magnetic field levels are assessed and evaluated in EIS Volume 4 Section 33 Human Health.

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12 FISH AND FISH HABITAT

12.1 Approach

This section of the EIS presents the assessment of the potential effects of the Project on the fish and fish habitat VC. As discussed below, fish and fish habitat would potentially be affected by the construction and operation of the Project. Fish and fish habitat is of concern to Aboriginal groups, the public, and stakeholders for a variety of reasons outlined below. Effects on fish and fish habitat are regulated both federally and provincially, including through the *Fisheries Act.*

The approach to the effects assessment takes into account the regulatory and policy setting for fish and fish habitat, and the results of consultation with the general public, regulators, stakeholders, community members, Aboriginal groups, and governments. In particular, BC Hydro has considered information from Traditional Land Use Studies (TLUS) provided by Aboriginal groups. The TLUS information indicates that Aboriginal groups use fish in the Peace River and its tributaries. The results of consultation and the TLUS have been incorporated into the baseline information for fish and fish habitat described below. The use of fish for traditional purposes is considered in the assessment of the potential effects of the Project on Current Use of Lands and Resources for Traditional Purposes, which is found in Volume 3 Section 19, and potential impacts of the Project on the exercise of asserted or established Aboriginal and treaty rights are discussed in Volume 5 Section 34 Asserted or Established Aboriginal Rights and Treaty Rights, Aboriginal Interests and Information.

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.

12.1.1 Regulatory and Policy Setting

Both federal and provincial agencies have mandates relevant to the protection and management of fish and fish habitat.

The federal legislation that has guided the assessment of the potential for the Project to adversely affect fish and fish habitat is the *Fisheries Act* (R.S.C., 1985, c.F-14) and the *Species at Risk Act (S.C., 2002, c. 29).*

British Columbia is responsible for regulation of non-salmon freshwater fisheries, including management, conservation, and recreation. The province's Freshwater Fisheries Program Plan has the stated aim of "A naturally rich and sustainable freshwater fish resource supporting diverse uses for all British Columbians." (B.C. Government 2007).

The Draft Fish, Wildlife and Ecosystem Resources and Objectives for the Lower Peace River Watershed Site C Project Area (B.C. Government 2011) provides guidance for the Site C EIS based on the province's mandate to protect and manage fish and fish habitat.

The stated purpose of the document is to “Identify and recommend valued environmental components (VECs) and management objectives for fish, wildlife and ecosystem resources for consideration in assessing the proposed Site C project and its possible development.” The document defines a VEC as “characteristics or attributes that, if degraded, would compromise the integrity of the key values”. The document further identifies key values as “Environmental elements that are important in maintaining environmental sustainability and ecological integrity.”. The document and the VECs were taken into account in the identification of species for consideration in this assessment.

The assessment of potential effects on fish and fish habitat was designed by taking into account the draft Fish, Wildlife and Ecosystem Resources and Objectives for the Lower Peace River Watershed Site C Project Area (B.C. Government 2011).

12.1.2 Key Issues and Identification of Potential Effects

The key issues raised by the public, Aboriginal groups, and government agencies guided the scope of the fish and fish habitat assessment (refer to Volume 1 Section 9 Information Distribution and Consultation). Key issues raised included the following:

- Integration of traditional knowledge
- Fish populations and habitats on which they rely that could be potentially affected by the Project
- Opportunities to mitigate or enhance fish outcomes with project design

The key issues and the approach used to address the issues are presented in Table 12.1.

Table 12.1 Key Issues: Fish and Fish Habitat

Key Issues	Approach to Addressing Key Issues
Integration of traditional knowledge	Integration of traditional knowledge is addressed in Section 12.2.2 and 12.3 Baseline Conditions.
Fish populations and habitats on which they rely that could be potentially affected by the Project	Potential effects on fish population and fish habitats are addressed in relevant effects assessment subsections below.
Opportunities to mitigate or enhance fish outcomes with project design	Opportunities to mitigate or enhance fish outcomes are addressed in relevant effects assessment sections and in Section 12.4 Mitigation Measures.

The key aspects identified in the EIS Guidelines included the following:

1. Habitat changes created by the reservoir in the mainstem and affected tributaries, as well as upstream and downstream of the dam due to flow alterations
   - Upstream and downstream fish migrations by species and life history stage and their potential to be affected by the Project
   - Fish mortality
   - Potential impacts on the genetic diversity of fish populations above and below the project site

- Potential impacts to predator-prey interactions and expected changes
- Potential impacts to food web composition and structure
- Potential impacts of gas pressure on fish resulting from water discharge over the structure

Because of the overlapping nature of these seven key aspects, for the purpose of this assessment, they have been grouped into three categories of potential effects:

- Changes to fish habitat
- Changes to fish health and fish survival
- Changes to fish movement

This approach was used for the following reasons:

1. It permits a structured evaluation process
   - Each category represents major federal and/or provincial regulatory mandates
   - Each category represents an important component of fish population ecology

Each of these potential effects is described briefly below.

The Project has the potential to affect fish habitat in two ways. The Project may destroy fish habitat by placing a permanent physical structure on that habitat, or the Project may alter fish habitat by changing the physical or chemical characteristics of that habitat in such a way as to make it unusable by fish. Destruction or alteration of important habitats may be critical to the sustainability of a species population.

The Project may affect fish health and survival. It may cause direct mortality of fish or indirect mortality of fish by changing system productivity, food resource type and abundance, and environmental conditions on which fish depend (e.g., water temperature).

The Project may affect fish movement by physically blocking upstream and downstream migration of fish or by causing water velocities that exceed the swimming capabilities of fish, which results in hindered or blocked upstream migration of fish. Blocked or hindered fish movement has consequences to the species population. Fish may not be able to access important habitats in a timely manner or not at all (e.g., spawning habitats). Blocked fish movement may result in genetic fragmentation of the population.

Potential Project interactions with fish and fish habitat are summarized in Volume 2 Appendix A Project Interactions Matrix, Table 2. As defined in Volume 2 Section 10 Effects Assessment Methodology, a rank of “2” indicates that the effects of an interaction may not be fully avoided or mitigated through the application of standard mitigation measures, or are not well understood. Therefore, they were further analysed and evaluated in the effects assessment.

Project interactions with a ranking of “2” are summarized in Table 12.2 below.

Table 12.2 Interaction of the Project with Fish and Fish Habitat

Project Activities and Physical Works	Fish and Fish Habitat – Categories of Effects		
	Fish Habitat	**Fish Health and Survival**	**Fish Movement**
Construction Phase			
Dam & Generating Station Construction – Component Level Interactions			
Site clearing and preparation	✓	✓	✓
Temporary and permanent access roads	✓	✓	
Relocation of surplus excavated material	✓	✓	
Temporary construction access bridge across the Peace River	✓	✓	
Stage 1 channelization and diversion works (north bank)	✓	✓	
Stage 1 channelization works (south bank)	✓	✓	
Stage 2 – diversion	✓	✓	
Stage 2 – Diversion | Earthfill dam and north bank excavation	✓	✓	
Stage 2 – Diversion | South bank structures	✓	✓	
Reservoir Preparation and Filling – Component Level Interactions			
Hudson's Hope Shoreline Protection	✓	✓	
Water management during confinement	✓	✓	✓
Water management during diversion	✓	✓	✓
Water management during reservoir filling	✓	✓	✓
Highway 29 Realignment – Component Level Interactions			
Highway 29 Realignment	✓	✓	✓
Operations Phase			
Reservoir and Generating Station Operations – Component Level Interactions			
Operation of the powerhouse, substation, and reservoir; includes downstream water management	✓	✓	✓

NOTE:

Only Project interactions ranked as “2” in Volume 2 Appendix A Project Interactions Matrix, Table 2 are carried forward to this table. A ✓ indicates that a project component or activity is likely to interact with the VC.

12.1.3 Standard Mitigation Measures and Effects Addressed

Volume 2 Appendix A Project Interactions Matrix, Table 2 provides a ranking for each Project component, physical work, and associated activity by Project Phase (Construction and Operation) in relation to its potential effect on fish and fish habitat.

Rankings of “0” in Volume 2 Appendix A Project Interaction Matrix, Table 2 indicate that there is no interaction between the Project component and fish and fish habitat. Of the 67 items listed, 17 were rated as “0”. As these project activities have no interaction with fish and fish habitat, they are not considered further in the assessment.

Rankings of “1” in Volume 2 Appendix A Project Interactions Matrix, Table 2 mean that an interaction would occur but that it is well understood and can be avoided or mitigated through the application of standard mitigation measures and would be negligible. Of the 67 interactions listed, 34 were given a ranking of “1”. For these activities, such as worker accommodation, quarry operations, and right-of-way vegetation maintenance, standard mitigation measures will be implemented when activities are conducted adjacent to a watercourse. These are not considered further in the effects assessment.

12.1.4 Selection of Key Indicators

The key indicators for assessing the potential effects on fish and fish habitat, which encompass the terms listed above, and their rationale for selection are listed in Table 12.3.

Table 12.3 Key Indicators for Fish and Fish Habitat

Categories of Effect	Key Indicator	Rationale for Selection of the Key Indicators [a]
Change in fish habitat	Quality and quantity of fish habitats, habitat availability, water depth, velocity, water temperature, sedimentation, water quality, ice regime, aquatic productivity, and food resources, competition for food and habitat	Federal and/or provincial mandate for management
Change in fish health and survival	Species diversity; fish population distribution, fish population relative abundance, fish population biomass, sedimentation, stranding, fish entrainment, total dissolved gas	Incorporates traditional knowledge (harvesting); federal and/or provincial mandate for management
Change in fish movement	Fish species population, movement patterns and general life history parameters (i.e., access to habitats), swim speeds, entrainment	Federal and/or provincial mandate for management

NOTE:
[a] Includes input from consultation with the public, Aboriginal groups, and government agencies as well as regulatory guidelines, policies, and programs

12.1.5 Spatial and Temporal Boundaries

12.1.5.1 Spatial Boundaries

The spatial boundaries for assessing the potential effects on fish and fish habitat are listed in Table 12.4 and shown in Figure 12.1. The spatial boundaries were initially set based on information collected on resident fish populations in the Peace River and TLUS information was subsequently reviewed to confirm adequate boundaries.

The Local Assessment Area (LAA) is defined as the Peace River downstream from the Peace Canyon Dam to Many Islands, Alberta and its tributaries entering the proposed reservoir. In determining the LAA, consideration was given to the extent of potential changes to:

Surface water regime (i.e., minimum and maximum flow, seasonal flows, rate of flow, and stage change)

Water quality (i.e., nutrients available for trophic production, total dissolved gases)

Water temperature (magnitude of change, seasonal thermal regime)

Geomorphology and sediment transport (river channel morphology, bedload, and suspended sediment transport)

Downstream ice regime

The downstream limit of the LAA was set at a point where the physical changes in the river are expected to diminish to the point where the change could no longer have a measurable effect that would influence fish and fish habitat.

For the Regional Assessment Area (RAA), consideration was given to the geographic extent, or maximum distribution, of fish populations residing in the LAA and associated meta-populations in the Peace River and tributaries flowing into the future reservoir. In general, a fish population can be defined as a group of individuals of the same species that live at the same point in time in a geographically defined area (Wootton 1990). For a given species, the meta-population within the geographic boundary of the RAA consists of distinct groups or populations. For meta-populations residing in the Peace River, this geographic boundary can be defined as the Peace River downstream from the Peace Canyon Dam and upstream from Vermilion Chutes (Mill et al. 1997).

Table 12.4 Spatial Assessment Areas for Fish and Fish Habitat

Local Assessment Area	Regional Assessment Area
• 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 (207 km) • Watercourses and water bodies within the transmission line and roadway rights-of-way • Watercourses and water bodies within the Project activity zone (construction materials) • Riparian areas adjacent to identified watercourses and water bodies	• Peace River from Peace Canyon Dam, B.C. to Vermilion Chutes, Alberta

12.1.5.2 Temporal Boundaries

Project component and activities that could affect fish and fish habitat would occur during the construction and operations phases of the Project (see Volume 1 Section 4 Project Description).

The potential for construction activities to result in changes to key aspects have been assessed for Years 1 through 8 of the Project. Changes to key aspects resulting from the operations phase have been assessed on the basis that the operations would begin in Year 8 and would continue through the operating life of the Project.

12.2 Information Sources and Methodology

The description of the baseline conditions in the section below was compiled based on available literature, field studies, and traditional knowledge. Refer to Appendix O Fish And Fish Habitat Technical Data Report and Appendix P Aquatic Productivity Reports for detailed fish and fish habitat information.

12.2.1 Summary of Available Studies

Fisheries studies in the Peace River system have been conducted since the 1970s. Work has occurred in the Williston and Dinosaur reservoirs, mainstem Peace River, and many of its tributaries in B.C. and Alberta. The following provides a general overview of the fisheries studies conducted in the Peace River system.

A general investigation of 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 occurred starting in 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, 1991b), again in anticipation of development. This work focused primarily upstream of the Site C Dam site 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) in order 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 encompassed the Peace River in British Columbia that focused on small fish habitat utilization 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, to map fish habitats, and to 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.

In 2001, BC Hydro initiated a multi-year, annual Large River Fish Community Indexing Program on the Peace River (P&E 2002; Mainstream Aquatics Ltd. et al. 2012). 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 Licence Requirements 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 LAA. They include the following:

Standardized fish investigations of the Peace River within British Columbia and downstream into Alberta (Mainstream Aquatics Ltd. 2009a, 2010a, 2012)

Standardized fish investigations of the Moberly and Halfway Rivers (Mainstream Aquatics Ltd. 2009a, 2009b, 2009c, 2010b, 2010c, 2011a, 2011b)

Fish habitat surveys in all minor and major tributaries affected by the Site C Clean Energy Project reservoir (AMEC and LGL 2008b; Mainstream Aquatics Ltd. 2009a, 2009b, 2009c)

Movement studies of sport fish using radio telemetry (AMEC and LGL 2008a, 2008b, 2008c, 2008d, 2010a, 2010b)

Fish fences to document spring and fall fish use of tributaries (AMEC and LGL 2008b; Mainstream Aquatics Ltd. 2009a, 2009b)

Rotary screw traps in the Peace River and major tributaries to monitor downstream movements of fish (Mainstream Aquatics Ltd. 2010d, 2011b)

Bull trout spawner and redd surveys of the Halfway River watershed (Diversified and Mainstream 2009, 2011b)

Examination of fish recruitment sources using the elemental signature method (Clarke et al. 2010; Earth Tone Environmental and Mainstream 2012)

Examination of genetic characteristics selected fish populations (Taylor and Yau 2012)

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

An evaluation of Peace River side channel characteristics and fish community structure (NHC et al. 2010)

A study designed to map and quantify fish habitats at five river flows (Mainstream Aquatics Ltd. et al. 2012)

A study that described Peace River riparian habitats (MacInnis et al. 2011)

A number of investigations also have been completed 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. boundary to the Peace-Athabasca Delta) were completed – one in 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 RL&L (2000a) and Mainstream Aquatics Ltd. (2006a, 2006b, 2009d, 2009e, 2010e).

12.2.2 Traditional Knowledge

Traditional Land Use Studies (TLUS) provided information on the harvest of particular species of fish at particular locations on the Peace River and its tributaries by Aboriginal groups. TLUS were prepared for a number of First Nation communities and presented to BC Hydro for review. These included Blueberry River First Nation Traditional Land Use Study (Bouchard and Kennedy 2011); Duncan's First Nation Ethnohistorical Review (Bouchard and Kennedy 2012a); Horse Lake First Nation Ethnohistorical Overview

(Bouchard and Kennedy 2012b); Doig River First Nation, Prophet River First Nation, Halfway River First Nation, and West Moberly First Nation Traditional Land Use Study (Chandler 2012); Saulteau First Nation Culture and Traditions Study (NesooWatchie Resource Management Ltd. 2011), Kelly Late Métis Settlement Society Aboriginal Traditional Knowledge Assessment (KS Davidson & Associates & KCD Consulting Incorporated 2012), Dene Tha' Traditional Land Use with Respect to BC Hydro's Proposed Site C Dam (Stevenson 2012), and Fort Nelson First Nation Background and Rational for Involvement in the Site C Project (Wolfenden 2012). TLUS references are listed in Volume 5 Appendix A.

12.3 Baseline Conditions

The baseline conditions for fish and fish habitat are described in terms of the following:

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 LAA. These include critical or sensitive areas such as spawning, rearing, and overwintering habitats and migration routes.

Changes in environmental factors (e.g., food, water temperature, sediment transport)

12.3.1 Fish Species

In total, 32 fish species have been recorded in the LAA (Table 12.5). None of the species are officially listed as endangered, thoureatened, 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.

In British Columbia, one species is listed as "red" (endangered or thoureatened): 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 12.5 Fish Species Recorded by Baseline Studies in the Local Assessment Area

Group	Species [a]		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
	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

The B.C. Government considers bull trout as a species warranting special management (BCMOE 1994). A review of the status of bull trout populations in British Columbia ranked the conservation status in several core areas of the Lower Peace Ecological Drainage Unit (Hagen and Decker 2011).

The Halfway/Peace core area, which would be potentially affected by the Project, received a Rank of C2 – At Risk. “At Risk” is defined by Hagen and Decker (2011) as follows:

Core area at risk because of very limited and/or declining numbers, range, and/or habitat, making the bull trout in this core area vulnerable to extirpation

The B.C. Government has identified six fish species of interest in the Lower Peace River Watershed Site C Project Area (B.C. Government 2011). These species are Arctic grayling, bull trout, burbot, goldeye, mountain whitefish, rainbow trout, and walleye. Indicator species were identified to represent a variety of ecological communities, thermal regimes, trophic levels, and biogeographical origins, and intended to capture potential effects across a wide range of conditions and faunas that may be affected by the Project. Two species of conservation concern were not identified as suitable for this purpose. Spottail shiner (red listed) were excluded because this species, while present, is not native to the Project area. The northern pearl dace (blue listed) is identified as a species of concern due to its limited distribution in B.C. The species is not found in the mainstem Peace River but is present in some nearby watersheds (B.C. Government 2011).

Fish species listed in Table 12.5 may have traditional use, recreational use, or management value. All fish species listed in Table 12.5 have ecological function value (i.e., an integral part of fish community function) and have the potential to be affected by the Project. Table 12.6 provides a summary of traditional knowledge associated with fish and fish habitat provided in TLUS studies.

The use of fish for traditional purposes is considered in the assessment of the potential effects of the Project on Current Use of Lands and Resources for Traditional Purposes, which is found in Volume 3 Section 19.

Table 12.6 Summary of Traditional Knowledge Provided in Traditional Land Use Studies Reports

Group	Water Body	Area	Fish Harvested	Common Name	Harvest Month/ Season
Blueberry	Beatton River		Suckers	Sucker species	
	Carbon Creek		Trout	Trout species	
	Charlie Lake		Suckers	Sucker species	
	Chinaman L.		Trout	Trout species	
	Farrell Creek		Grayling	Arctic grayling	
			Rainbow	Rainbow trout	
			Squawfish	Northern pikeminnow	
	Gwillim Lake		Walleye	Walleye	
	Halfway River	Cameron River	Dolly Varden	Bull trout	Winter
			Grayling	Arctic grayling	July, August
			Kokanee	Kokanee	
			Sucker	Sucker species	
		Cust Creek	Dolly Varden	Bull trout	Winter
			Lake Trout	Lake trout	Winter
		Dunlevy Creek.	Dolly Varden	Bull trout	Winter
			Lake Trout	Lake trout	Winter
		Gravel Creek	Dolly Varden	Bull trout	Winter
			Lake Trout	Lake trout	Winter

Group	Water Body	Area	Fish Harvested	Common Name	Harvest Month/ Season
			Lake Trout	Bull trout	
			Grayling Jackfish Kokanee Ling cod Pike Rainbow Squawfish Suckers	Arctic grayling Northern pike Kokanee Burbot Northern pike Rainbow trout Northern pikeminnow Sucker species	July, August June, July October
	Jackfish Lake		Jackfish	Northern pike	
	Moberly Lake		Dolly Varden Pike Rainbow Trout	Bull trout Northern pike Rainbow trout Trout species	September
	Moberly River		Jackfish	Northern pike	
	Peace River	Bear Flats	Dolly Varden Rainbow trout	Bull trout Rainbow trout	
		Beatton River confluence	Walleye	Walleye	
		Halfway River confluence	Brown trout Dolly Varden Grayling Jackfish Kokanee Pickerel Pike Rainbow Suckers Trout Walleye Whitefish	Brown trout Bull trout Arctic grayling Northern pike Kokanee Walleye Northern pike Rainbow trout Sucker species Trout species Walleye Whitefish species	
		Lynx Creek Confluence	Dolly Varden Grayling Rainbow	Bull trout Arctic grayling Rainbow trout	
		Mainstem Peace River	Arctic grayling Dolly Varden Pike Rainbow Trout Whitefish	Arctic grayling Bull trout Northern pike Rainbow trout Trout species Whitefish species	Aug, Sep, Oct
	Pine River		Grayling	Arctic grayling	May
	Stuart Lake		Whitefish	Whitefish species	
	Upper Stoddart		Suckers	Sucker species	

Group	Water Body	Area	Fish Harvested	Common Name	Harvest Month/ Season
	Williston Lake	Dunlevy Reach Upper Reach	Catfish Dolly Varden	Burbot Bull trout	Winter
			Lake Trout Ling cod	Lake trout Burbot	
Saulteau	Carbon Creek		Trout	Trout species	
	Moberly Lake		Grayling Ling cod Pike Suckers Trout Whitefish	Arctic grayling Burbot Northern pike Sucker species Trout species Whitefish species	
Kelly Lake Metis	Belcourt Lake		Dolly Varden	Bull trout	
	Onion Lake		Rainbow trout	Rainbow trout	
	Blue Lake Steep Rock Creek	Upper Lower	Bull trout Bull trout Walleye Suckers	Bull trout Bull trout Walleye Sucker species	
Dene Tha'	Peace River	East of Manning	Various species	Various species	
	Charlie Lake		Various species	Various species	
	Sulphur Lake		Various species	Various species	Late Summer
Fort Nelson	Various locations		Various species		
Treaty 8 (Doig River, Halfway River, Prophet River, and West Moberly)	Charlie Lake		Jackfish	Northern pike	
	Peace River	Farrell Creek confluence	Sucker Bull trout	Sucker species Bull trout	
		Halfway River confluence	Bull trout	Bull trout	
		Lynx Creek confluence	Sucker Whitefish	Sucker species Mountain whitefish	
		Downstream. of Halfway River	Jackfish Lake trout	Northern pike Lake trout	
		Upstream of Halfway River	Bull trout Jackfish Lake trout Whitefish	Bull trout Northern pike Lake trout Mountain whitefish	
		Peace Canyon Dam Tailrace	Bull trout	Bull trout	
		Williston Lake	Lake trout Fish	Lake trout Fish species	
Duncan	Beatton River		Various species	Fish species	
	Charlie Lake		Various species Jackfish	Fish species Northern Pike	

Group	Water Body	Area	Fish Harvested	Common Name	Harvest Month/ Season
	Peace River	Beatton River confluence	Various species	Fish species	
		Hudson's Hope	Jackfish Bull trout	Northern Pike Bull trout	
		Moberly River confluence	Various species Jackfish	Fish species Northern Pike	
		Upstream of. Halfway River	Walleye	Walleye	
	Pine River		Bull trout Various species Jackfish	Bull trout Fish species Northern Pike	
Horse Lake	Beatton River	Upper Beatton River	Various	Fish species	
	Charlie Lake		Various Jackfish Walleye	Fish species Northern Pike Walleye	
	Moberly Lake		Various Jackfish	Fish species Northern Pike	
	Peace River	Downstream of Halfway River	Walleye	Walleye	
		Pine River confluence Upstream of Halfway River	Various Jackfish Walleye	Fish species Northern Pike Walleye	
	Pine River		Various Jackfish	Fish species Northern Pike	

12.3.2 Fish Ecology

The 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 text discusses these factors of the ecology of fish populations recorded in the LAA. Table 12.7 presents a general summary of the ecology of fish species populations recorded in the LAA. More detailed summaries of fish population distribution, habitat use, movement strategies, and recruitment sources within the LAA are provided in Table 12.8 and Table 12.9.

12.3.2.1 Coldwater Versus Coolwater Fish Groups

There are two primary groups of sport fish observed in the LAA, and are categorized as coldwater and coolwater fish. As the name implies, coldwater species reside in coldwater habitats, and require large-textured sediments and clean, well-oxygenated water to complete their life requisites. These species 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 than the coldwater species. Most of these species spawn in spring and have short egg incubation periods.

The transition zone for cool and coldwater fish is within the LAA. Coldwater species dominate the fish community primarily upstream of the Pine River confluence; however, coolwater fish also migrate or reside in the coldwater type habitat upstream of the Pine River. The abundance of the coolwater fish increases downstream of the Pine River confluence and becomes the dominant fish group at the B.C./Alberta boundary.

Table 12.7 Summary of the Ecology of Fish Populations Recorded in the Local Assessment Area

Group	Species [a]	Distribution [b] and Relative Abundance		Important Habitats [d]				Recruitment Source [e]			Movement Strategy [f]
		Upst.	Dwst.	Upst.		Dwst.		Type	Stream Resident Populations		
				Peace R.	Tribs.	Peace R.	Tribs.		Upst.	Dwst.	
Sport fish (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
Sport fish (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

Group	Species [a]	Distribution [b] and Relative Abundance		Important Habitats [d]				Recruitment Source [e]			Movement Strategy [f]
		Upst.	Dwst.	Upst.		Dwst.		Type	Stream Resident Populations		
				Peace R.	Tribs.	Peace R.	Tribs.		Upst.	Dwst.	
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	S		S, R, F, W	F,W	S, R, F, W	N	x	x	L

NOTES:

[a] Species: Italics indicate incidental species recorded only rarely in the LAA

[b] Distribution: Upst. (Upstream of the Site C Dam site location); Dwst. (Downstream of Site C Dam site location); + (Present); – (Not present)

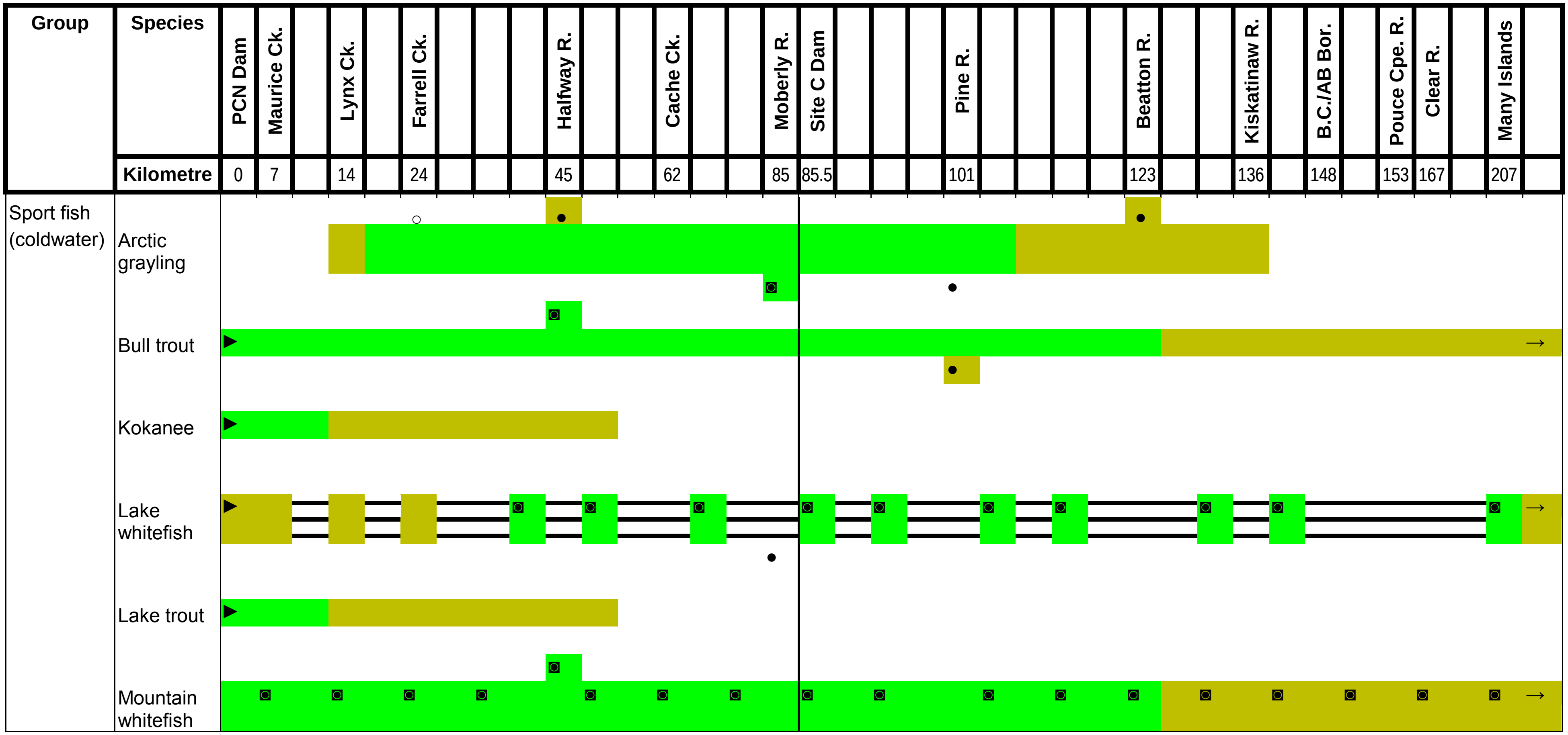
[c] Relative Abundance: A (Abundant); P (Present); S (Scarce); I (Incidental)

[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 12.8 Summary of Large-Fish Population Distribution, Habitat Use, Movement Strategy, and Recruitment Sources in the Local Assessment Area



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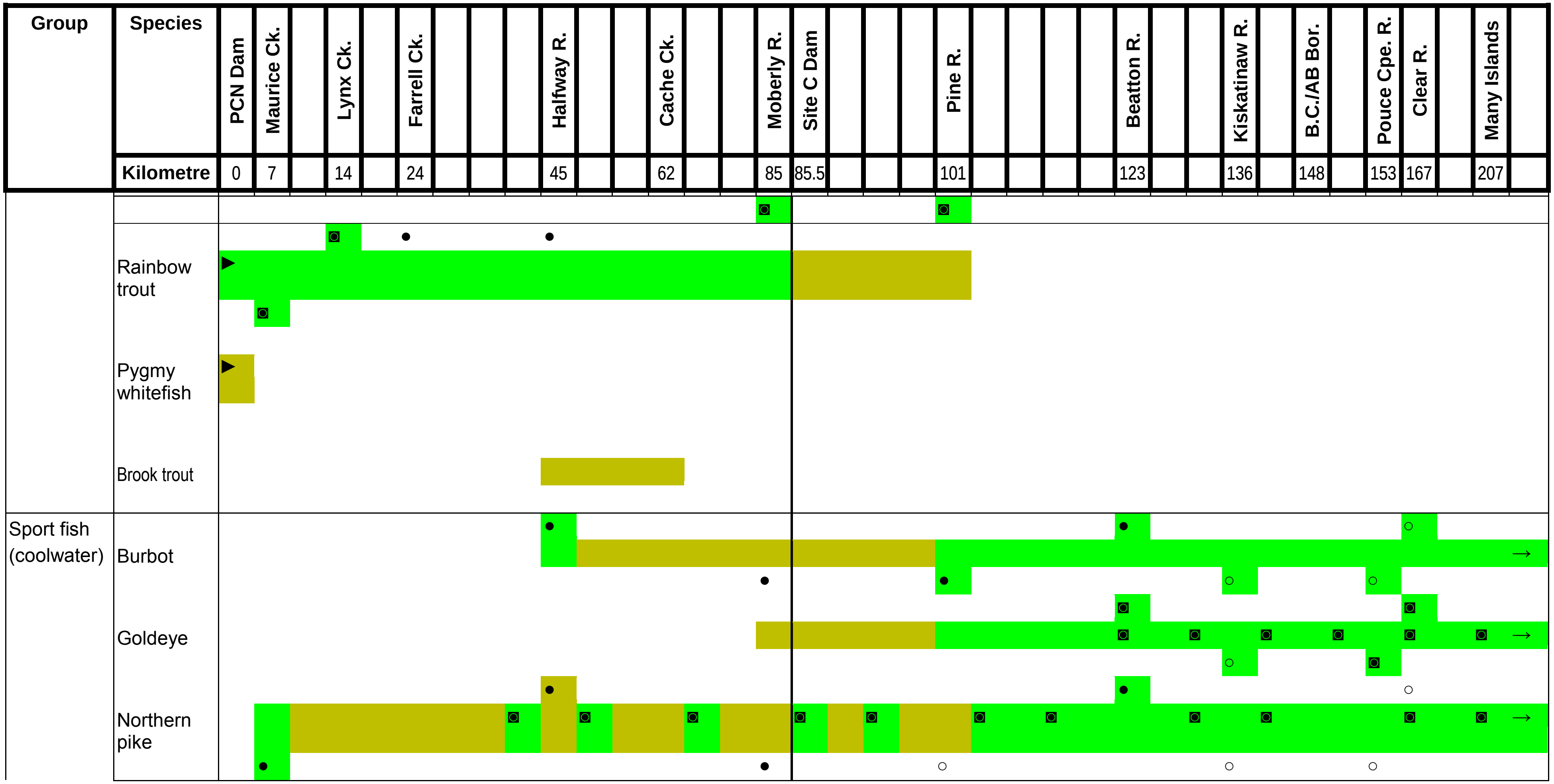
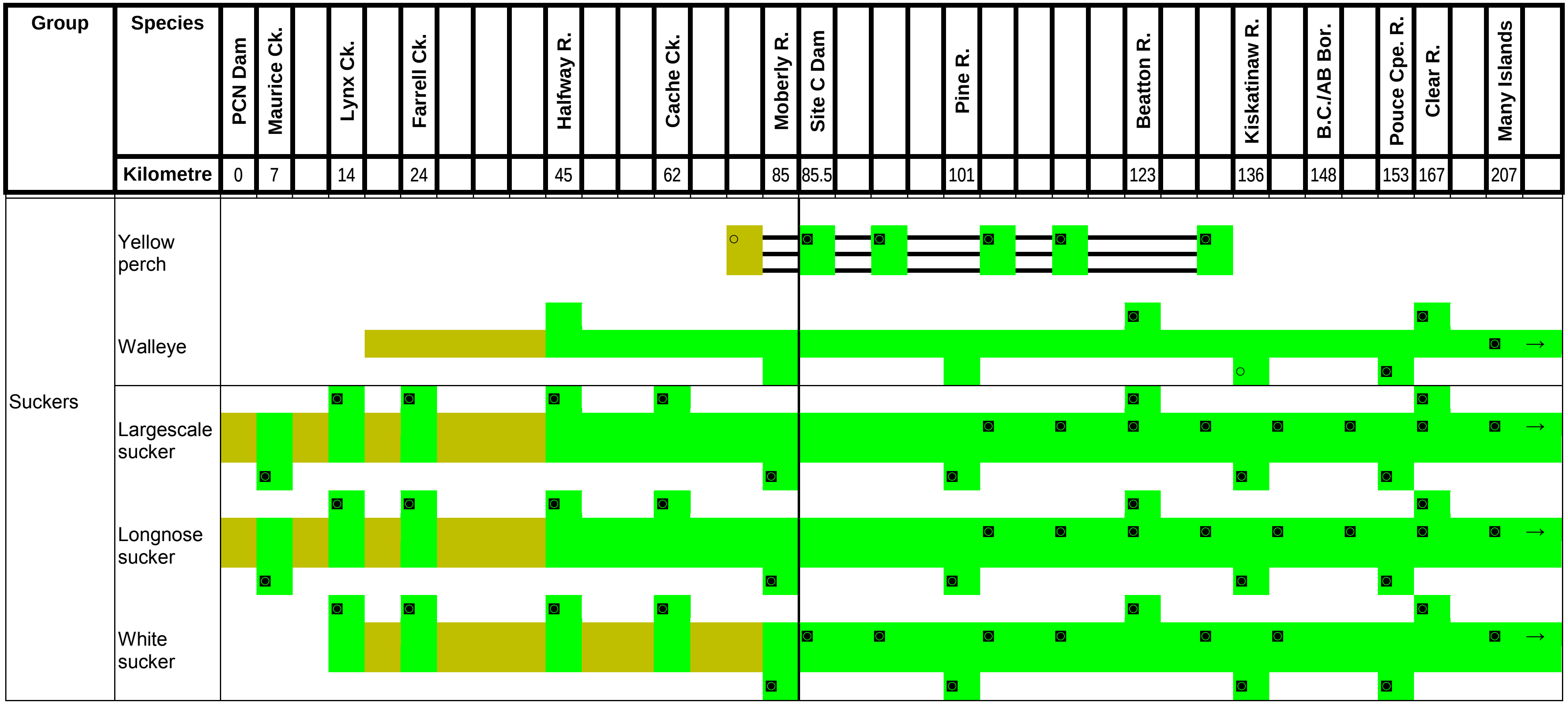

Group
Species
PCN Dam
Maurice Ck.
Lynx Ck.
Farrell Ck.
Halfway R.
Cache Ck.
Moberly R.
Site C Dam
Pine R.
Beatton R.
Kiskatinaw R.
B.C./AB Bor.
Pouce Cpe. R.
Clear R.
Many Islands
Kilometre
0
7
14
24
45
62
85
85.5
101
123
136
148
153
167
207
Rainbow trout
Pygmy whitefish
Brook trout
Sport fish (coolwater)
Burbot
Goldeye
Northern pike



NOTES:

Core population defined by area of frequent occurrence and high abundance relative to remainder of population in LAA.

Extended population defined as area of infrequent occurrence and low abundance relative to remainder of population in LAA.

Area of population separation

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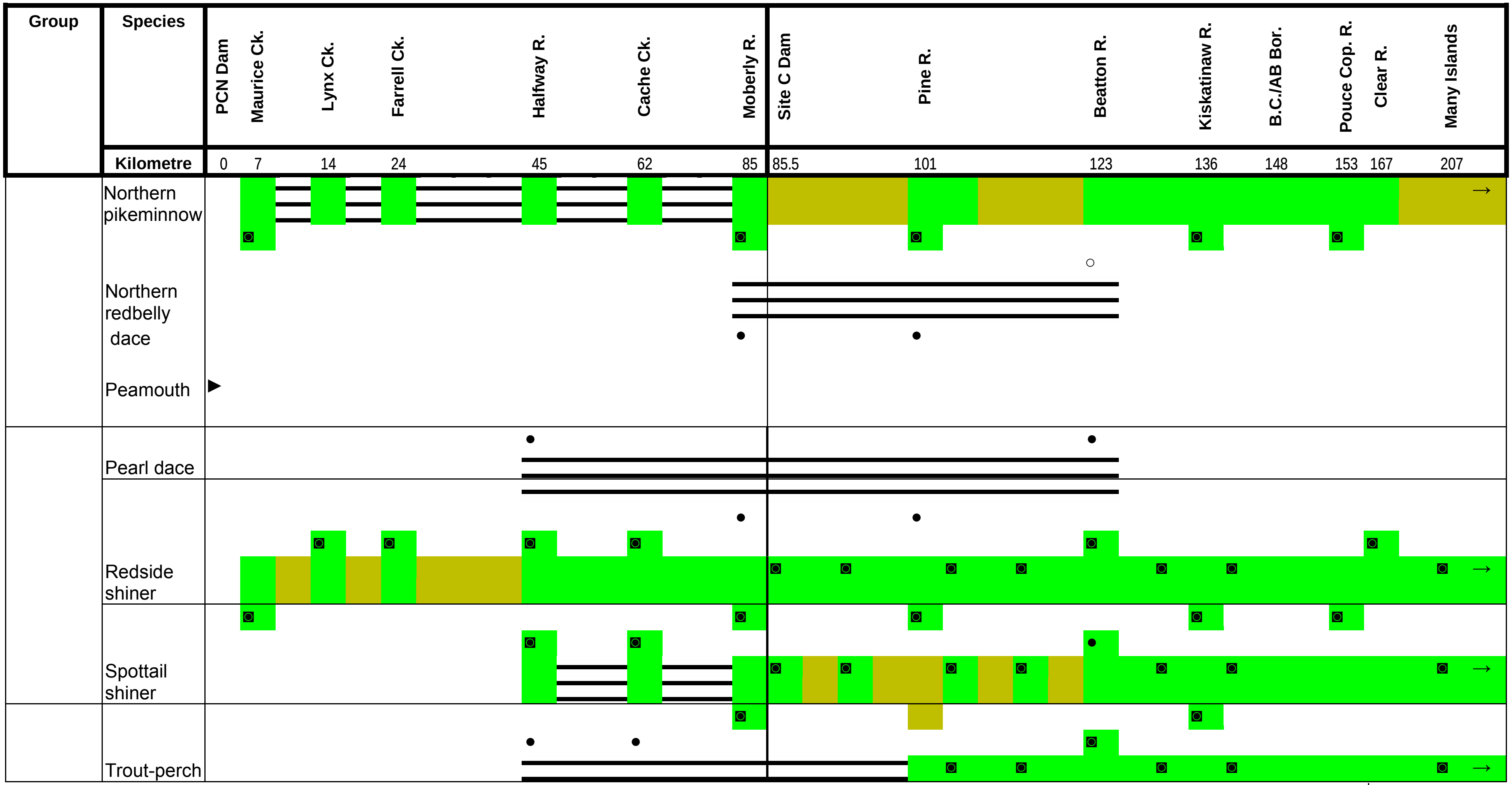
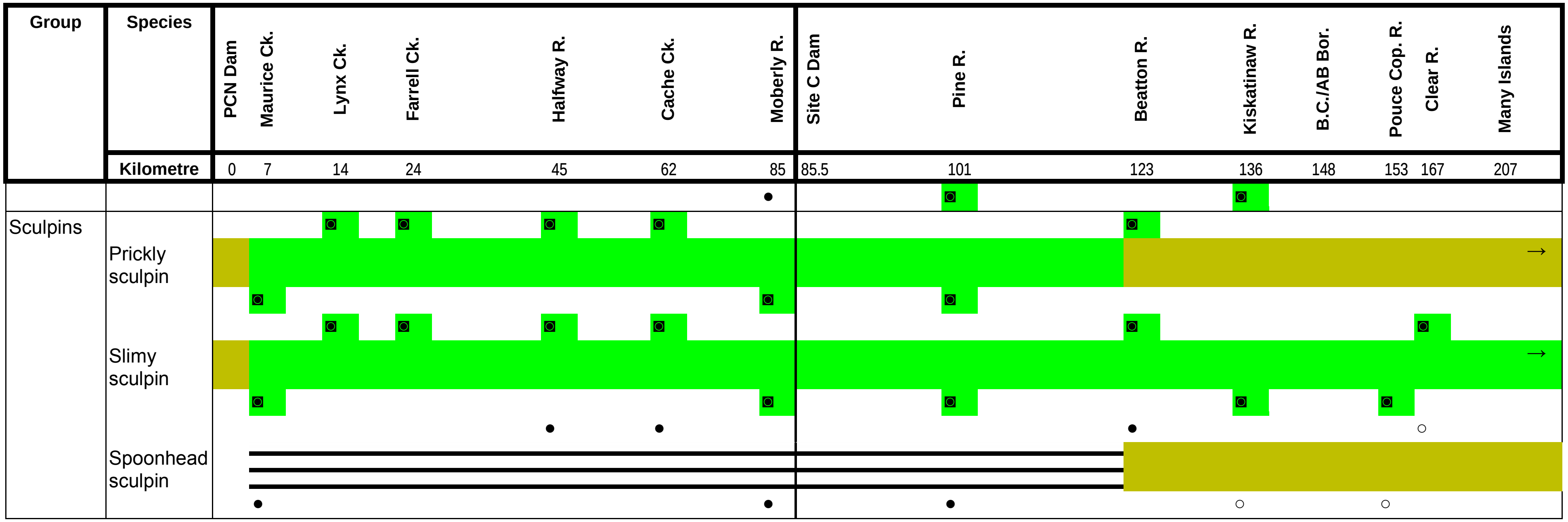
►	Recruitment by entrainment from upstream sources.
●	Tributary resident population that is a recruitment source for Peace River population.
○	Suspected recruitment source for Peace River population.
◙	Important spawning or rearing habitat and recruitment source for Peace River population.
→	Distribution extends downstream outside of LAA.

Table 12.9 Summary of Small-Fish Population Distribution, Habitat Use, Movement Strategy, and Recruitment Sources in the Local Assessment Area.

Group	Species	PCN Dam	Maurice Ck.	Lynx Ck.	Farrell Ck.	Halfway R.	Cache Ck.	Moberly R.	Site C Dam	Pine R.	Beatton R.	Kiskatinaw R.	B.C./AB Bor.	Pouce Cop. R.	Clear R.	Many Islands
	Kilometre	0	7	14	24	45	62	85	85.5	101	123	136	148	153	167	207
Minnows	Brook stickleback															
	Finescale dace															
	Flathead chub															
	Longnose dace															
	Lake chub															


Group
Species
PCN Dam
Maurice Ck.
Lynx Ck.
Farrell Ck.
Halfway R.
Cache Ck.
Moberly R.
Site C Dam
Pine R.
Beatton R.
Kiskatinaw R.
B.C./AB Bor.
Pouce Cop. R.
Clear R.
Many Islands
Kilometre
0
7
14
24
45
62
85
85.5
101
123
136
148
153
167
207
Northern pikeminnow
Northern redbelly dace
Peamouth
Pearl dace
Redside shiner
Spottail shiner
Trout-perch



NOTES:

Core population defined by area of frequent occurrence and high abundance relative to remainder of population in LAA.
Extended population defined as area of infrequent occurrence and low abundance relative to remainder of population in LAA.
Area of population separation
► Recruitment by entrainment from upstream sources.
● Tributary resident population that is a 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 LAA.

BC hydro FOR GENERATIONS

Seven sport fish 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. Rainbow trout and Arctic grayling are the only species in the group that are a spring spawners. Rainbow trout is also a species whose population has limited natural recruitment within the LAA.

Five sport fish species belong in the coolwater group including walleye, goldeye, northern pike, burbot, and yellow perch.

Fish species that also occupy the coolwater habitats 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 occupy 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 LAA 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. They are present, but individuals of these species represent transients from populations that reside outside the influence of the LAA.

12.3.2.2 Small Versus Large Fish

The LAA fish community was 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 includes sport fish and suckers. In the small-fish group, all age classes are smaller than 200 mm. This category includes minnows and sculpins. The only exception to this length criterion is northern pikeminnow in the minnows 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 river current. Due to their small size, small-fish species undertake shorter upstream movements compared to large-fish species. Small-fish species and younger age classes of large-fish species can complete long distance movements during downstream dispersal.

12.3.2.3 Extended Versus Local Movements

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 alternating 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 (Nelson and Paetz 1992; Mill et al. 1997; McPhail 2007); however, certain species are known to undertake extensive movements (extended), whereas others undertake only local movements (local).

There are four movement strategies identified below. These movement strategies are not mutually exclusive as a given species, life stage, or distinct group may use one or more of these strategies.

Extended Movement Strategy: Several species demonstrate extended movements, including Arctic grayling, bull trout, mountain whitefish, goldeye, and walleye. Movements by adults involve long distance migrations to tributary spawning habitats and foraging areas.

- Arctic grayling migrate to the Moberly River, where they spawn 20 to 60 km upstream from the Peace River confluence
- Mountain whitefish migrate throughout the Peace River to the Moberly and Halfway rivers to spawn
- Bull trout travel as much as 300 km in order to access spawning habitats in upper Halfway River tributaries
- Walleye undertake post-spawning feeding movements in the Peace River from spawning areas in the Beatton River, Clear River, and Pouce Coupe River to as far upstream as the Halfway River, 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 migratory species that can travel long distances from wintering habitats downstream to spawning and feeding habitats to as far upstream as the Moberly River. The goldeye population spawns in the Peace River and in several tributaries, primarily in Alberta.

Local Movement Strategies: Some fish species 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 spawning and feeding areas in the tributaries.

Combined Extended and Local Movement Strategies: Some species 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 more than 80 km in order to access tributary spawning habitats in the Pine River, Moberly River, and Halfway River.

Downstream Dispersal Movement Strategy: Downstream dispersal by small-fish species and younger age classes of large-fish species, which can be active or passive, has been recorded for most species present within the Peace River and from all tributaries. This movement strategy is a source of recruitment to the Peace River for some fish populations (e.g., Arctic grayling). For other populations, it represents a loss (e.g., kokanee). Examples are as follows:

- Juvenile Arctic grayling are 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 emigrate from rearing tributaries such as the Moberly River and Halfway River
- Kokanee in the Peace River recruit from the upstream Williston and Dinosaur reservoirs. These fish then disperse through the LAA to downstream areas.
- Recently emerged mountain whitefish fry in the upper Peace River disperse downstream in spring and by mid-summer are absent from upstream of the Halfway River confluence

12.3.2.4 Recruitment Sources – Natural Versus Entrainment

Natural recruitment of fish populations in the LAA originate from the mainstem Peace River and/or Peace River tributaries. Tributaries provide spawning and early rearing habitats for species populations that reside in the Peace River. In addition, some tributaries contain resident populations that provide recruitment to the Peace River via downstream dispersal. Baseline studies indicate that resident fish in Maurice Creek are a recruitment source for Peace River rainbow trout. The Halfway River, Pine River, and Beatton River are important sources for recruitment of Arctic grayling.

Few fish populations rely entirely on mainstem Peace River for recruitment. Spawning sculpin species, mountain whitefish, sucker species, and 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 utilize tributary spawning and early rearing habitats that are located outside of the influence of the Peace River.

An importance source of recruitment for some fish populations in the LAA is entrainment. Recruitment via entrainment 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.

12.3.2.5 Habitat Use: Peace River Habitats versus Tributary Habitats

The Peace River fish community 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 that drives this outcome is the absence of suitable habitats needed by small-sized fish in the Peace River (more detail on fish habitat characteristics is provided in Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). This is caused by the regulated flow regime of the Peace River and life history strategies that rely on tributary habitats for the life requisites spawning and early rearing. Downstream of the Halfway River, this pattern of large-fish versus small-fish diminishes, but still remains the primary feature of the Peace River fish community. Species populations that do not follow this pattern are rainbow trout and kokanee, which 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 LAA support a diverse number of small- and large-fish species. The fish species populations that utilize tributaries depend on the environmental characteristics of the watercourse. Smaller tributaries and the lower sections of larger tributaries have limited coldwater fish habitats due to water flow regimes that are dominated by large spring freshets, 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. Areas such as Lynx Creek, Farrell Creek, lower Halfway River, and Cache Creek support populations of minnows and suckers, which use tributary confluence areas as population focal points.

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

12.3.2.6 Habitat Use: Main Channel Habitats versus Side Channel Habitats

The Peace River fish community 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 can be more protected than habitats in main channel areas (i.e., lower water velocities). 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.

Some side channels provide 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 are few in number within the LAA. These side channel areas support five species populations including lake whitefish, northern pike, yellow perch, white sucker, and spottail shiner.

12.3.2.7 Fish Abundance and Distribution

In terms of overall abundance of large-fish and small-fish, fish numbers are much higher in the LAA compared to further downstream. Extensive work in the Dunvegan area of the Peace River, which is 120 km downstream of the LAA, recorded an order of magnitude lower abundance of large-fish and of small-fish.

Mountain whitefish is the dominant species in the LAA. In 2011 within the Peace River, there were an estimated 275,500 large-sized mountain whitefish (70,400 kg) upstream of the proposed Site C Dam site and an estimated 86,000 large-sized mountain whitefish (29,000 kg) downstream of the proposed Site C Dam site (Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). Longnose sucker replaces mountain whitefish as the dominant large-fish species downstream of the Beatton River confluence. Redside shiner is the numerically dominant small-fish species in the Peace River LAA upstream and downstream of the proposed Site C Dam site.

Smaller tributaries contain fish communities numerically dominated by suckers and minnows. Spring trapping studies recorded several thousands of fish belonging to these groups in monitored streams (Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). These included Lynx Creek, Farrell Creek, and Cache Creek. Maurice Creek 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 sport fish such as Arctic grayling, bull trout, and rainbow trout.

12.3.2.8 Fish Age 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. The availability and quantity of small-fish habitats is limited by the Peace River flow regime. Small-fish species do occur upstream of the Halfway River, but are more abundant 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.

12.3.3 Fish Habitats

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 (Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). 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.

12.3.4 Environmental Factors

Physical and biological information used to describe baseline conditions for fish and fish habitat are described in more detail in other volumes and sections of the EIS as identified in Table 12.10. These environmental factors and their influence on fish habitat are described in detail in Volume 2 Appendix O Fish and Fish Habitat Technical Report.

Table 12.10 Environmental Factors Supporting Fish and Fish Habitat

Environmental Factors	Volume 2, Section Number	Volume 2 Appendices
Previous Development	Section 11.1 Previous Development	–
Geology, Terrain, and Soils	Section 11.2 Geology, Terrain, and Soils	Appendix B Geology, Terrain Stability, and Soil Reports
Surface Water	Section 11.4 Surface Water Regime	Appendix D Surface Water Regime Technical Memos
Water Quality	Section 11.5 Water Quality	Appendix E Water Quality Baseline Conditions in the Peace River
Thermal and Ice Regime	Section 11.7 Thermal and Ice Regime	Appendix G Downstream Ice Regime Technical Data Report Appendix H Reservoir Temperature and Ice Regime Technical Data Report
Fluvial Geomorphology and Sediment Transport	Section 11.8 Fluvial Geomorphology and Sediment Transport Regime	Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report
Methylmercury	Section 11.9 Methylmercury	Appendix J Mercury Technical Data Reports
Aquatic Productivity		Appendix P Aquatic Productivity Reports

12.4 Effects Assessment

The creation of the Site C reservoir will change the river ecosystem. Upstream of the dam, a new aquatic ecosystem, with a fish community, will develop in the reservoir created by the impoundment of the river. For a distance downstream of the dam, the operation of the dam and generating station would modify the surface water regime and other characteristics of the river aquatic ecosystem and influence aquatic habitat conditions, ecological productivity, and fish community composition. The dam would also impede upstream and downstream movement of migratory species and can directly affect survival of fish passing through it. The Project therefore has the potential to adversely affect fish and fish habitat.

The assessment of the potential for the Project to affect fish and fish habitat took into consideration the potential changes to the following key aspects:

1. Habitat changes created by the reservoir in the mainstem and affected tributaries, as well as upstream and downstream of the dam due to flow alterations

- Upstream and downstream fish migrations by species, their life history stage, and their potential to be affected by the Project
- Fish mortality
- Potential impacts on the genetic diversity of fish populations above and below the project site
- Potential impacts to predator-prey interactions and expected changes
- Potential impacts to food web composition and structure
- Potential impacts of gas pressure on fish resulting from water discharge over the structure

Because of the overlapping nature of these seven key aspects, for the purpose of this assessment, they have been grouped into three categories:

- Changes to fish habitat
- Changes to fish health and fish survival
- Changes to fish movement

This approach was used for the following reasons:

1. It permits a structured evaluation process
2. Each category represents major federal and/or provincial regulatory mandates
3. Each category represents an important component of fish population ecology

The following sections discuss each of the potential changes to fish habitat, fish health and survival, and fish movement resulting from effects of the construction and operation phases of the Project resulting from the key issues identified in Section 12.1.2 above and interactions summarized in Table 12.11 below.

Table 12.11 lists the interactions that may cause a change to one or more of the three categories of effects by Project phase and component. Some interactions are common to project components and phases (e.g., sediment inputs), while others are specific to a particular phase and component (e.g., entrainment of fish).

Table 12.11 Interaction of the Project by Phase, Project Component and Category of Effects

Interaction	Phase and Project Component														Category of Effects		
	Construction							Operation									
	Access Roads	Dam & Generating Station	Highway 29 Realignment and Hudson's Hope shoreline protection	Quarried & Excavated Materials	Reservoir Creation a	Transmission System	Worker Accommodation	Access Roads	Dam & Generating Station	Highway 29 Realignment	Quarried & Excavated Materials	Reservoir Operation	Transmission System	Worker Accommodation	Fish Habitat	Fish Health and Survival	Fish Movement
Sediment inputs		X	X		X										X	X	
Footprint of infrastructure		X	X												X		
Obstructed fish movement		X							X								X
Stranding of fish		X			X				X			X				X	
Entrainment of fish		X							X							X	
Altered total dissolved gas		X			X				X							X	
Altered depth and velocity					X							X			X		
Altered surface water regime		X							X						X		
Altered sediment regime		X			X				X			X			X		
Altered thermal regime									X			X			X		
Altered ice regime									X						X		

NOTE:
[a] Refers to channelization and diversion headpond and reservoir filling

12.4.1 Effects Assessment – Construction – Change in Fish Habitat

Fish habitat would be potentially be changed by the following Project components and activities during operations:

Construction of dam and generating station, Highway 29, and Hudson's Hope shoreline protection

Construction headpond and reservoir filling

12.4.1.1 Change in Habitat Due to Construction of the Dam and Generating Station, Highway 29, and Hudson's Hope Shoreline Protection

The construction of the dam and generating station, Highway 29 realignment, and Hudson's Hope shoreline protection infrastructure footprint would potentially affect fish habitat. The surface area of these components and activities that would potentially affect fish habitat are provided in Table 12.12.

Table 12.12 Surface Area of the Project Components and Activities that Would Potentially Affect Fish Habitat

Project Component and Activities	Surface Area (ha)
Dam and Generating Station Construction Zone	**198.5**
Dam, generating station, and spillway	
L5 surplus excavated materials area	
Aggregates processing and stockpiles	
North bank haul road (2.95 km of Peace River shoreline)	
L6 relocated surplus excavated materials area	
Peace River construction bridge	
Moberly River construction bridge	
Highway 29 Realignment	**10.6**
Halfway River bridge	0.2
Lynx east (1.76 km of Peace R. shoreline)	10.4
Reservoir: Hudson's Hope Shoreline Protection	**6.1**
Berm (1.52 km)	4.6
Bank setback (0.77 km of Peace R. shoreline)	1.5
Total	**215.2**

Construction of the dam and generating station would result in the loss of 198.5 ha of fish habitat. Fish habitats affected are primarily in the Peace River, but habitats in the Moberly River would be affected by the construction bridge. Moberly River fish habitats that would be affected include spawning and rearing habitats for mountain whitefish, suckers, and minnows, and feeding habitats for all adult species, in particular for goldeye and walleye. Peace River fish habitats affected include a side channel area along the south bank that provides spawning, rearing, feeding, and wintering habitats for several species. Peace River mainstem channel areas that are affected include spawning, rearing, feeding, and wintering habitats for several fish species. Within the dam and generating station construction zone, there are two locations that contain high-quality fish habitats. High quality is defined as habitat that supports highest numbers of fish. The first includes the river channel located along the north bank of the Peace River, which provides high-quality rearing habitats for Arctic grayling and mountain whitefish. The second is the river channel located along the north bank of the Peace River that would be changed by the 2.95 km North Bank Haul Road. The area provides high-quality rearing habitats for Arctic grayling, bull trout, mountain whitefish, and rainbow trout. The area also provides high-quality feeding habitats for Arctic grayling, bull trout, rainbow trout, and walleye.

Construction of Highway 29 realignment would result in the loss of 10.6 ha of fish habitat. This includes 0.2 ha of habitat in the Halfway River and 10.4 ha along a 1.76 km shoreline of the Peace River. The Halfway River within the Highway 29 Realignment construction footprint provides spawning and rearing habitats for suckers and minnows and feeding habitats for bull trout. The shoreline located along the north bank of the Peace River provides several types of high-quality habitats. These include high-quality spawning habitats for mountain whitefish, high-quality rearing habitats for Arctic grayling, bull trout, mountain whitefish, and rainbow trout, and high-quality feeding habitats for Arctic grayling, bull trout, and mountain whitefish.

Construction of the Hudson's Hope shoreline protection would result in the loss of approximately nine ha of fish habitat. This includes the berm, and fish habitat affected by construction activities associated with the shoreline setback. The Peace River in the area of the Hudson's Hope shoreline protection provides several types of high-quality fish habitats. These include high-quality rearing habitats for bull trout and rainbow trout, and high-quality feeding habitats for bull trout, mountain whitefish, and rainbow trout. This section of the Peace River is used by lake trout for rearing and feeding. It also contains physical characteristics that provide high-quality spawning habitat for lake trout.

12.4.1.2 Change in Habitat Due to the Construction Headpond and Reservoir Filling

During channelization and diversion, a headpond would form upstream of the dam and generation station construction site. During the channelization period (approximately 36 months) the maximum upstream extent of the headpond would be approximately 10 km, and approximately 387 ha of the Peace River valley outside of the active channel would be inundated. During the diversion period (approximately 39 months), the maximum upstream extent of the headpond would be approximately 27 km and approximately 1,630 ha of the Peace River valley would be inundated.

The headpond would alter existing Peace River fish habitats by increasing water depth and decreasing water velocity. Sediment inputs from erosion of newly inundated areas outside of the active Peace River channel and sedimentation caused by deposition of suspended sediments would alter existing clean riverbed materials.

Both stages of construction (channelization and diversion) would lead to an increase in the water levels upstream of the construction site, which would provide additional fish habitat. During the channelization period, upstream water levels would be up to 1 m higher than under existing conditions at the upstream end of the river constriction; the difference would be less with increasing distance upstream. Although the daily range of water levels upstream of the construction site during channelization would be slightly higher than under existing conditions, the difference in the hourly rate of change would be negligible.

During diversion there would be a greater influence on upstream water levels than during the channelization period. Water levels adjacent to the cofferdam during diversion would be increased by 1.5 m or more (compared to existing conditions) 90% of the time, and water levels would be increased by 8.6 m or more 10% of the time. The difference would again be less with increasing distance upstream. Although the daily range of water levels in the construction headpond would be greater than under existing conditions, the difference in the hourly rate of change is minimal.

The increase in wetted surface area of the headpond would potentially provide additional fish habitats; however, water levels would fluctuate. This fluctuation would limit the ability of fish to utilize the newly formed habitats in the headpond.

Peace River fish habitats affected by the headpond include main channel and side channel areas that provide spawning, rearing, feeding, and or wintering habitats for most species recorded upstream of the Site C Dam (see Table 12.7).

Filling of the Site C reservoir would result in the loss of 28.0 km^2 of Peace River fish habitat area and 1.63 km^2 of tributary fish habitat area. The lotic habitat areas would be replaced by 9.42 km^2 of littoral area (defined as water depth < 6 m) and 83.57 km^2 of limnetic area. The different habitat types currently existing in the Peace River and Peace River tributaries, are described in Volume 2 Appendix O Fish and Fish Habitat Technical Data Report. A description of the timeline for reservoir filling and commissioning is presented in Volume 1 Appendix B Reservoir Filling Plan.

Based on the continual change from riverine habitat to reservoir habitat during headponding and reservoir filling, it is expected that the fish species that have critical riverine habitat requirements upstream of the Site C Dam, specifically the Moberly River Arctic grayling, mainstem spawning mountain whitefish, and perhaps migratory Halfway River bull trout would be most affected by the creation of the reservoir.

12.4.2 Effects Assessment – Operations – Change in Fish Habitat

Fish habitat would be potentially be changed by the following Project components and activities during operations:

Reservoir transformation during operations

Generating station operation effects on downstream Peace River

12.4.2.1 Transformation of Reservoir Habitat During Reservoir Operation

Following reservoir creation, the reservoir would undergo a dynamic ecosystem transformation, where there would be an initial surge of nutrients and productivity in the newly flooded reservoir over the short term, diminishing over time as the reservoir reaches equilibrium. The following section describes the changes that would occur during the reservoir transformation period. Predicted changes to the fish habitats during the transformation of the Site C reservoir are presented in Volume 2 Appendix P Aquatic Productivity Reports, Part 3 Future Conditions in the Peace River. Changes in fish habitat are based on calculations that quantify conversions of lotic habitats in the existing Peace River and its tributaries to lacustrine habitats in the Site C reservoir. Lacustrine habitats include littoral and pelagic habitats. The Site C reservoir would include 9.42 km^2 of littoral area and 83.57 km^2 of pelagic area.

Site C reservoir water levels would range between 460.0 m to 461.8 m elevations or 1.8 m (Section 4.3 in Volume 1 Section 4 Project Description). The daily range of Site C reservoir levels (i.e., the maximum daily reservoir level minus the minimum daily reservoir level) is expected to be 0.6 m or less 60% of the time (Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

Most species that presently reside in the Peace River and its tributaries within the reservoir inundation zone would be present in the Site C reservoir after inundation. However, the relative abundance and biomass of fish species within the reservoir fish community would change during the transition of the reservoir. The short-term (10 years), medium-term (10 to 30 years), and long-term fish communities (> 30 years) would reflect the transition in ecological conditions of the Site C reservoir and tributaries flowing into the reservoir, including:

Physical environment (i.e., water depth and velocity, water temperature, water quality)

Availability of habitats needed to support the fish population

Aquatic productivity and food resources

Recruitment from sources outside of the reservoir (i.e., upstream and downstream)

Competition for food and space

Species that are able to reside within the new physical environment, that can exploit increases in aquatic productivity, food resources, and newly formed habitats, and that can outcompete other fish for food and space would dominate the Site C reservoir fish community.

A quantitative ecosystem approach was used to analyze the range of possible changes in fish and fish habitat, both upstream and downstream of the proposed Site C Dam, by considering changes to the ecological conditions listed above (Volume 2 Appendix P Aquatic Productivity Reports: Part 1 Baseline Aquatic Productivity in the Upper Peace River, Part 2 Hydrodynamic, Water Quality and Productivity Modelling for the Site C Project; 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 productive capacity that may result from operation of the Project.

Fish populations depend on important habitats and on available food resources to meet their energy needs. Food requirements vary with fish species and life stages, and may include aquatic and terrestrial insects, zooplankton, or other fish. The food web that supports the fish community, in turn, is affected by many physical and chemical factors including the rate at which water moves through a river or reservoir, and the quality of that water, particularly its sediment and nutrient content, which affects primary production.

These flows of energy and interactions are schematically illustrated in Figure 12.2. The operation of Site C reservoir can potentially affect fish both directly (e.g., mortality during turbine passage), or indirectly through changes to their habitats, movements, and food resources. These interactions were examined and a range of possible future conditions following the creation of the Site C reservoir were explored. The following questions were used to define the metrics for evaluating possible changes in productive capacity. This study focuses on five sets of metrics:

1. Total habitat area before and after construction and operation of Site C

    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

Table 12.13 provides an overview of the aquatic productivity evaluation structure, including the questions addressed, the specific linkages considered (with reference to Figure 12.2) and the set of methods used.

Table 12.13 Overview of the Aquatic Productivity Evaluation Structure

Question	Description	Methods [Links in Figure 12.2] [a]
1	What are the projected changes in the area of lotic, littoral, and pelagic/profundal habitat with the creation of the Site C reservoir?	GIS analysis of habitat maps (link 2)
2	What changes in water quality, lower trophic levels, and fisheries have been observed following the creation of other reservoirs, particularly within Western Canada?	Literature review (all links)
	What are the expected changes in phytoplankton and periphyton in both the Site C reservoir and downstream areas? How do the answers to the above question vary under different assumptions about flow, nutrients, and suspended sediment?	CE-QUAL-W2 simulation model applied to Dinosaur, Site C reservoir and Peace River (links 1a, 2, 4)
3	What covariates best explain observed variations in benthic production within the Peace River? What are the effects of water level fluctuations on benthos? What are the expected changes in benthic production downstream of Site C, relative to current conditions?	Multiple regression equations developed from 2010 and 2011 field data, and then applied to conditions following construction and operation of the Site C Dam (links 3a, 3b, 5)
	How would overall secondary production (zooplankton plus benthos) in Site C compare to current secondary production in the reaches of the Peace River and tributaries that would be flooded?	Estimates based on 2010 and 2011 field measurements of production and GIS analyses of areas (link 3b)
4 and 5	What are the expected changes in the biomass and production of different species groups and the structure of the food web following construction and operation of the Site C Dam? How do the answers to the above question change under a range of assumptions about the sensitivity of fish species to dam construction and operation, as well as assumptions about the factors affecting primary production scenarios?	Application of the Ecopath model based on field data, literature, CE-QUAL-W2 simulations (Section 3), habitat changes (Section 4), empirical models (Section 5) (all links considered either directly or indirectly)

NOTE:

[a] The linkages in square brackets in the second column refer to the pathways in Figure 12.2 (modified from Volume 2 Appendix P Aquatic Productivity Reports: Part 3) Future Conditions in the Peace River Table 1.1)

The following is a summary of the evaluation presented in Volume 2 Appendix P Aquatic Productivity Reports, Part 3 Future Conditions in the Peace River.

<u>Question 1 – Habitat Area</u>

Existing fluvial habitat types (i.e., riffles, pools, runs, side channels) used by fish would be lost through the inundation of the Peace River mainstem and lower tributary sections of the Site C reservoir, but new lacustrine habitat types (i.e., littoral and limnetic zones) would be created within the reservoir. Overall, the creation of the Site C reservoir would result in the loss of 28.0 km^2 of mainstem lotic area (predominantly deep run/glide habitat) and 1.63 km^2 of tributary lotic area (a mix of pool, riffles, runs, and other habitat types). The lotic areas would be replaced by 9.42 km^2 of littoral area (defined as < 6 m) and 83.57 km^2 of limnetic area. It is expected that littoral habitats within the inundated area would provide new spawning and juvenile rearing habitats, both for some riverine (but adaptable) fish species found in the Peace River, as well as for lake-adapted species that would become more common in the reservoir. The increased limnetic zone is expected to provide extensive deeper water habitat for use by foraging juveniles and adults of different fish species. The total area would increase by 3.3-fold as the river is converted to a reservoir, which should be recognized in the interpretation of before-after comparisons of total biomass (i.e., no change in total biomass is consistent with a one-third reduction in biomass per unit area).

Question 2 – Primary Production

Phytoplankton and periphyton biomasses were predicted for the Site C reservoir and Peace River under two time snapshots (i.e., early and longer-term stages of the reservoir operation). Phytoplankton and periphyton biomasses in both aquatic systems were predicted to be similar during the early and longer-term stages of operations, since nutrient contributions from shoreline erosion occurring in the reservoir do not differ substantially between the two stages.

In the reservoir, projected changes reflect a shift in primary production from periphyton to phytoplankton as the river becomes a reservoir. Phytoplankton biomass densities ($t \cdot km^{-2}$ or $g \cdot m^{-2}$) 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) would 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 would 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).

Question 3 – Secondary Production

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 would 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 would 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.

Questions 4 and 5 – Fish Production and Harvest

Ecopath models were developed for the area upstream of Site C, under current conditions and two periods following completion of the Project (early term and longer term). Input assumptions to Ecopath blended five factors: information on fish and lower trophic level organisms; influence of species-specific habitat preferences and life history strategies; CE-QUAL-W2 estimates of changes in phytoplankton and periphyton; the results of single species passage models; and empirical models of expected changes in benthic biomass. Ecopath was used to determine if the input assumptions were ecologically feasible, given the diet preferences and productivities of each ecosystem component, and adjustments in biomass or diet were made where necessary to ensure mass balance, taking into account prey preferences. Sensitivity analyses were completed across a range of assumptions for both the reservoir fish community assemblage (maximum, most likely, minimum) and levels of primary production (low bookend, most likely, high bookend). The analysis used the extreme bookends of the 27 scenarios run in CE-QUAL-W2 to bracket the full range of productivity. The key findings (summarized for each group of ecosystem components, based on the most likely CE QUAL-W2 scenario) are as follows:

Results for the most likely fish community scenario indicate about a 3-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.

The following changes are expected to other ecosystem components in the Site C reservoir relative to current conditions in the Peace River: a 100-fold increase in phytoplankton biomass, a 40% decrease in periphyton biomass, a 2.3-fold increase in benthic biomass, and a 4 to 10-fold increase in the biomass of small fish, suckers, and northern pikeminnow (taken as a group, though, northern pikeminnow is expected to decrease).

The above outcomes are insensitive to the low and high bookend CE-QUAL-W2 scenarios, as there is little variation in phytoplankton production

Conclusion

Based on the outcome of the aquatic productivity evaluation and examination of other factors that include availability of habitats needed to support reservoir fish populations, and recruitment from sources outside of the reservoir, the following is a prediction of the fish community as it would change through time as the reservoir transitions following operation of the facility:

<u>Short Term (1 to 10 Years)</u>

Over the short term, the Site C reservoir fish community would reflect a fish community undergoing rapid transition. Existing fish populations that are specifically adapted to river habitats would be affected. These include Arctic grayling and mountain whitefish, the sculpin species, and possibly bull trout. Bull trout are included in this list because the current adfluvial species is closely tied to mountain whitefish abundance, which is a primary food source, and at least a portion of the bull trout population would migrate downstream past the Site C Dam. These three riverine species abundance would be reduced in the lower section of the reservoir, but would still likely be found in the upper reservoir and tributaries where riverine characteristics would remain. Tributary resident populations would persist in the Halfway River.

Species that are able to rapidly exploit new habitats, that are tolerant of perturbations to the aquatic environment (e.g., elevated suspended sediment concentrations and sedimentation of clean bed materials), and that presently utilize tributary habitats would quickly dominate the system. These would include the sucker species largescale sucker, longnose sucker, and white sucker, and the minnow species lake chub, northern pikeminnow, redside shiner, and spottail shiner. If northern pikeminnow is able to fully exploit the new the environment, then this species may become the top pelagic predator.

In the existing Peace River, burbot are rarely encountered upstream of the dam and generating station construction zone, but it is the dominant predator in the Peace River in the lower portion of the LAA and farther downstream in Alberta. Formation of the Site C reservoir would provide habitat for burbot that recruit from the Halfway River and the Moberly River and that would be able to exploit newly formed reservoir habitat and abundant food resources originating from the tributaries. Depending on the reproductive capacity of the reservoir burbot population, it may become the top benthic predator in the reservoir.

Five species that recruit from upstream sources would enter the newly formed reservoir, including kokanee, lake whitefish, lake trout, rainbow trout, and peamouth. Rainbow trout and peamouth would be able to utilize tributary habitats for spawning and rearing and they have flexible food requirements; therefore, these populations should successfully colonize over the short term. This would be particularly true for peamouth, which has flexible food requirements being able to exploit both pelagic (zooplankton) and benthic food sources.

The abundance of kokanee and lake trout (a primary predator of kokanee) over the short term would depend on the ability of kokanee to exploit pelagic food resources (zooplankton) in the reservoir, annual recruitment from upstream sources, and entrainment rates through the Site C Dam. Zooplankton biomass production would depend on water quality (i.e., suspended sediment concentrations), primary productivity, zooplankton residence time, competition from other species, and entrainment rates through the Site C Dam. There would be limited or no kokanee spawning habitats in the reservoir and limited accessible spawning habitats in tributaries (i.e., kokanee spawning habitats are available in the Halfway River system starting at least 100 km upstream of the Site C reservoir).

<u>Medium Term (10 to 30 Years)</u>

Over the medium term, water quality should improve due to reduction of sediment inputs from valley wall erosion. Fish populations that were not able to utilize Site C reservoir habitats or that were not maintained by upstream recruitment sources would have been affected over the short term. Species belonging to the sucker and minnows group would still dominate the system. Species that have a lower reproductive capacity, but that can effectively exploit reservoir habitats may increase in importance during the medium term.

Lake whitefish would recruit from upstream sources. This species is able to exploit benthic and pelagic food resources; therefore, it would compete directly with kokanee. If there is sufficient recruitment from upstream sources, lake whitefish could become established and eventually exploit spawning habitats in the Site C reservoir and in tributaries such as the Moberly River and Halfway River. If the fish community in Williston Reservoir, which was dominated by lake whitefish (Volume 2 Appendix O Fish and Fish Habitat Technical Data Report) is assumed to be representative of the Site C reservoir fish community over the medium term, lake whitefish would be a dominant pelagic species. Lake whitefish would be a food source for bull trout and lake trout.

Northern pike is a piscivorous species that would be present in the Site C reservoir at the time of inundation. Northern pike currently recruit from several Peace River tributaries and from side channel areas of the Peace River. The abundance of northern pike in the reservoir would be largely dependent on recruitment from important spawning and early rearing habitats in the form of shallow water areas dominated by submergent or emergent aquatic vegetation. Shallow water areas are limited in surface area in the Site C reservoir. However, stable water elevations and an abundance of sand bed materials originating from valley wall erosion could promote development of aquatic vegetation in these areas, as has occurred in Dinosaur Reservoir. Northern pike would become an important top predator in these areas of the Site C reservoir over the medium term; however, its overall importance to the reservoir fish community would depend on availability of habitats.

It is uncertain whether walleye would reside in the reservoir. Walleye regularly occur in the Site C reservoir section of the Peace River. Walleye would be upstream of the dam and generating station construction zone at the time of scheduled closure of the Peace River in Year 4 of construction. The resulting construction headpond would allow walleye to remain upstream until creation of the Site C reservoir. If sufficient numbers of walleye are present at the time of reservoir formation, a population could become established. Walleye is a species that can exploit reservoir habitats, and there would be abundant food resources. In addition, historical spawning and rearing habitats traditionally utilized by the Peace River walleye population (i.e., Halfway River system) would be available.

Over the medium term, kokanee could become the dominant pelagic species in the reservoir. This would be based largely on the ability to out-compete lake whitefish for pelagic food resources, recruitment levels from upstream sources, and levels of secondary productivity (zooplankton biomass). If kokanee dominate, then lake trout and possible bull trout abundance in the reservoir would increase over the medium term.

<u>Long-term (> 30 Years)</u>

At the end of 30 years, fish species populations able to adapt to a reservoir environment and out-compete other species would be well established and reservoir conditions would have stabilized. This species assemblage would form the basis of the long-term fish community. Sucker populations would be the dominant group that exploits benthic production. Lake whitefish or kokanee would be the dominant group that exploits pelagic production. The top predators in the reservoir would include northern pikeminnow, burbot, and northern pike. Depending on kokanee biomass, lake trout or bull trout would be top predators if there was sufficient recruitment to sustain the population. Rainbow trout would also be present, but it would not become a dominant species in the Site C reservoir. It is uncertain whether a self-sustaining population of walleye will become established in the reservoir.

12.4.2.2 Downstream Habitat Changes

In contrast to the changes from creation of the reservoir, the downstream changes are incremental. Peace River surface water regime immediately downstream of the Site C Dam would be similar to conditions currently experienced immediately downstream of the Peace Canyon Dam (i.e., a regulated flow regime). Farther downstream, the effects of Site C Dam operations would be dampened by tributary inputs and flow attenuation.

Operations of the dam and generating station would interact with fish habitat downstream of the Site C Dam based on the following parameters:

Surface water regime

Sediment transport regime

Thermal and ice regime

Aquatic productivity

<u>Surface Water Regime</u>

As described in Volume 2 Appendix D Surface Water Regime Technical Memos, changes in the surface water regime result from the following factors:

A change in the location of flow regulation

A change in the generating capacity (or range of generating capacity) at the point of flow regulation

The capture of tributary inflows between Peace Canyon dam and the Site C Dam

In general, Site C discharges would follow the same general pattern as the provincial demand for electricity; higher during the winter and lower during the summer on a seasonal basis, higher during weekdays and lower during weekends on a weekly basis, and higher during daylight hours and lower during late night hours on a daily basis (Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

In general, the limited amount of active storage (storage within the normal operating range) limits the degree to which the Project could change the downstream flow regime. The following discusses factors that would affect fish habitats and fish utilization of fish habitats downstream of Site C based on the surface water regime.

The timing of releases from Site C would be expected to follow the daily load pattern and would be similar to the timing of releases from Peace Canyon Dam today. Due to the travel time required for water to flow between the Peace Canyon outlet and the location of the proposed Site C tailrace, operational changes at points downstream of Site C would occur approximately 10 to 12 hours sooner with Site C. For example, if releases were increased from Peace Canyon at 6:00 a.m., the flow increase would be noticeable at the location of the proposed Site C Dam between 4:00 p.m. and 6:00 p.m. Under the existing conditions at the Site C Dam site, discharge is highest during hours of darkness (6:00 p.m. to 6:00 a.m.) and lowest during hours of daylight (6:00 a.m. to 6:00 p.m.). The reverse would occur with Site C operation.

The operational releases of the Peace Canyon Dam are bounded by the minimum flow requirement of 283 m^3/s and the maximum licensed discharge of 1,982 m^3/s. The proposed minimum flow for the Project is 390 m^3/s and the proposed maximum turbine discharge capacity is about 2,520 m^3/s. The range of operational releases is 1,699 m^3/s under existing conditions and would be approximately 2,130 m^3/s with the Project. Although the range of operational releases immediately downstream of the Site C Dam would be higher with the Project, the actual range of flows immediately downstream would be lower with the Project, due to tributary inputs between Peace Canyon Dam and the Site C Dam site. There would be no change in the range of flows experienced downstream of the Pine River confluence.

Under existing conditions, the greatest daily range in flows is experienced immediately downstream of the point of regulation (i.e., at the Peace Canyon Dam outlet). This daily range is reduced in the downstream direction due to natural attenuation and tributary inflows. Site C would shift the existing point of regulation by a distance of 85 km downstream and hence increase the daily range of flows at that location and for some distance downstream. As shown in Section 11.4.5.2 in Volume 2 Section 11 Environmental Background, the increase in the daily range of water levels due to the Project would be on the order of 0.5 m at the location of the Site C tailrace and reducing to approximately 0.3 m near the Alces River confluence.

The influence of the Project on the average rate of change of water levels from one hour to the next was analyzed as described in Volume 2 Appendix D Surface Water Regime Technical Memos, Part 2 Downstream Flow Modelling (1D). Duration curves are provided in that appendix that indicate the percentage of time a particular rate of change of water level (whether increasing or decreasing) would be experienced with and without the Project, based on 10 years of simulated flows. At the Site C tailrace, results suggest that water level decreases of 0.25 m/hour or more would only occur 9% of the time with the Project, compared to never without the Project. At Taylor, the modelling suggests that water level decreases of 0.25 m/hour or more would occur only 3% of the time with the Project, compared to never without the Project.

In addition, the two-dimensional model described in Volume 2 Appendix D Surface Water Regime Technical Memos, Part 3 Downstream Flow Modelling (2D) was used to investigate the influence of the Project on the wetting and drying of side channels downstream. A worst-case scenario was simulated both with and without the Project where flows were increased from minimum to maximum over a short period of time. The rates of change in flows are presented in Table 12.14.

Table 12.14 Flow Comparisons at Site C Dam Tailrace During High Operations Period

Location	Rate of Change (m^3/15 min)	
	Increasing Flow	Decreasing Flow
Peace Canyon Dam tailrace	26.7	-51.7
Existing Site C Dam location	7.4	-3.2
Site C Dam tailrace	46.7	-54.0
Percentage difference from Peace Canyon Dam tailrace	75.0	4.5

The Site C Dam tailrace would have a predicted maximum rate of change for increasing flows of 46.7 m^3/15 min and a predicted maximum rate of change for decreasing flows of -54.0 m^3/15 min. These values are higher than maximum rates of change under existing conditions at the Site C Dam site (7.4 m^3/15 min for increasing and -3.2 m^3/15 min for decreasing). The predicted maximum rates of change for the Site C Dam tailrace would be higher than predicted maximum rates of change that presently occur at the Peace Canyon Dam tailrace (i.e., 75% higher for increasing and 4.5% higher for decreasing) based on this worst-case scenario.

Changes to the flow regime would affect the temporal and spatial availability of Peace River fish habitats. The effects would be highest in the 15.9 km section of Peace River between the Site C Dam and the Pine River confluence because there are no large tributary inputs that would attenuate the flows. During periods of low tributary flows (i.e., late summer, fall and winter) the changes would extend farther downstream. Under present conditions, habitat availability in the vicinity of the Site C Dam is greatest during hours of darkness when fish species require feeding habitats. Availability of habitats located in shallow water areas (i.e., main channel margins and side channels) would be most affected by flow changes. A portion of these habitats would not be available during hours of darkness, depending on Site C operations.

The change in range of daily flow caused by Site C operation would potentially alter habitat availability. Habitat availability was examined by comparing the wetted surface area at minimum and maximum operational flows under existing Peace Canyon Dam and predicted Site C operations (BC Hydro 2012). Wetted surface area for the Peace River from the Site C Dam site to the Pine River confluence was calculated using hydrodynamic modelling assuming steady state flow and 10 percentile tributary discharges for each scenario (Table 12.15).

Table 12.15 Comparison of Peace River Wetted Surface Areas from the Site C Dam to the Pine River Confluence Under Existing Peace Canyon Dam and Site C Dam Operations.

Scenario	Synthetic Discharge (m^3/s)	Wetted Surface Area (ha)	Difference	
			Hectares	Percent
Minimum Peace Canyon Dam	294	547.5	+29.7	5.4
Minimum Site C Dam	390	577.2		
Maximum Peace Canyon Dam	1,993	837.0	+115.0	13.7
Maximum Site C Dam	2,540	952.0		

With 10 percentile tributary inputs, the increase in the minimum flow from 294 m^3/s (existing) to 390 m^3/s (Site C operation) would improve habitat availability during low flow conditions. The increase in wetted surface area would be 29.7 ha or a 5.4% increase compared to existing conditions. There would also be an increase in wetted surface area at the upper range of flow: 1,993 m^3/s (existing) versus 2,540 m^3/s (Site C operation). The increase in wetted surface area would be 115.0 ha or a 13.7% increase compared to existing conditions. However, this potential positive effect could be effected by daily flow regulation (i.e., additional habitat surface would be subjected to dewatering).

The rate at which habitats become dewatered due to daily flow regulation would diminish downstream of the Site C Dam site during operations. Habitat types most affected by dewatering would be shallow-water rearing habitats used by large-fish species and shallow-water habitats used by small-fish species.

Sediment Transport Regime

The following changes to suspended sediments are expected downstream of the Site C Dam with respect to baseline conditions (Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report):

Suspended sediment concentrations are expected to decrease in the closest reach between the Site C Dam and the Pine River confluence during the spring freshet period

Timing of elevated freshet concentrations is expected to become longer due to reservoir attenuation (i.e., the concentrations in the outflows are not as 'spiky' as in the baseline)

Suspended sediment composition downstream of the Site C Dam would shift from dominant silt to dominant clay, with no sand in suspension

Suspended sediment concentrations consisting mostly of clay are expected to increase in the reservoir outflows in the fall/winter period due to increased shoreline sediment inputs into the reservoir

Lateral variability in turbidity that is present under current conditions would be replaced by full mixing in the reach from the dam to the Pine River confluence

Changes due to reservoir operations are expected to decrease with time as the shoreline sediment recruitment decreases and new equilibrium is reached between reservoir water levels and shorelines. Changes would become less apparent as a result of inputs from each tributary confluence downstream, where more water and sediment is contributed to the Peace River. The mean annual sediment transport load from the Project would be reduced by 54% due to the settling in the reservoir. Reductions would decrease to 21% at the Pine River confluence, 8% at the Alces River confluence, and 2% at the Smoky River confluence.

Expected median daily suspended sediment concentration immediately downstream of the Site C Dam site (baseline and operations phase) is shown in Table 12.16.

Table 12.16 Expected Median Daily Suspended Sediment Concentration Immediately Downstream of the Site C Dam Site (Baseline and Operations Phase)

Season	Baseline (mg/l)	Operations (mg/l)
Winter (January–March)	0.1	0.6
Spring (April–June)	39.6	14.3
Summer (July–September)	3.2	11.6
Autumn (October–December)	0.1	6.9

The following changes to bedload sediments would occur for the Peace River downstream of the Site C Dam with respect to the baseline conditions:

The Project would intercept the Moberly River bedload material that has been accumulating in the Peace River channel below the confluence since the onset of regulation in 1967

Elsewhere, the Project is not expected to result in any changes in channel erosion or deposition patterns, which are either natural (i.e., valley wall erosion and landslides along the river), or are driven by the ongoing response of the river channel to upstream flow regulation that started in 1967 (i.e., aggradation below tributary confluences, local bank erosion opposite from tributary confluences, and vegetative encroachment onto gravel bars and into secondary channels)

The sediment transport regime predicted for the operation of the Project would cause higher suspended sediment concentrations during the fall and winter periods and lower concentrations during the spring and freshet than presently occurs. Higher suspended sediment concentrations would consist of mainly clay and a small amount of silts, which are not expected to settle out prior to the Pine River confluence. Increased sediments would potentially affect clear water fish species including Arctic grayling, bull trout, mountain whitefish, and rainbow trout occupying the river downstream of the dam.

Thermal and Ice Regime

The thermal and ice regime of the Peace River would change due to the Project (Section 11.7 Thermal and Ice Regime in Volume 2 Section 11 Environmental Background). The following changes are expected to occur with respect to the baseline conditions:

Water temperatures in the Peace River at the outlet of the Site C Dam are expected to be warmer than existing conditions between July and January, with differences ranging between 0.3°C (July) and 1.5°C (October)

Water temperatures in the Peace River just downstream of the Site C Dam are expected to be between 0.4°C and 0.9°C cooler from March to June

In all months, a smaller daily range than the existing temperature regime is expected

Water temperatures 62 km downstream of the Site C Dam (i.e., the Alces River confluence) are expected to range from 0.9°C cooler in May to 0.7°C warmer in November

Operation of the Project would alter the Peace River water temperature regime at least to the Alces River, but the changes are within the annual range of water temperatures of fish habitats under existing conditions.

The ice regime of the Peace River would change due to the Project. The following changes would occur with respect to the baseline conditions:

The maximum extent of the ice front would move farther downstream compared to existing conditions

The change may improve existing wintering fish habitats. Wintering habitats used by large fish in the Peace River can be characterized by deep water, low velocity areas that provide protection from solid ice (surface ice and ice anchored to the channel bed) and frazil ice (Hildebrand 1990; Pattenden 1993; Power et al. 1993; Brown et al. 1994). Smaller fish, such as minnows and sculpins, also seek protection within interstitial spaces provided by rock substrates in areas that are not subjected to freezing or damage from ice (Cunjak and Power 1986). In general, wintering fish are closely associated with river edges and protected areas that provide refugia from high flows, as has been demonstrated by Whalen and Parrish (1999). Based on the characteristics described above, wintering habitats presently available to large and small fish are affected by the ice front that forms as far upstream as Taylor under existing conditions.

Operation of the Project would move the ice front downstream on average approximately 40 km, potentially resulting in an increase in fish wintering habitat and overwintering survival rate.

Aquatic productivity

A quantitative ecosystem approach used to analyze changes to aquatic productivity (Volume 2 Appendix P Aquatic Productivity Reports, Part 3 Future Conditions in the Peace River) concluded that the total biomass of fish would be expected to increase by 1.2-fold to 1.4-fold downstream of the Site C Dam. Details are as follows:

Total biomass of fish in the three focal groups of fish is expected to result in a net increase of 1.2-fold to 1.4-fold. This net increase in total biomass is accounted for by a 45% to 80% decrease in the biomass of group 1 fish (burbot, lake trout, rainbow trout, walleye, northern pike), counteracted by a 1.8-fold to 1.9-fold increase in the biomass of group 2 fish (Arctic grayling, mountain whitefish, bull trout). The increase in group 2 fish is due primarily to a doubling of mountain whitefish, which are assumed to benefit from increased water clarity (decrease in sediment inputs) downstream of the Site C Dam. Bull trout and Arctic grayling are expected to decline. Group 3 fish (kokanee and lake whitefish) contribute a negligible amount of biomass to the river.

The following changes are expected to other ecosystem components downstream of the Site C Dam relative to current conditions in the Peace River: a 3.7-fold increase in periphyton; a 3-fold decrease in benthic biomass, and a 50% decrease in the biomass of small fish, suckers, and northern pikeminnow (taken as a group), driven by a 50% decrease in suckers. Despite the reduction in benthic biomass, there was enough benthos to support all the fish species in the downstream model.

The above outcomes were sensitive to the low bookend CE-QUAL-W2 scenario, where a halving of periphyton biomass (relative to current conditions) is assumed to propagate up the food chain, resulting in a 40 to 50% decrease in total fish biomass relative to current conditions, driven by decreases in both fish groups 1 and 2

Conclusion

Based on the outcome of the aquatic productivity evaluation and examination of other factors that include changes in fish habitats needed to support downstream fish populations, and recruitment sources, the following is a prediction of the fish community downstream of the facility.

Species that presently reside in the Peace River downstream of the Site C Dam site would initially be present in the Peace River during operations. The relative abundance and biomass of a species within the downstream Peace River fish community would change. The fish community would reflect the ecological changes in fish habitat downstream of the dam. Ecological conditions considered for predicting the future fish community include the following:

Physical environment (i.e., flow regime, sediment regime, water temperature, and ice regime)

Aquatic productivity and food resources

Availability of habitats needed to support the fish population

Recruitment from sources (i.e., upstream, downstream)

Competition for food and space

The Peace River downstream of the Site C Dam would be characterized by a regulated flow regime similar to what presently occurs downstream of the Peace Canyon Dam. The fish community that utilizes those habitats of the Peace River downstream of the Site C Dam would be similar to what presently occurs downstream of the Peace Canyon Dam.

Recruitment sources of the Peace River fish community downstream of the Peace Canyon Dam include upstream reservoirs, tributaries, and the Peace River. The primary tributary recruitment source for Arctic grayling is the Moberly River, and for bull trout the primary tributary recruitment source is the Halfway River. Recruitment sources of the Peace River fish community downstream of Site C would include upstream reservoirs (Site C reservoir), tributaries, and the Peace River. The Pine River would be the only potential natural downstream tributary recruitment source for Arctic grayling, bull trout, and mountain whitefish (see Section 12.3).

Operations of the Project would result in ecological conditions that would allow Arctic grayling, bull trout, mountain whitefish, and rainbow trout populations to persist and potentially extend their distribution further downstream in Alberta. Other species such as kokanee and lake trout would establish distributions immediately downstream of the Site C Dam, similar to the pattern that presently exists downstream of the Peace Canyon Dam. Most of these populations would be maintained by recruitment from the Site C reservoir. There would be the potential for these populations to access spawning and rearing habitats in the Pine River system in order to generate natural recruitment; however, this outcome cannot be predicted with certainty. Some limited natural recruitment of mountain whitefish would occur directly from the Peace River.

Burbot, northern pike, walleye, and goldeye populations would remain downstream of the Pine River due to the regulated flow regime, cooler summer water temperatures, and the reduced sediment load during freshet. Burbot, northern pike, and walleye may not reside in the Peace River between the Site C Dam and the Pine River confluence, but still might forage upstream of the Pine when conditions are favorable. Goldeye would migrate as far upstream as the Beatton River. Similarly, the regulated flow regime caused by operations of the Project might limit sucker and minnow populations to at least downstream of the Pine River and as far downstream as the Beatton River.

The extent of the change on all fish populations downstream of the Pine River would be based primarily on the degree to which Pine River and other tributary inputs (i.e., Beatton River, Kiskatinaw River, Clear River, and Pouce Coupe River) would attenuate the flow and thermal and ice regime as a result of the operations of the Project.

12.4.3 Effects Assessment – Construction – Fish Health and Survival

Fish health and survival would potentially be changed by construction activities as follows:

Sediments inputs during in-stream activities, surface runoff from disturbed areas including transportation routes and surplus excavated material storage sites, and bank erosion caused by backwatering of river during channelization, diversion, and reservoir filling

Stranding of fish due to water level fluctuations

Fish entrainment through the diversion tunnels and spillways

Increased total dissolved gases concentrations during spillway commissioning

Each of these potential effects are described in more detail below.

12.4.3.1 Changes in Fish Health and Survival Due to Sediment Inputs

Sediment inputs may result in potential effects on fish health and survival during construction of the dam and generating station, formation of the construction headpond and reservoir filling, and from realignment of Highway 29.

Dam and Generating Station Construction Zone

Several activities associated with the dam and generating station construction zone have the potential to introduce sediments into the aquatic environment. Major sources include the following:

Surface runoff from disturbed locations

Transport of excavated materials across and adjacent to watercourses to storage areas (includes dust and slurry)

Drainage from excavated materials storage areas

In-stream works including:

- Excavation of the riverbed
- Placement of materials in the watercourse
- Pile driving cofferdam sheets and bridge piers
- Activation of the diversion tunnels
- Removal of in-stream materials (e.g., Stage 1 cofferdams)

Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report estimates sediment load resulting from construction activities at the dam and generating station construction zone. The list of construction activities, the type and amount of materials, and the timing are presented in Table 5.1 of that appendix. With mitigation, the simulated total suspended sediment (TSS) increases could be reduced to below 25 mg/l above background concentrations for the majority of dam construction activities listed in Table 5.1. Sediment input from construction activities examined that cannot be mitigated include flushing the diversion tunnels, tailrace, and discharge channels.

Table 12.17 summarizes background TSS concentrations of the Peace River (Table 5.2 of Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report). The 5%, 50% and 95% exceedance values for daily concentrations in each quarter are provided in the table below.

Table 12.17 Background Total Suspended Solids Concentrations in the Peace River

Quarter	Baseline Suspended Sediment Concentration (mg/L)		
	5%	50%	95%
1	0.0	0.1	1.6
2	1.1	40	383
3	0.3	3.2	210
4	1.0	0.1	1.4

The suspended sediment concentrations of the Peace River show a strong seasonal pattern. Highest concentrations occur in spring (40 mg/L at 50% exceedance during Quarter 2), whereas much lower concentrations occur in summer, fall and winter (≤ 3.2 mg/L at 50% exceedance).

Elevated suspended sediment concentrations are known to be harmful to fish (Newcombe 1994; Anderson et al. 1995). These effects include decreased health and reduced viability of eggs and larvae, irritation of gills, and smothering of food production areas, making habitats unsuitable for fish.

The potential for these concentrations to impair fish health and survival can be quantified using an empirical model developed by Newcombe and Jensen (1996). The model, which incorporates sediment concentration and duration of exposure, provides ratings of ill effects for fish life stages (e.g., adults or larvae). The calculated severity of ill effects (SEV) index is based on a 15-point scale that is used to categorize fish response as follows:

Nil effect (0)

Behavioural effect (1 to 3)

Sublethal effect (4 to 8)

Lethal effect (9 to 14)

The application of the model is limited to coldwater salmonids, such as Arctic grayling, bull trout, mountain whitefish, and rainbow trout. It is not directly applicable to coolwater species because they are more tolerant of sediment effects.

Using predicted TSS concentrations at 50% exceedance flows, severity of ill effects ratings indicate that adult and juvenile salmonid fish would be subjected to lethal concentrations of sediments for 11 of the 18 activities for which TSS concentrations were predicted (Table 12.18). The remaining seven activities would cause sublethal TSS concentrations for adult and juvenile salmonid fish. Severity of ill effects ratings indicate that salmonid fish eggs and fry would be subjected to lethal concentrations of sediments for 16 of the 18 activities for which TSS concentrations were predicted (Table 12.18). The remaining two activities would cause sublethal TSS concentrations.

Table 12.18 Severity of Ill Effects Based on Predicted Suspended Sediments a Caused by Construction Activities of the Dam and Generation Station

Activity	Predicted TSS (mg/L) at 50% Flow Exceedance	Duration (days)	Severity of Ill Effects Rating by Fish Life Stage	
			Eggs and Larvae	Juveniles and Adults
North Bank Haul Road	26.1	90	**13.2**[b]	**10.5**
Inlet Diversion Cofferdam	28.8	30	**12.3**	**10.0**
Outlet Diversion Cofferdam	28.8	90	**13.5**	**10.7**
L6 Disposal Dyke	20.6	90	**13.1**	**10.4**
L6 Disposal Dyke	19.5	90	**13.1**	**10.4**
North Bank Cofferdam	26.1	60	**12.7**	**10.2**
Excavate diversion inlet channel	0.5	30	**10.8**	8.6
Excavation berms	20.6	30	**11.9**	**9.6**
Place riprap in excavated channel	0.8	30	**10.9**	8.7
Excavate diversion outlet channel	0.5	60	**11.5**	**9.1**
Excavation berms	26.1	60	**12.7**	**10.2**
Place riprap in excavated channel	0.8	60	**11.7**	**9.2**
Remove diversion inlet cofferdam	0.1	30	**10.2**	8.1
Remove diversion outlet cofferdam	0.1	30	**10.2**	8.1
Flush diversion tunnel	420.0	0	5.6	5.8
In-stream excavation of tailrace	0.5	30	**11.4**	**9.1**
Place riprap in excavated areas	0.6	30	**11.4**	**9.1**
Flush tailrace and discharge channel	35.0	0	4.9	5.1

NOTE:

[a] Source: Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report

[b] Bold indicates values that represent lethal effects on fish life stage

It is assumed that the effect of elevated TSS concentrations caused by activities in the dam and generating station construction zone would extend to the Pine River confluence, or a distance of 15.9 km. This assumption is based on no major tributary inputs in the river section between the construction area and the Pine River that would dilute TSS concentrations. Based on the Site C Dam site construction schedule, the TSS effects would occur continuously or near continuously in Year 1 and continuously for four years from Years 4 to 7.

Adults and juveniles of salmonid populations that are present between the Site C Dam site and the Pine River confluence are Arctic grayling, bull trout, mountain whitefish, and rainbow trout. Mountain whitefish eggs and fry are also abundant and widely distributed in this river section.

Construction Headpond and Reservoir Filling

A construction headpond would form upstream of the dam and generation station construction zone during the channelization (approximately 36 months) and diversion (approximately 39 months) periods (subsequently referred to as construction headpond). Confinement of the channel would result in an increase in upstream water levels relative to current conditions due to the reduced ability to pass Peace River flows (Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

During the channelization period, water levels would be up to 1 m higher than existing conditions. The maximum upstream extent of the construction headpond during channelization would be approximately 10 km (Figure 11.4.13 in Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

During the diversion period, water levels would be up to 8.6 m higher (in the 90^{th} percentile water levels) than existing conditions. The upstream extent of the construction headpond during the diversion period would be 27 km (Figure 11.4.13 in Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

The construction headpond water levels would vary (see Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background), which could result in bank instability and bank erosion, potentially resulting in sediment inputs. Shoreline erosion is expected to occur in an episodic manner, primarily during windstorm events when the headpond level is high (Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report). It is expected that shoreline erosion events of one-day duration would generate incremental increases in suspended sediment concentration on the order of 1 to 20 mg/L, as observed in fully mixed river flow downstream of the tunnel outlets. These events would be most common in the autumn and winter (averaging 12 and 15 daily events per season, per year), and least common in the spring and summer (averaging seven daily events per season, per year), due to seasonal differences in wind conditions and wave energy in the headpond.

Reservoir filling would occur at the end of the construction phase and would require approximately three months to complete. Water levels would be increased in a staged fashion to allow commissioning of the facility. Reservoir filling would increase water levels, resulting in bank instability and bank erosion, potentially resulting in sediment inputs.

Highway 29 Realignment and Hudson’s Hope Shoreline Protection

Highway 29 realignment includes construction of new bridge crossings on four fish-bearing watercourses: Cache Creek, Halfway River, Farrell Creek, and Lynx Creek. Farrell Creek, Halfway River, Cache Creek, and Lynx Creek support primarily sucker and minnow species; however, sport fish species can be present. Life stages most affected would be adults, eggs, and fry during the spring period. During the summer, fall, and winter period, adults would be most affected.

The majority of construction activities would occur away from the current watercourses. The bridges would be clear span structures, with only the Halfway River bridge having piers in the current active river channel. In-stream activities such as pier placement and abutment work could generate sediment inputs. Depending on the crossing, bridge construction would require from two to two-and-a-half years to complete each highway section (see Table 4.15 in Volume 1 Section 4 Project Description).

The Hudson's Hope shoreline protection base case design consists of a 10 m high, 295,000 m³ shore protection berm 1,650 m long immediately below the residential areas of Hudson's Hope. The berm would be constructed of granular fill and protected with riprap. A majority of the construction works would be conducted adjacent to the Peace River, including river bank and in-stream works that could generate sediment inputs.

The Peace River in the vicinity of the construction activities provides several types of high-quality fish habitats. These include high-quality rearing habitats for bull trout and rainbow trout, and high-quality feeding habitats for bull trout, mountain whitefish, and rainbow trout. Lake trout also use this area for rearing and feeding.

12.4.3.2 Stranding of Fish

Flow changes during the construction of the Project may result in increased risk of stranding for fish species residing in the Peace River. A description of flow changes expected during construction (channelization and diversion) stage of the Project is provided in Section 11.4.3 Surface Water Conditions during Construction in Volume 2 Section 11 Environmental Background.

A construction headpond would form upstream of the dam and generation station construction zone during the channelization and diversion periods (subsequently referred to as construction headpond). Confinement of the channel would result in an increase in upstream water levels relative to current conditions, due to the reduced ability to pass Peace River flows (see Section 12.3.3.1 for description). The large surface area outside of the active river channel potentially subjected to frequent dewatering (approximately 387 ha during the channelization period and approximately 1,630 ha during the diversion period) and the large range in fluctuation (1.0 m during the channelization period and 8.6 m during the diversion period) could cause an increased risk of fish stranding.

Downstream of the dam and generating station construction zone, downstream flows (levels, and rates of stage change) would be unaffected during the channelization stage with the exception of small (average 20 cm) increase in water level at the downstream portion of the river constriction. During the diversion phase, the headpond would dampen changes to the rate of changes in flow, resulting in smaller, less abrupt changes in Peace River flows downstream of the constriction. Hydraulic changes would be negligible at Taylor and further downstream. There would be no increase in the risk of fish stranding downstream of the dam and generating station construction area.

12.4.3.3 Fish Entrainment

Entrainment occurs when a fish is drawn into a water intake and cannot escape (Fisheries and Oceans Canada 2007). For hydroelectric developments, entrainment commonly refers to any downstream movement of fish through the facility. Entrainment can also refer to the movement of fish into an intake for a water pump (Fisheries and Oceans Canada 1995).

Fish may be entrained during construction Stage 2, River Diversion: a) fish may be entrained in the diversion tunnel inlet and downstream through the diversion tunnels;

b) during reservoir filling (see Volume 1 Appendix B Reservoir Filling Plan), which occurs during the latter part of the river diversion stage, fish may be entrained through a modified diversion tunnel or the spillways.

Approach to Evaluate Fish Entrainment

The approach to evaluate the potential for entrainment is described in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment. In general, the approach:

Adhered to **principles** used previously in regulatory discussions concerning entrainment at existing facilities (the BCH-DFO-MOE Fish-Hydro Management Committee's Working Principles for the BC Hydro Entrainment Strategy) (Fish-Hydro Management Committee 2011)

Followed established **methods** used to assess entrainment at existing BC Hydro facilities (e.g., the Entrainment Risk Screening and Evaluation Methodology; BC Hydro 2006)

Followed guidance from **regulatory guiding documents** relevant to managing entrainment and fish passage management [e.g., Practitioner's Guide to Fish Passage for DFO Habitat Management Staff (Fisheries and Oceans Canada, 2007)] and Practitioners Guide to the Risk Management Framework for DFO Habitat Management Staff (Fisheries and Oceans Canada No date)

Given this overall approach, the technical assessment broadly mirrored that used to assess and manage entrainment at existing BC Hydro facilities (e.g., Revelstoke, Mica, Hugh Keenleyside) and the approach used in the environmental assessment of other BC Hydro facilities (e.g., John Hart and Aberfeldie redevelopments).

Two main components are used to evaluate entrainment:

a) Entrainment rate: Entrainment rate is used to estimate the consequences to the upstream fish populations (i.e., those fish populations that inhabit the Peace River between Peace Canyon Dam and the Site C Dam site, including tributaries)

b) Survival rate of entrained fish: Survival of entrained fish is estimated for each entrainment route, and is used to determine the fate of entrained fish

Entrainment Rates

The movement strategies of fish during the diversion period are predicted to be similar to baseline conditions (baseline conditions are described in Section 12.3.2.3 above). Species that make extended movements and seasonal migration (e.g., Arctic grayling, bull trout) are expected to continue these movement patterns, and therefore that portion of the population that moves downstream past the Site C Dam are assumed to be entrained. For species with local movement patterns (e.g., small-fish species), only that portion of the population that resides close to the diversion location is expected to be entrained.

Survival Rate of Entrained Fish

The survival of fish entrained through the diversion tunnels is estimated to be high (described in Volume 2 Appendix Q Fish Passage Management Plan, Attachment C-4 Fish Mortality During River Diversion). Given the tunnel design and hydraulic conditions, there is a low risk of fish contacting tunnel walls or the outlet structure and low risk of shear-related injury in tunnel exit velocities. Fish that are entrained are expected to have high survival and can reside in the Peace River downstream of the diversion tunnel.

The survival of fish entrained over the spillway and spillway undersluices is estimated to be high. The spillway configuration is similar to that of the Columbia River system dams, with radial gates controlling submerged discharges to similarly sloped spillway ramps equipped with deflectors that produce near surface flow in the stilling basins. Investigations of fish survival rates at Columbia River system dams have been conducted using advanced monitoring techniques that provide reliable measures of fish survival in the range of 98 to 100%. The survival of fish entrained in the Project spillway undersluices is a configuration similar to Removable Spillway Weir systems that have been installed at several dams in the Columbia River system dams. Fish survival measured at Removable Spillway Weir systems is in the range of 98% to 99%. Site C has higher head than the Columbia River facilities where these studies occurred. Therefore, survival is likely lower at Site C than the Columbia River facilities.

The survival of entrained fish during river diversion will vary, given the specific sequence of activities and associated entrainment routes (e.g., diversion tunnels, modified diversion tunnel, spillway, spillway undersluices) during reservoir filling (See Volume 1 Appendix B Reservoir Filling Plan). These entrainment routes and associated fish survival are:

Fish survival through the single, non-modified diversion tunnel is estimated to be high as described above

Fish survival through the modified diversion tunnel is estimated to be low, given the hydraulic impacts of the energy dissipating devices(s) that will be installed in the modified tunnel. The modified diversion tunnel is expected to be operated for one to two weeks, depending on reservoir inflow.

Fish survival through the spillway undersluices and spillway during reservoir filling is estimated to be high, as described above

12.4.3.4 Total Dissolved Gas

This section examines the potential for dissolved gas supersaturation to impair fish health and survival associated with the construction of the Project. A general background narrative on total dissolved gases (TDG) and effects on fish health and survival is provided first. Expected TDG generation during the construction phase of the Project is then reviewed.

Background

Total dissolved gas is “air” dissolved in water. The TDG pressure (all gases plus water vapour) is commonly measured and regulated as a percentage of saturation expressed as a percentage of the amount of air that water will hold when it is in equilibrium (100%) with the atmosphere at ambient water surface conditions. Beneath the water’s surface, the pressure steadily increases with increasing depth due to the hydrostatic pressure (weight of water) above the depth of interest. This increased pressure increases the amount of atmospheric gases that the water will hold when in equilibrium (saturated) at the specific depth. Thus, greater increases in depth result in greater increases in hydrostatic pressure and greater amounts of air in solution at equilibrium. For example, water 2 m deep will hold at equilibrium 120% of the air the same water will hold at surface pressure. Increasing gas solubility with increasing pressure (depth) is the factor that causes TDG supersaturation to occur. When air bubbles are entrained or mixed in water and the air-water mixture is carried to some substantial depth, the gases pass into solution to a substantially greater amount than the water can hold in equilibrium when it returns to the surface pressure. This produces TDG supersaturated water (relative to the surface pressure). As long as the supersaturated water remains under the increased pressure, there is no potential for the amount of dissolved gas to decrease. For this reason, once supersaturated, the level of TDG supersaturation tends to remain in water bodies unless there is considerable turbulence and exposure of the water to surface pressure. For this reason, TDG supersaturation tends to persist and slowly decrease downstream in reservoirs and rivers.

The effects of TDG supersaturation to fish and invertebrates depend on a variety of factors, including the level of supersaturation, the depths occupied by the fish, and duration of exposure to supersaturation (for a review, see Weitkamp 2008). Gas bubble disease (GBD) occurs in fish and invertebrates exposed to substantial levels of TDG supersaturation under near surface pressures. GBD is the formation of bubbles in the blood and other tissues of fish. GBD can range from mild with a few visible bubbles, to severe with numerous bubbles, hemorrhaging, and exophthalmia (bulging eye). Acute GBD occurs to fish restrained in shallow water with a high level of supersaturation (approximately 140% or greater). With acute GBD, numerous small bubbles may form in the blood, resulting in blocked circulation to vital organs and the death of the fish. However, fish that remain under substantial pressures (depths) do not develop GBD even though they are exposed to TDG supersaturation. The same total pressure that causes supersaturation also provides pressure compensation, preventing fish and invertebrates from developing internal bubbles when they are in supersaturated water.

In British Columbia, generalized guidelines have been established based largely on the results from laboratory investigations of the effects of TDG on fish and aquatic life. The guideline limits TDG supersaturation to 110 %, as a conservative means to avoid any occurrence of GBD in natural waters (http://www.env.gov.bc.ca/wat/wq/BCguidelines /tgp/tgp_over.htm). The available literature indicates that the frequency of occurrence and the severity of GBD in natural river conditions are much less than predicted by laboratory investigations, particularly where sufficient habitat depths are available to compensate for pressure (Weitkamp 2008). The literature indicates that TDG supersaturation results in little or no gas bubble disease (GBD) at levels up to 120% of saturation when compensating depths (2 m or more) are available. This occurs for a variety of reasons:

Depths occupied by fish greatly decrease the actual exposure of individual fish because actual TDG saturation is relative to ambient pressure

GBD has been commonly recorded under conditions where fish are restrained or more easily captured in shallow water

GBD is rapidly reduced or eliminated by increasing hydraulic pressure as a fish moves deeper

Signs of GBD do not necessarily indicate decreased survival of individuals or populations

Commonly, fish show only minor signs that likely do not influence behaviour or survival

TDG does not bioaccumulate, as recovery from exposure to supersaturation can be rapid with no apparent chouronic effects, or residual effects compounding subsequent exposure

Effects of TDG are site specific, depending on fish population distribution and habitat use, and physical habitat conditions in the receiving environment, and the period of exposure to TDG (Fidler 2003; Weitkamp 2008).

Peace River supports a diverse community of large- and small-body fish that seasonally utilize different mainstem habitats and tributary habitats (see Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). The basic characteristics of the Peace River (e.g., channel morphology, flow depth, and flow velocity) and the distributions of its fish populations restrict exposure to TDG supersaturation to a portion of each population.

Given known utilization of tributary and confluence habitats, together with the expected depth distributions of the fish present in the main channel habitat, many fish are exposed to little or no TDG supersaturation. For example, fall spawning occurs predominantly in tributary habitats, placing reproductive life stages outside the area potentially affected by TDG supersaturation. However, individuals of each population may tend to occupy shallow water of the mainstem and side channels along Peace River (< 2 m). Where TDG concentrations exceed 120%, this may expose those fish to elevated levels of TDG supersaturation during the reservoir filling period that are sufficient to cause GBD.

<u>TDG Generation during Construction</u>

River Confinement

River confinement activities do not actively control river flow or transfer flow through discharge facilities that could create physical conditions required to cause gas supersaturation. As a result, there is no potential to increase TDG in the river during the confinement phase of dam construction, and no residual effects on fish or fish habitat are expected during that period.

River Diversion

During the diversion stage of construction, two tunnels will be used to control flow and divert river flows around the dam and generating station construction zone. The duration of the diversion phase of the project is approximately 36 months. During this period, the diversion tunnels would not create hydraulic conditions for entrainment of air required to increase total dissolved gas concentration over the ambient condition. As a result, diversion tunnel operation would not cause GBD in fish or other aquatic life.

Reservoir Filling

Following the diversion phase, reservoir filling would be undertaken in three stages over approximately three months. The three stages of reservoir filling and the predicted effect of magnitude and duration of elevated total dissolved gas generation are described below:

Stage 1 – Stage 1 filling is planned to begin in the first or second week of September. At that time, river flows will be reduced to a minimum discharge (> 390 m^3/s) to begin reservoir filling for a period of one to two weeks to allow the reservoir level to rise to elevation 440 m. During this period, all flows will be released from a single modified diversion tunnel and TDG concentrations are predicted to be 120% ± 5% saturation.

Stage 2 – During Stage 2, rising reservoir levels would pass elevation 440 m and allow downstream releases to be accomplished through spillway undersluices. Once flows are confirmed through the undersluices, the diversion tunnel discharge will be terminated. Filling rate is dependent on reservoir inflows and would take between one and two weeks to attain a reservoir level of elevation 452 m. The reservoir would be held at elevation 452 m for about four weeks to allow the commissioning of turbines and generators to begin. This hold period will be between late September and early October. During this period, TDG concentrations released from the undersluice structures are predicted to range between 113% ± 4% and 118% ± 4% saturation.

Stage 3 – The final stage of filling the reservoir would occur between mid-October and late November, depending on inflow conditions. Downstream flows would be controlled by the spillway to ensure minimum flows are sustained and managed to allow reservoir level to safely rise from elevation 452 m to 461.8 m. TDG generated from spillway releases are expected to range between 113 ± 4% and 119% ± 4% saturation for a period of up to four weeks.

There is no quantitative method to estimate the uncertainty of these evaluations. The evaluations are qualitative, based on investigations at numerous constructed dams over many years. There is also a bias in the observations of GBD in fish exposed to TDG supersaturation in rivers and reservoirs, where the fish sampled include only those residing in shallow water, and therefore those most likely to develop GBD signs. The predictions of TDG produced by the Site C spillway are based on the best modelling techniques available and prior monitoring efforts from existing upstream dams on the Peace River. Although the accuracy of predictions cannot be quantitatively evaluated, any bias in modelling estimates would affect equally and in the same manner the estimate of each spillway alternative modelled.

12.4.4 Effects Assessment – Operation – Change in Fish Health and Survival

Fish health and survival would be potentially be changed by operation activities as follows:

Stranding of fish in the reservoir and downstream, due to water level fluctuations

Entrainment of fish over the spillway and through the turbines

Spillway operation may increase total dissolved gas pressure

12.4.4.1 Stranding of Fish

The factors associated with fish stranding risk are poorly understood but are attributed to local site and flow regime characteristics, fish species and size, time of year, and specific time of day when flow changes occur. No detailed studies of the risk of fish stranding or observations of fish stranding are available to quantify the level of fish stranding that occurs under the baseline condition in the Peace River system.

The relative change in the risk of fish stranding resulting from the Project would depend on how the Project would change the daily range of flows/water levels and the rate of stage change under operating conditions. Baseline conditions for flow and water level in the Peace River are described in Section 11.4.2.4 Baseline Flows and Water Levels in Volume 2 Section 11 Environmental Background, and also in BC Hydro (2012). Current operations of Peace Canyon Dam produce daily flow and level variations that have potential to strand fish. Over any given day, water levels may both rise and fall to follow demand for electrical power. In general, observed water levels at Hudson's Hope rise ~45% of the time and fall ~45% of the time, leaving 10% of the time when no change (<0.1 cm change) occurs. Risk of stranding occurs only when water levels decrease. Under the baseline condition, the range and rate of water level reductions is greatest immediately below Peace Canyon Dam and generally diminishes moving downstream as a result of flow attenuation and tributary inflows. For example, for the period 2008 to 2010, below Peace Canyon Dam, the average daily water level range at Water Survey of Canada stations was 0.54 m at Hudson's Hope and 0.26 m at Taylor. Rates of stage change follow this same general pattern, where the rate of water level reduction is largest immediately below Peace Canyon Dam at Hudson's Hope and diminishes moving downstream. Based on the 2008–2010 period, the rate of water level reduction from one hour to the next exceeded 5 cm/hour 12.2 % of the time at Hudson's Hope and 7.0 % of the time at Taylor (BC Hydro 2012).

Changes to fish stranding risk would result from the creation of the reservoir and the alteration of the downstream flow regime. A description of the baseline flow regime and the changes expected during the operation of reservoir and dam and generating station are provided in Section 11.4.5 Surface Water Conditions during Operations in Volume 2 Section 11 Environmental Background. The simulated operation of the Project shows that the Site C reservoir would be operated within the top 0.6 m of the normal operating range, between elevations 461.8 and 461.2 m, at least 83% of the time (see Volume 2 Appendix D Surface Water Regime Technical Data Reports, Part 1 Operations Study). The daily range of Site C reservoir levels was predicted to be 0.6 m or less 60% of the time, and 1.0 m or less 75% of the time. These ranges are similar to the observed conditions at Hudson's Hope from 2008 to 2010. As the changes to the reservoir water level would be more gradual, the risk of stranding would be reduced in the reservoir relative to that existing in the river under the baseline condition.

Downstream of the dam, however, the daily range of water levels and rate of water level change from one hour to the next would increase (see Table 11.4.9). This change would be the greatest in the proximal reach immediately below the Project. For example, the predicted daily range of water levels has been predicted to increase from 0.5 m to 1.0 m at the tailrace of Site C, and from 0.4 m to 0.8 m at Taylor. Changes to the rates of stage change follow this pattern [see Volume 2 Appendix D Surface Water Regime Technical Memos, Part 2 Downstream Flow Modelling (1D)]. The risk of stranding downstream of the Site C Dam would therefore increase as a result of the Project. This increase in fish stranding risk would be most prominent in the section of the Peace River between Site C Dam and the Pine River.

12.4.4.2 Fish Entrainment

Fish may be entrained through the generating station and spillways during the operations phase. Fish entrainment will occur primarily through the generating station since spilling is estimated to be infrequent (Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

Entrainment Rates

The entrainment rates for all species in the LAA were calculated using a heuristic model of entrainment risk (described in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment). The model was based on the Entrainment Risk Screening and Evaluation Methodology (BC Hydro 2006); the model expanded on this methodology to provide quantitative estimates of entrainment rates, measured as the proportion of the population entrained per year. The model is based on species-specific information on fish distribution, habitat preference, movement rates, response to velocity fields, and swimming capability, as well as the configuration and operation of the Project, and information on entrainment rates from other hydroelectric facilities.

Annual entrainment rates during the operations phase may differ from baseline conditions, given changes in fish habitat. As described in this section, formation of the Site C reservoir will fundamentally change fish habitats between Site C and the Peace Canyon Dam. These changes in physical conditions and fish habitat may change fish movement patterns and entrainment risks.

Annual entrainment rates estimated by the heuristic model are low ($\leq$ 10% of the population) for all species except for bull trout, kokanee, lake whitefish. and lake trout. Entrainment rates for most species are low due to several factors, which vary by species and include the following:

Only a portion of the population is present in the Site C reservoir, and a portion remains in tributaries to the Site C reservoir

Fish have restricted movement rates and habitat preferences that result in only a portion of fish in the reservoir approaching the dam and generating station

Fish respond to velocity fields and have swimming capabilities to avoid being passively entrained

Bull trout had relatively higher entrainment rates based on their potential future directed movements downstream past Site C by a portion of the population. The population-level consequences to bull trout of these entrainment rates, as well as the subsequent return of entrained bull trout upstream via trap and haul mitigation are examined in more detail in a population model (see Volume 2 Appendix Q Fish Passage Management Plan, Part 3 Technical Report: Using Single Species Population Models of Bull Trout, Kokanee and Arctic Grayling to Evaluate Site C Passage Alternatives), and summarized in the section on upstream passage below. Kokanee, lake whitefish, and lake trout had higher annual entrainment rates, based primarily on their preference and adaptations for offshore pelagic habitat. The population-level consequences to kokanee that may colonize the reservoir are examined in more detail in a population model (see Volume 2 Appendix Q Fish Passage Management Plan, Part 3 Technical Report: Using Single Species Population Models of Bull Trout, Kokanee and Arctic Grayling to Evaluate Site C Passage Alternatives).

Entrainment Survival

Fish entrained through the generating station and turbines during operations will have 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 Q Fish Passage Management Plan, Attachment C-3 Turbine Passage Survival Estimates). Fish survival rate was estimated using a predictive equation developed under the U.S. Department of Energy's Advanced Hydro Turbine System Program (Franke et al. 1997). This equation is based on a comprehensive analysis of fish survival rates from other hydroelectric projects. Fish survival rate is calculated using turbine characteristics, flow, head, mechanical efficiency, and fish length to estimate the probability that a fish of a given size will come near to or in contact with a structural element as it passes through the turbine. The large, slow-rotating Francis turbines proposed for the Project are relatively safe for fish passage, as compared to other typical Francis turbines, especially for smaller fish. The size of the turbine is dictated by the large flow capacity requirements, but is advantageous for fish passage because it creates large volumes for the fish to pass between the buckets of the runner, reducing the likelihood that they will come in contact with them. The rotational speed is relatively low as compared to many turbine-generator installations.

Survival of fish entrained over the spillway during operations is estimated to be high as described above.

12.4.4.3 Total Dissolved Gas Supersaturation

This section examines the potential effects of dissolved gas supersaturation on fish health and survival associated with the operations phase of the Project. A general background narrative on total dissolved gases (TDG) and biological effects of fish and fish habitat is provided as background in Section 12.4.3.4 and in Weitkamp (2012). This section reviews expected TDG generation during the operations phase of the Project, reviews efforts undertaken to mitigate TDG effects, and assesses whether residual effects on the health and survival of fish result from TDG generation.

<u>Total Dissolved Gas Generation During Operations</u>

The operation of the dam spillway and generating station may elevate TDG downstream of the dam through 1) powerhouse operations under low turbine flow conditions, and 2) spillway operation. Normal turbine operations do not raise TDG above 110%. During occasional low flow conditions, a turbine may be operated in a manner that introduces dissolved gas. Low flow turbine operation can raise TDG supersaturation by introducing air under pressure during synchouronous condense operation (no load turbine operation) and during periods of rough load entrainment through atmospheric control (valve/injection). In this situation, turbine discharge volume will be low; however, TDG concentration in the outflow from the single turbine may exceed 120% saturation. Depending on duration of the low flow turbine operation, specific operation of adjacent turbines, and local tailwater mixing processes, this may create spatial zones immediately downstream of the dam with elevated TDG concentration.

Engineering assessments have been conducted to evaluate the TDG generation from the use of the spillway and design options to mitigate it (see Section 12.4.3.4). The concentration of TDG generated by operation of the spillway is a function of total magnitude of discharge release. Spillway operation is expected to produce TDG supersaturation levels in the portion of the discharge passing over the spillway. For spillway discharges of <900 m^3/s, no elevation of TDG levels is expected above typical range of observed ambient conditions (i.e., up to 110%) (Millar and Wilby 1997). For discharges approximately 900 m^3/s and 1350 m^3/s, the predicted TDG levels elevated to

113% ± 4% and 118% ± 4%, respectively (Gulliver 2012). For spillway discharges of approximately 1800 m^3/s, TDG levels may exceed the 120% saturation level required to cause GBD in fish and other aquatic life (122% ± 4%) (Gulliver 2012).

An analysis of expected frequency of spill events for the Project is presented in Section 11.4.4.2 in Volume Section 11 Environmental Background. Two methods were used to predict the frequency, magnitude, and duration of spill events to bracket uncertainty in spill operations. To provide a conservative assessment of effects on health and survival of fish through TDG exposure, this assessment considers the Historical Analysis scenario, which predicts more frequent and larger spills and a consequently higher TDG concentration. Based on the Historical Analysis scenario, on average, a spill is expected once every three years. When spills occur, they can last from several days to as long as several weeks. The average magnitude of spillway discharge is predicted to be 416 m^3/s, which, based on engineering assessments, would not produce elevated TDG, or consequent GBD symptoms in fish or aquatic life. However, the predicted maximum daily average spillway discharge under that scenario is estimated at 1,950 m^3/s; this has potential to produce spillway discharge with TDG concentrations in excess of general thresholds for GBD (120% saturation when fish remain near the water surface or > 2 m compensating depths are available) (Weitkamp 2008).

Factors that would reduce the potential for effects of TDG generation on the health and survival of fish in the river downstream of the dam are:

Mixing of spillway discharge with turbine discharge

Tributary dilution effects

Physical characteristics of the downstream environment

Observed biological characteristics of resident fish populations living in the Peace River

TDG supersaturation created by spillway discharges will be reduced by mixing with turbine outflows from the generating station. During normal operational spills, up to six available turbines in the powerhouse would be operated at full discharge capacity, allowing approximately 2,500 m^3/s of water from the reservoir to be mixed with TDG-laden spillway discharges. If spills at the Project occur during periods of spill from upstream facilities, the TDG concentration in turbine discharge would likely range between 110% and 120% saturation (Millar and Wilby 1997). If spills at the Project occur when upstream facilities are not spilling, then the TDG concentration in turbine flows would be between 100% and 110% saturation, allowing dilution of TDG concentration. Tributary discharges to the Peace River downstream from the Project will also reduce the TDG supersaturation levels in the river. Since tributary water will be near 100% of saturation, localized areas at tributary confluences and immediately downstream will have reduced TDG concentration (Millar and Wilby 1997). Therefore, average spillway discharges will not create levels known to be harmful for health and survival of aquatic life. However, when maximum spill volume does occur, depending on the duration of peak spillway discharges, there is potential to create GBD in fish and aquatic life.

Two additional factors that reduce the exposure of fish to elevated TDG conditions are the physical environment downstream of the dam and the biological characteristics of fish populations. The basic characteristics of the Peace River (e.g., channel morphology, flow depth, and flow velocity) and the distributions of its fish populations restrict exposure to TDG supersaturation to a portion of each population. Given availability of tributary and confluence habitats, together with the velocity preferences and depth distributions of most of the fish present in the main channel habitat, fish may be exposed to little or no TDG supersaturation during spill events. Spawning occurs predominately in tributary habitats, placing reproductive life stages outside the area potentially affected by TDG supersaturation. Thus, only those individuals of each population tending to occupy shallow water (< 2 m) are exposed to any level of TDG supersaturation during most of the spill events.

Effects of TDG are site specific, depending on fish population distribution and habitat use, and physical habitat conditions in the receiving environment, and the period of exposure to TDG (Fidler 2003; Weitkamp 2008). The basic characteristics of the Peace River (e.g., channel morphology, flow depth, and flow velocity) and the distributions of its fish populations restrict exposure to TDG supersaturation to a portion of each population. Peace River supports a diverse community of large- and small-body fish that seasonally utilize different mainstem habitats and tributary habitats (see Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). Given known utilization of tributary and confluence habitats, together with the expected depth distributions of the fish present in the main channel habitat, many fish are exposed to little or no TDG supersaturation. However, individuals of each population may tend to occupy shallow water of the mainstem and side channels along Peace River (< 2 m). Where TDG concentrations exceed 120%, this may expose those fish to elevated levels of TDG supersaturation during use of the spillway during the operations phase of the Project.

There is no quantitative method to estimate the uncertainty of these evaluations. The evaluations are qualitative, based on investigations at numerous constructed dams over many years. The predictions of TDG produced by the Site C spillway are based on the best modelling techniques available and prior monitoring efforts from existing upstream dams on the Peace River. Although the accuracy of predictions cannot be quantitatively evaluated, any bias in modelling estimates would affect equally and in the same manner the estimate of each alternative mitigation modelled.

12.4.5 Effects Assessment – Construction – Change in Fish Movement

Upstream fish movement may be affected during:

1. Construction Stage 1, river channelization, due to changes in water depths and velocities in the section of the Peace River that is channelized

    Construction Stage 2, river diversion, where the diversion dam and tunnels will create a complete blockage to upstream passage

The overall approach to evaluate upstream fish movement is described in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment. The approach was coordinated with the assessment of entrainment, which is described above.

River channelization confines the Peace River to a single channel, which increases average water velocities (i.e., averaged across the channel) for a given discharge (Section 11. 4 Surface Water Regime in Volume 2 Section 11 Environmental Background). This change has the potential to affect upstream fish movement. Potential effects on upstream movement during river channelization were evaluated using: i) minimum water depth and maximum velocity criteria for upstream fish movement, and

ii) a two-dimensional hydraulic model that predicts water depths and velocities under baseline conditions and during river channelization (Section 11. 4 Surface Water Regime in Volume 2 Section 11 Environmental Background). The analysis was based on minimum fish size of 150 mm fork length. The analysis used a minimum water depth of 25 cm for upstream movement, based on guidelines (Fisheries and Oceans Canada 1993; British Columbia Ministry of Transportation and Highways 2000; Washington Department of Fish and Wildlife 2003) and the criteria used in other fish passage assessments (NHC and Focus Environmental Inc. 2006). The analysis used a maximum water velocity of 0.4 m/s based on the prolonged (30 minute) swim speed for 150 mm fork length fish (described in Volume 2 Appendix Q Fish Passage Management Plan, Attachment C-5 Fish Swimming Speeds). The channel area that meets these depth and velocity criteria was estimated under baseline conditions and during river channelization, over a range of river discharges. The channel area that meets these criteria is reduced during channelization because i) the total channel area is reduced, since the Peace River is confined to a single channel, and ii) average water velocities increase. However, during channelization, there is sufficient channel area that meets the depth and velocity criteria for fish to continue to move upstream. Therefore, no effect on upstream passage is anticipated.

The upstream movement patterns during the river diversion period are predicted to be similar to baseline conditions (baseline conditions are described in Section 12.3.2.3 above), since much of the LAA remains as river habitat. Blocked upstream movement would potentially affect those species with an extended (upstream) movement strategy and a core or extended distribution that extends upstream and downstream of the Site C Dam location, as described in Tables 12.7, 12.8 and 12.9. Species that make extended movements and seasonal migration (e.g., Arctic grayling, bull trout) are expected to continue these movement patterns. Thus, a portion of the population is expected to attempt to move upstream of the diversion dam to return to spawning habitats upstream. Species with local movement patterns (e.g., small-fish species) would not be affected by blocked upstream passage because they can complete their life history in habitats downstream of the diversion dam.

12.4.6 Effects Assessment – Operations – Change in Fish Movement

Upstream fish movement will be affected during operations because the dam and generating station will create a complete blockage to upstream fish movement.

The assessment evaluated potential effects on fish movement during construction and operation separately, because habitat conditions and expected movement strategies are predicted to differ between these project phases. As described in this chapter, formation of the Site C Reservoir will fundamentally change fish habitats between the Site C and the Peace Canyon dams. There will also be changes to physical conditions and fish habitat in the Peace River downstream of the Project, in particular that section of the Peace River between the Site C Dam and the Pine River confluence. These habitat changes may change fish movement patterns as fish adapt their life history and movement patterns to these physical conditions. Thus, changes to fish movement consider both the potential habitat effects and blocked upstream movement from the dam.

The approach to evaluate upstream fish movement is described in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment. Given the linkages between entrainment and upstream movement, the approach was coordinated with the assessment of entrainment, which is described above.

The future movement patterns of fish downstream of the Site C Dam during operations are predicted to change from baseline movement patterns (described in Section 12.4.4.2), given changes in physical conditions and fish habitat, described above. Species with local movement patterns would not be affected by blocked upstream passage because they can complete their life history in habitats downstream of the Site C Dam. Species with extended movement strategies may attempt to move upstream past the dam. In the cold/clear water sport fish group, adult Arctic grayling, bull trout, and mountain whitefish that originated from upstream of the Site C Dam may be motivated to move upstream past the Site C Dam in an attempt to return to spawning tributaries (i.e., Moberly River for Arctic grayling and mountain whitefish; Halfway River for bull trout and mountain whitefish). In the cool/turbid water group, walleye, burbot, northern pike, and the three sucker species may be motivated to move upstream of Site C. However, the future distribution of the cool/turbid group in the Peace River is expected to be restricted primarily to downstream of the Pine River confluence (described in Section 12.4.2.2 above), thereby reducing their motivation to move upstream as far as or past the Site C Dam.

More detailed population modelling was completed to predict the potential effects of entrainment and upstream movement on those species predicted to continue to attempt upstream movements past the Site C Dam (summarized in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment). Single-species population models examined the potential effects fish entrainment and blocked upstream passage for those species predicted to continue to attempt upstream movements past the Site C Dam: bull trout that spawn in the Halfway River and inhabit the Peace River, and Arctic grayling that spawn in the Moberly River downstream of Moberly Lake and inhabit the Peace River. The combined effects of entrainment and blocked upstream movement have a potential effect on the abundance of bull trout, but would not affect population-level conservation objectives. Habitat change from reservoir formation may restrict Arctic grayling movements (see Volume 2 Appendix Q Fish Passage Management Plan, Part 3 Technical Report: Using Single Species Population Models of Bull Trout, Kokanee and Arctic Grayling to Evaluate Site C Passage Alternatives).

12.5 Mitigation Measures

This section provides a description and the expected effectiveness of measures to mitigate potential effects identified in Section 12.4 above. A summary of potential effects and mitigation measures is provided in Table 12.19 below.

12.5.1 Change in Fish Habitat

12.5.1.1 Construction

Loss of Habitat Due to Construction of the Dam and Generating Station, Highway 29, and Hudson's Hope Shoreline Protection

Potential effects on habitat due to construction of the dam and generating station, Highway 29, and Hudson's Hope shoreline protection will be addressed through a combination of avoidance and mitigation measures, including:

Implement the Fisheries and Aquatic Habitat Management Plan (Volume 5 Section 35 Summary of Environmental Management Plans)

A 15 m riparian buffer will remain adjacent to watercourses during reservoir clearing

Material relocation sites resulting from dam site excavation (R5a, R5b, and R6) will be relocated 15 m back from the high water level to avoid affecting Peace River fish habitat

Material relocation sites resulting from dam site excavation upstream of the dam will incorporate fish habitat into the final capping design. The relocation areas will be contoured and capped with gravels and cobble substrate between elevations 455 m and 461 m to provide productive fish habitat that will be available to fish during the operation phase.

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

Fish habitats affected by Highway 29 watercourse crossings will be compensated in the vicinity of the habitat loss. Fish habitat features will be incorporated into the final designs of the watercourse crossings. Disturbed riparian areas will be replanted with local vegetation. The Highway 29 roadway that would border the reservoir, east of Lynx Creek, will also have fish habitat features incorporated into the final design of the footprint.

The Hudson's Hope shoreline protection will be constructed of large material that will provide replacement fish habitat. Additional fish habitat features (e.g., shear zones and point bars) will be incorporated into the final design of the Hudson's Hope shoreline protection.

Temporary structures will be removed as soon as they are no longer required

Construction activity footprints are minimized, where possible, to reduce the area of fish habitat. Further efforts will be made during the finalization of design.

Loss of Habitat Due to Construction Headpond and Reservoir Filling

Due to the potential extent of changes to fish habitat caused by the construction headpond and reservoir filling, there are no technically feasible mitigation options for the loss of the riverine habitat due to reservoir creation.

Habitat mitigation measures are proposed where a construction activity presents an opportunity to provide potential fish habitat, including:

BC hydro FOR GENERATIONS

Highway 29 borrow sites will be located between the Peace River and the future reservoir shoreline. Borrow sites that are located in the littoral zone of the reservoir will be contoured prior to decommissioning to provide gravel/cobble littoral fish habitat.

Material repositioning areas will be capped with gravels and cobbles, and contouring will be undertaken to enhance fish habitat conditions

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

12.5.1.2 Operations

Transformation of Reservoir Habitat during Reservoir Operation

The transformation of the reservoir during reservoir operations has the potential to affect fish and fish habitat. The Site C reservoir operation has been designed to have a minimal reservoir fluctuation during operation of 1.8 m, which reduces the effects to the shoreline (littoral) fish habitat. As a result of the nature and uncertainty of future habitat changes in the reservoir during the operation, it is not technically feasible to propose effective mitigation options. Future mitigation and compensation options will be evaluated after reservoir development and follow-up monitoring. Compensation options that are technically and economically feasible will be implemented.

Downstream Habitat Changes

Operation of the Project will result in limited changes to the pattern of flow released and the changes to fish habitat downstream of the Project. Potential effects will be limited to the section of the river between the dam and the Pine River confluence. To mitigate for these potential effects the proposed measures would include:

The enhancement of side channel complexes (e.g., Old Fort) in the reach between the dam site and the confluence of the Peace and Pine rivers to increase wetted habitat during low flows

Creation of wetted channels and back channel restoration on the south bank island downstream of the dam to create off channel and back channel habitat

12.5.2 Fish Health and Survival

12.5.2.1 Construction

Sediment Inputs by Dam and Generating Station Zone

The introduction of sediment to fish habitat as a result of construction activity associated with the dam and generating station has the potential to impair fish health and survival. The following mitigation measures are proposed:

Erosion prevention and sediment control plan (in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of standard preventive measures such as silt fences or other erosion prevention materials.

Dust control plan (Air Quality Management Plan Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of dust suppression techniques to prevent airborne deposition into water bodies.

Surface water quality management plan (Section 35.2.21 Surface Water Quality Management Plan in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include control, management, and treatment of surface runoff.

Adjust the timing construction activities to coincide with periods of high background sediment levels, where feasible

Select clean rock materials or wash rock materials for riprap construction to minimize the amount sediments that are introduced into the aquatic environment

Reduce equipment production rates to reduce the amount of sediments generated by equipment where required

Sediment Inputs by Construction Headpond and Reservoir Filling

The introduction of sediment to fish habitat as a result of the presence of the construction headpond and due to the filling of the reservoir has the potential to effect fish health and survival. The following measures are proposed to mitigate adverse effects:

Berm or cap areas with high potential to produce sediments

During reservoir clearing, stumps in the headpond area will be left in place to reduce soil disturbance and potential sedimentation issues where feasible

Soil disturbance during reservoir clearing will be minimized by clearing in winter where feasible

Sediment Inputs by Highway 29 Realignment and Hudson's Hope Shoreline Protection

The introduction of sediment to fish habitat as a result of the realignment of Highway 29 and the Hudson's Hope shoreline protection has the potential to effect fish health and survival. The following measures are proposed to mitigate adverse effects:

Erosion prevention and sediment control plan (in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of standard preventive measures such as silt fences or other erosion prevention materials.

Dust control plan (Section 35.2.2.7 Dust Control Program in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of dust suppression techniques to prevent airborne deposition into water bodies.

Surface water quality management plan (Section 35.2.21 Surface Water Quality Management Plan in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include control, management, and treatment of surface runoff.

Select clean rock materials or wash rock materials for riprap construction to minimize the amount of sediments that are introduced into the aquatic environment

In-stream construction will be conducted in isolated work areas when feasible

Stranding of Fish

A program of fish salvage and fish relocation is recommended to mitigate for the potential effects of stranding due to water fluctuation on the health and survival of fish during construction. The program will involve:

Surveillance of fish habitat areas where periodic exposure of channel margins occurs as a result of headpond fluctuation

As feasible, salvage and relocation of fish trapped in potholes, side channels, or other habitat area at risk of dewatering as a result of headpond fluctuation

Fish Entrainment

Mitigation options for fish entrainment during construction are summarized in Volume 2 Appendix Q Fish Passage Management Plan, Attachment C-4 Fish Mortality During River Diversion, and require consideration for the river diversion and reservoir filling stages of Project construction.

During river diversion, the design of the large diameter diversion tunnels and associated hydraulics provide a low risk of fish injury or mortality. Additional specific design features to be integrated, where possible, into the construction and operations of the tunnels will reduce the risk of injury or mortality, by:

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) in the tunnel tailrace area

The final approach to implementation of these features will be determined during detailed design and construction. The assessment of residual effects considers that these design features will be implemented since they also increase hydraulic performance of the structures, and will reduce, but not eliminate, low potential risk for fish strike and de-scaling that can cause injury or mortality.

During reservoir filling, the potential effects of injury or mortality of entrained fish during reservoir filling will be mitigated by operating the modified diversion tunnel for a short duration, as described in Volume 1 Appendix B Reservoir Filling Plan. The mitigation will be applied to the diversion tunnels (described above under river diversion), since fish will pass through the diversion tunnels at times during reservoir filling.

Approaches to mitigate the potential effects of fish entrainment on health and survival of fish during construction are considered in more detail in the Fish Passage Management Plan. A structured approach was used to assess mitigation options in terms of potential fish passage risks (effects on health and survival, and on impeded movement), technical feasibility, biological benefits, and costs (summarized in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment). The Fish Passage Management Plan summarizes the recommendation from this assessment as a coordinated series of actions and testing to manage upstream and downstream fish passage at Site C, and associated effectiveness monitoring during the construction and operation of Site C.

Increased Total Dissolved Gas

The Project has the potential to increase TDG, and effect health and survival of fish during construction. BC Hydro has undertaken two general approaches to the mitigation of the potential effects of TDG generation on fish and fish habitat during construction. These measures include:

Modifying spillway design to reduce the magnitude of TDG generated

Developing an operational plan to reduce magnitude, duration, and geographic extent of TDG generation during reservoir filling

To reduce the magnitude of TDG generated during the use of the spillway, BC Hydro undertook an engineering assessment of alternative spillway designs. Four mitigation options were identified: jet deflectors, deflector basin, high ported weir, and low ported weir. The mitigation options would be applicable for mitigating gas generation for any water releases through spill control gates and through undersluices during construction or operational phases of the Project. The assessment used computational modelling to evaluate hydraulics characteristics of the spillway structures and the behaviour of entrained air (bubbles) in spillway flows. The results were applied to estimate flow- dependent TDG generation characteristics for each design option (Gulliver 2012). Preferred options for mitigation of TDG were referred to further evaluations using a physical model to support computational model analyses. Based on the results of modelling and physical model analyses, a jet deflector spillway design was chosen for implementation. Implementation of a jet deflector design was predicted to reduce TDG supersaturation levels from the 139% to 146% range for the original base design to 115%, 118%, and 122% of atmospheric saturation at spillway discharges of approximately 900 m^3/s, 1,350 m^3/s, and 1,800 m^3/s; respectively (Gulliver 2012).

To further minimize the potential for TDG generation during reservoir filling, an iterative process was undertaken to develop and refine an operation procedure to minimize the magnitude and duration of exposure of fish and aquatic life to elevated gases. Seven alternative reservoir filling plans were evaluated to select a preferred operational approach for reduce the frequency and duration of TDG during reservoir filling. In addition to TDG mitigation through spillway design, the plan included consideration for:

Avoidance of local basin freshet to allow controlled filling to minimize spillway discharges during filling

Maintenance of ice control flows during freeze-up at the Town of Peace River (1,450 m^3/s ± 1,000 m^3/s, depending on inflows)

Maintenance of 900 m^3/s at the Project during the ice season (beginning November 15)

Diversion tunnel discharge control structure requirements

The number and duration of reservoir hold periods for engineering stability assessments

Duration of the filling period

12.5.2.2 Operations

Stranding of Fish

The operation of the Project will result in increased daily changes in water level and rates of water level change downstream of the Project. Potential increases to the risk of fish stranding will be limited to the section of the river between the dam and the Pine River confluence. To mitigate for these potential effects, the proposed measures would include:

Surveillance of fish habitat areas where periodic exposure of side channel and mainstem margins occurs as a result water fluctuations

The enhancement of side channel complexes (e.g., Old Fort) in the reach between the dam site and the confluence of the Peace and Pine rivers to increase wetted habitat and to reduce stranding potential during low flows

Where practical, contouring mainstem bars to minimize the potential for fish stranding

Fish Entrainment

The operation of Project has the potential to affect the health and survival of fish through entrainment. The proposed approach for mitigating the effects of entrainment include:

The large and slow-rotating Francis turbines, which produce high survival relative to other facilities

Incorporating smooth and gradual transitions at the approach channel, 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 finishing

Reducing obstructions (e.g., boulders) from the turbulent zone in the spillway and tailrace areas

Approaches to mitigate the potential effects of fish entrainment on health and survival of fish during operation are considered in more detail in the Fish Passage Management Plan. A structured approach was used to assess mitigation options in terms of potential fish passage risks (effects on health and survival, and on impeded movement), technical feasibility, biological benefits, and costs (summarized in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment). The Fish Passage Management Plan summarizes the recommendation from this assessment as a coordinated series of actions and testing to manage upstream and downstream fish passage at Site C, and associated effectiveness monitoring during the construction and operation of Site C.

Total Dissolved Gas

BC Hydro has undertaken two general approaches to avoid and mitigate the effects of TDG generation on health and survival of fish during operations: 1) incorporation of avoidance/mitigation through spillway design, and 2) development of operational procedures to reduce magnitude and duration of TDG events. The overall approach for avoidance and mitigation of TDG effects through design are described in Section 12.5.2.1 (Total Dissolved Gas). These activities resulted in selection of a jet deflector design for the spillway. This mitigation reduced the predicted gas generation from 139% to 146% for the original spillway base design to 115%, 118%, and 122% of atmospheric saturation at discharges of approximately 900 m^3/s, 1,350 m^3/s, and 1,800 m^3/s, respectively (Gulliver 2012). The production of TDG supersaturation at the Site C Dam would be further minimized through operation procedures to minimize gas production. These measures include:

Initiate spillway discharge operations through multiple gates to reduce the rate of discharge at each gate

Minimize operation of turbines in water discharge ranges that produce 'rough load' operation

12.5.3 Fish movement

12.5.3.1 Construction

Obstructed Fish Movement

The Project has the potential to obstruct movement of fish upstream past the dam during the diversion stage of dam construction. The following measures are proposed to mitigate effects resulting from change in fish movement:

Upstream fish passage during construction (river diversion stage) will be provided by a trap and haul facility

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

Approaches to mitigate the potential effects of obstructed fish movements during the construction stage of the Project are considered in more detail in the Fish Passage Management Plan. A structured approach was used to assess mitigation options in terms of potential fish passage risks (effects on health and survival, and on impeded movement), technical feasibility, biological benefits, and costs (summarized in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment). The Fish Passage Management Plan summarizes the recommendation from this assessment as a coordinated series of actions and testing to manage upstream and downstream fish passage at Site C, and associated effectiveness monitoring during the construction and operation of Site C.

12.5.3.2 Operations

Obstructed Fish Movement

The Project has the potential to obstruct movement of fish upstream past the dam during the operation stage of the Project. The following measures are proposed to mitigate effects resulting from change in fish movement:

Upstream fish passage during operations will be provided by a trap and haul facility

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

Approaches to mitigate the potential effects of obstructed fish movements during the operations of the Project are considered in more detail in the Fish Passage Management Plan. A structured approach was used to assess mitigation options in terms of potential fish passage risks (effects on health and survival, and on impeded movement), technical feasibility, biological benefits, and costs (summarized in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment). The Fish Passage Management Plan summarizes the recommendation from this assessment as a coordinated series of actions and testing to manage upstream and downstream fish passage at Site C, and associated effectiveness monitoring during the construction and operation of Site C.

Environmental Monitoring

An environmental monitoring program during construction will be developed in accordance with Volume 5 Section 35 Summary of Environmental Management Plans. Environmental monitoring during construction would be conducted to: 1) evaluate the effectiveness of standard mitigation measures for reducing sedimentation and fish stranding in the construction headpond and proximal reach of the river downstream of the dam, and 2) to validate predictions about physical changes to habitat in the reservoir area during the development and operation of the construction headpond during the diversion stage of the project. A systematic monitoring program design would be conducted over the approximate eight-year construction period. Physical and biological monitoring would be conducted to an appropriate scale to document spatial and temporal changes occurring in physical environmental conditions resulting from headpond hydrology, and in localized areas in relation to the effects of construction activities and mitigation procedures. The environmental construction monitoring program will also confirm the effectiveness of mitigation measures for management of predicted effects of sediment and fish stranding, and provide information required to adjust the mitigation program to reduce unforeseen adverse effects, as required.

A Site C Habitat Compensation Plan will be developed in accordance with the *Fisheries Act* Section 35(2) Authorization.

1 **Table 12.19 Summary of Potential Project Effects and Mitigation Measures on Fish and Fish Habitat**

Project Phase	Potential Effects	Key Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Loss of habitat due to construction of the dam and generating station, Highway 29 and Hudson's Hope shoreline protection	Implement Fish and Aquatic Habitat Management Plan (Volume 5 Section 35 Summary of Environmental Management Plans) A 15 m riparian buffer will remain adjacent to watercourses during reservoir clearing Material relocation sites (R5a, R5b, and R6) will be relocated 15 m back from the high water level to avoid affecting Peace River fish habitat. Material relocation sites upstream of the dam will incorporate fish habitat into the final capping design. The spoil area will be contoured and capped with gravels and cobble substrate between elevations 455 m and 461 m to provide productive fish habitat that will be available to fish during the operation phase. 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. Fish habitats affected by Highway 29 watercourse crossings will be compensated in the vicinity of the habitat loss. Fish habitat features will be incorporated into the final designs of the watercourse crossings. Disturbed riparian areas will be replanted with local vegetation. The Highway 29 roadway that would border the reservoir, east of Lynx Creek, will also have fish habitat features incorporated into the final design of the footprint. The Hudson’s Hope shoreline protection will be constructed of large material that will provide replacement fish habitat. Additional fish habitat features (e.g., shear zones and point bars) will be incorporated into the final design of the Hudson’s Hope berm. Construction footprints are being finalized to reduce the size of the construction footprint. Temporary structures will be removed as soon as they are no longer required.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project.	BC Hydro

Project Phase	Potential Effects	Key Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Loss of habitat due to construction headpond and reservoir filling	Highway 29 borrow sites will be located between the Peace River and the future reservoir shoreline. Borrow sites that are located in the littoral zone of the reservoir will be contoured prior to decommissioning to provide gravel/cobble littoral fish habitat. Material repositioning areas will be capped with gravels and cobbles, and contouring will be undertaken to enhance fish habitat conditions. 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.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project.	BC Hydro
Operations	Altered fish habitat due to transformation of reservoir habitat during reservoir operations	The Site C reservoir operation has been designed to have a minimal reservoir elevation fluctuation during operation of 1.8 m, which minimizes the effects to the shoreline (littoral) fish habitat. Compensation options that are technically and economically feasible will be implemented.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project.	BC Hydro
Operations	Altered fish habitat downstream of Site C Dam	The enhancement of side channel complexes (e.g., Old Fort) in the reach between the dam site and the confluence of the Peace and Pine rivers to increase wetted habitat during low flows. Creation of wetted channels and back channel restoration on the south bank island downstream of the dam to create off channel and back channel habitat.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project.	BC Hydro

Project Phase	Potential Effects	Key Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Reduced fish health and survival due to sediment inputs by dam and generating station construction zone	Erosion prevention and sediment control plan (in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of standard preventive measures such as silt fences or other erosion prevention materials Dust control plan (Air Quality Management Plan Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of dust suppression techniques to prevent airborne deposition into water bodies. Surface water quality management plan (Section 35.2.21 Surface Water Quality Management Plan in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include control, management, and treatment of surface runoff. Adjust the timing construction activities to coincide with periods of high background sediment levels where feasible. Select clean rock materials or wash rock materials for riprap construction to minimize the amount of sediments that are introduced into the aquatic environment. Reduce equipment production rates to reduce the amount of sediments generated by equipment where feasible.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project.	BC Hydro
Construction	Reduced fish health and survival due to sediment inputs from construction headpond and reservoir filling	Berm or cap areas with high potential to produce sediments. During reservoir clearing, stumps in the headpond area will be left in place to reduce soil disturbance and potential sedimentation issues where feasible. Soil disturbance during reservoir clearing will be minimized by clearing in winter where feasible.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project.	BC Hydro

Project Phase	Potential Effects	Key Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Reduced fish health and survival due to sediment inputs by Highway 29 realignment and construction of Hudson's Hope shoreline protection	Erosion prevention and sediment control plan (in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of standard preventive measures such as silt fences or other erosion prevention materials Dust control plan (Section 35.2.2.7 Dust Control Program in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of dust suppression techniques to prevent airborne deposition into water bodies. Surface water quality management plan (Section 35.2.21 Surface Water Quality Management Plan in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include control, management, and treatment of surface runoff. Select clean rock materials or wash rock materials for riprap construction to minimize the amount of sediments that are introduced into the aquatic environment. In-stream construction will be conducted in isolated work areas when feasible.	Recommended measures will fully mitigate potential effects	BC Hydro
Construction	Reduced fish health and survival due to stranding	Collection and relocation of stranded fish. Surveillance of fish habitat areas where periodic exposure of channel margins occurs as a result of headpond fluctuation. As feasible, salvage and relocation of fish trapped in potholes, side channels, or other habitat area at risk of dewatering as a result of headpond fluctuation.	Recommended measures will fully mitigate potential effects	BC Hydro
Construction	Reduced fish health and survival due to fish entrainment	Large diameter diversion tunnels and associated hydraulics that provide low risk of fish mortality. 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) in the tunnel tailrace area. Operating the modified diversion tunnel for a short duration, as described in Volume 1 Appendix B Reservoir Filling Plan.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro

Project Phase	Potential Effects	Key Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Reduced fish health and survival due to increased total dissolved gas	Modify spillway design to reduce total dissolved gas generation. Develop and implement an operational procedure to minimize the number of hold points and the duration of the reservoir filling and turbine commissioning.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro
Operations	Reduced fish health and survival due to stranding	Surveillance of fish habitat areas where periodic exposure of side channel and mainstem margins occurs as a result water fluctuations. The enhancement of side channel complexes (e.g., Old Fort) in the reach between the dam site and the confluences of the Peace and Pine rivers to increase wetted habitat and to reduce stranding potential during low flows. Where practical, contouring mainstem bars to minimize potential for fish stranding.	Recommended measures will fully mitigate potential effects	BC Hydro
Operations	Reduced fish health and survival due to fish entrainment	The large and slow-rotating Francis turbines produce high survival relative to other large facilities. Incorporating smooth and gradual transitions at the approach channel, 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 finishing. Reducing obstructions (e.g., boulders) from the turbulent zone in spillway and tailrace areas.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro
Operation	Reduced fish health and survival due to increased total dissolved gas supersaturation	Modify spillway design to reduce total dissolved gas generation. Develop and implement an operational procedure to initiate spillway discharge operations through multiple gates to reduce the rate of discharge at each gate to reduce dissolved gas generation. Develop and implement an operational procedure to minimize operation of turbines in water discharge ranges that produce ‘rough load operation’ to reduce total dissolved gas concentration in tailwater.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro

Project Phase	Potential Effects	Key Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Hindered fish movement due to obstruction to fish passage	Upstream fish passage during operations will be provided by a trap and haul facility. 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.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro
Operation	Hindered fish movement due to obstruction to fish passage	Upstream fish passage during operations will be provided by a trap and haul facility. 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.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro

12.6 Residual Effects

Table 12.20 summarizes the residual effects after the implementation of mitigation measures describe above. Activities that have residual effects will be carried through the residual effects characterization in the next sections.

Table 12.20 Summary of Residual Effects on Fish and Fish Habitat

Project Phase	Category of Effect	Potential Effect	Potential Residual Effect
Construction	Habitat	Loss of habitat due to construction of the dam and generating station, Highway 29, and Hudson's Hope shoreline protection	Yes – potential loss of 215 ha of fish habitat
Construction	Habitat	Loss of habitat due to construction headpond and reservoir filling	Yes – there would be a change in habitat
Operations	Habitat	Altered fish habitat due to transformation of reservoir habitat during reservoir operation	Yes – there would be a change in habitat
Operations	Habitat	Altered fish habitat downstream of Site C Dam	Yes – there would be a change in habitat
Construction	Health and Survival	Reduced fish health and survival due to sediment inputs by dam and generating station construction	Yes – sediment inputs affecting fish health and survival
Construction	Health and Survival	Reduced fish health and survival due to sediment inputs from construction headpond and reservoir filling	Yes – sediment inputs affecting fish health and survival
Construction	Health and Survival	Reduced fish health and survival due to Highway 29 realignment and Hudson’s Hope shoreline protection	No – mitigation eliminates potential effects
Construction	Health and Survival	Reduced fish health and survival due to fish stranding	No – mitigation eliminates potential effects
Construction	Health and Survival	Reduced fish health and survival due to fish entrainment	Yes – fish would be harmed due to entrainment
Construction	Health and Survival	Reduced fish health and survival due to increased total dissolved gas	Yes – fish would be exposed to TDG during spills
Operations	Health and Survival	Reduced fish health and survival due to fish stranding	No – mitigation eliminates potential effects
Operations	Health and Survival	Reduced fish health and survival due to fish entrainment	Yes – fish would be harmed due to entrainment
Operations	Health and Survival	Reduced fish health and survival due to increased total dissolved gas	Yes – fish would be exposed to TDG during spills
Construction	Movement	Hindered fish movement due to obstruction to fish passage	Yes – hindered fish movement would occur
Operations	Movement	Hindered fish movement due to obstruction to fish passage	Yes – hindered fish movement would occur

<u>Effect on Habitat</u>

Effects to habitat are predicted during the construction phase and operation of the Project. The infrastructure of dam and generating station, the Highway 29 realignment bridge crossings, and the Hudson’s Hope shoreline protection will cause a direct loss of fish habitat. The construction headpond and reservoir filling will reduce quality of habitat and culminate in the loss of riverine habitats upstream of the dam. The construction headpond and reservoir filling phase would transform the river ecosystem and create the Site C reservoir. Upstream of the dam, a new and productive aquatic ecosystem and fish community will develop in the reservoir. Existing fish populations that rely on Peace River mainstem habitats to sustain these populations would be negatively affected. Species that are expected to be adversely affected include: Arctic grayling, bull trout, and mountain whitefish. Distinct groups of fish from those species that are expected to be most negatively affected include: adfluvial components of the Moberly River Arctic grayling and Halfway River bull trout populations, as well as Peace River mainstem spawning mountain whitefish. Fish populations that can adapt to habitats available in the Site C reservoir and that can access important habitats needed to sustain the population may be positively affected, including kokanee, lake whitefish, lake trout, burbot, peamouth, and rainbow trout. Existing fish populations that are able to exploit the rapid change in environmental conditions during the reservoir transition (i.e., water quality, water temperature, nutrients, and food) would be positively affected during the transition period. These species include longnose and largescale suckers, redside shiner, lake chub, and peamouth.

Downstream of the Project, incremental changes in habitat will be observed during construction and operation. Limited changes to fish habitat will occur during construction, due to flow changes during diversion and reservoir filling stages. Operation of the dam and generating station would modify the surface water regime, temperature and ice regime, and sediment regime, as well as other physical characteristics of the Peace River aquatic ecosystem, ecological productivity, and fish communities downstream of the dam. Changes to the habitat would be most evident between the Site C Dam and the confluence of the Pine River, and the magnitude of changes would diminish downstream of the Pine River. The aquatic habitat between the dam and the Pine River would provide conditions that support a productive fish community similar to what presently occurs downstream of the Peace Canyon Dam. These same conditions would be unfavourable to other species, primarily due to changes to the flow, water temperature, and sediment regimes. Small-bodied fish, sucker species, burbot, goldeye, northern pike, and walleye might remain in the downstream areas of the Peace River that provide more favourable cool turbid water conditions. Mitigation activities will be effective in reducing the magnitude of effects; however, they will not eliminate them. Residual effects to habitat are therefore carried forward for characterization.

<u>Effects on Health and Survival</u>

Effects to health and survival are predicted to occur during both the construction and operation phase of the Project. Construction activities associated with the dam and generating station, construction headpond, and reservoir filling will cause sediment inputs that would reduce the quality of fish habitat and impair the health and survival of fish. Elevated concentrations of TDG would be generated during the reservoir filling stage of construction, and infrequent use of the dam spillway during the operations phase would create TDG concentrations that would induce GBD in a portion of the fish and aquatic life downstream of the dam (i.e., using depths of less than 2 m). Effects associated with sediment introduction and the creation of elevated levels of TDG would be reduced through proposed mitigation actions, but not eliminated. These effects on health and survival are therefore carried forward to characterization. Water level fluctuations in the headpond during the diversion stage of the construction phase, and in the reservoir and downstream area during operations phase of the Project have the potential to impair the health and survival of fish through stranding, but mitigation measures would be implemented to eliminate potential for residual effects.

Effects on Movement

Effects to fish movement are predicted during both the construction and operation phases of the Project. The construction of the dam will present a barrier that would physically delay or obstruct movements of some fish on the Peace River. Fish species affected may include bull trout and Arctic grayling. In addition, the creation of the reservoir itself may impede movement of fish from tributaries to other habitats in the reservoir or downstream river that are required to fulfill life history requirements. Mitigation actions (i.e., trap and haul) are proposed to reduce effects of impeded movement on bull trout past the dam, but there is uncertainty whether these measures are technically feasible and whether they will be biologically effective for other species such as Arctic grayling.

12.6.1 Characterization of Residual Effects

Characterization of residual effects is based on criteria provided in Table. 12.21.

Table 12.21 Characterization Criteria for Residual Effects on Fish and Fish Habitat

Criterion	Description	Definition of Criteria
Direction	This refers to the ultimate long-term trend of the fish and fish habitat effect	**Negative:** condition of the VC worsens in comparison to baseline condition
		Positive: condition of the VC improves in comparison to baseline condition
Magnitude	This refers to the amount of change in a key indicator or variable relative to baseline case. Consideration is given to factors such as the uniqueness of the effect, and the comparison to natural or background variation.	**Low:** Low: < 15% change in population or life stage abundance or biomass; hinder movement of small portion of the fish population; < 15% alteration/destruction of important fish habitat.
		Moderate: Moderate: 15% to 30% change in population or life stage abundance or biomass; hindered movement of a portion of the fish population; 15% to 30% alteration or destruction of important fish habitat.
		High: High: > 30% change in population or life stage abundance or biomass; hindered movement of a portion of an entire life stage of a fish population; > 30% alteration or destruction of important fish habitat.
Geographical Extent	This refers to the geographic areas in which a heritage effect of a defined magnitude occurs	**Site-specific:** discrete area within the immediate vicinity of a specific Project component or activity
		Local: Portion of LAA that includes sub-local geographic extent.
		LAA: Change occurs within entire LAA
Frequency	The number of times during a project or a specific project phase that a heritage effect may occur.	**Once:** occurs once
		Frequently: occurs frequently (on a regular basis and at regular intervals, but with extended rest periods
		Continuous: occurs on a regular basis and at regular intervals

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Criterion	Description	Definition of Criteria
Duration	The period of time required until the valued component returns to baseline condition, or the effect can no longer be measured or otherwise perceived	**Short term:** effect is limited to ≤ 1 year
		Medium term: effect occurs > 1 year ≤ 8 years (Construction Phase)
		Long-term: effect lasts from >8 years to the life of the Project (Operations Phase)
Reversibility	This refers to the degree or likelihood to which existing baseline conditions can be regained after the factors causing the effect are removed	Effect is **reversible**
		Effect is not reversible
Context	This refers to the extent to which the area within which an effect may occur has already been adversely affected by human activities; and is ecologically fragile and has little resilience and resistance to imposed stresses	**Disturbed:** Area has been substantially previously disturbed by human development or human development is still present
		Undisturbed: Area relatively pristine or not adversely affected by human activity
Level of Confidence	This is an evaluation of scientific certainty one has in the review of project-specific data, relevant literature, and professional opinion	**Low:** Low ability to predict the effect, relative to predicted changes and mitigation effectiveness
		Moderate: Moderate ability to predict the effect, relative to predicted changes and mitigation effectiveness
		High: High ability to predict the effect, relative to predicted changes and mitigation effectiveness
Probability	The likelihood that an adverse effect will occur	**Low:** An effect is unlikely to occur
		High: An effect is likely to occur

Residual effects of the Project on the fish and fish habitat VC are characterized in Table 12.22.

1 **Table 12.22 Characterization of Residual Fish and Fish Habitat Effects**

Activity	Potential Effect	Residual Environmental Effect Criteria								
		Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context	Probability	Level of Confidence
Construction										
Dam and generating station construction Highway 29 realignment Reservoir clearing Hudson's Hope shoreline protection	Loss of fish habitat (assumes a permanent effect)	N	L	L	H	L	I	D	H	H
Construction headpond and reservoir filling	Altered fish habitat	N	H	M	M	H	I	D	H	H
Operations										
Reservoir operation	Altered fish habitat in reservoir	N	H	M	H	H	I	D	H	H
	Altered downstream fish habitat	N	L	M	H	H	I	D	H	H
Construction										
Dam and generating station construction	Reduced fish health and survival due to sediment inputs	N	M	M	M	M	R	D	H	H
Construction headpond and reservoir filling	Reduced fish health and survival due to sediment inputs	N	M	M	M	H	I	D	H	H
Reservoir filling	Reduced fish health and survival due to fish entrainment	N	L	M	M	M	I	D	H	M
	Reduced fish health and survival due to increased total dissolved gas	N	L	M	L	L	R	D	H	H
Operations										
Reservoir operations	Reduced fish health and survival due to downstream fish entrainment	N	L	M	H	M	I	D	H	M
	Reduced fish health and survival due to increased total dissolved gas	N	L	M	L	L	R	D	H	H

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Activity	Potential Effect	Residual Environmental Effect Criteria								
		Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context	Probability	Level of Confidence
Construction										
Dam and generating station	Hindered fish movement due to obstruction to fish passage	N	H	M	M	M	I	D	H	M
Operation										
Dam and generating station	Hindered fish movement due to obstruction to fish passage	N	H	M	H	M	I	D	H	M

12.6.2 Standards or Thresholds for Determining Significance

The significance of each residual effect is evaluated taking into consideration the criteria provided in Table 12.22, existing knowledge about the fish and fish habitat, and the likely effectiveness of mitigation. A significant residual affect is assigned if the Project component or activity is predicted to result in either:

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

Threshold criteria for establishing significance of residual effects were selected to be consistent with priorities of the B.C. Freshwater Fisheries Program Plan (BCMOE 2007) and Conservation Framework (BCMOE 2009), and to align 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*.

The key goals of the British Columbia Freshwater Fisheries Management Program (BCMOE 2007) are to conserve wild fish and their habitats, and to optimize recreational opportunities based on the freshwater fisheries resources. Significance criterion “a” is consistent with the conservation goal. Significance criterion “b” is consistent with the goal of supporting long-term recreational opportunities. The provincial Conservation Framework provides an approach for resource managers to prioritize the conservation of species and ecosystems in British Columbia (BCMOE 2009). The goals of the conservation framework are: 1) to contribute to global efforts for species and ecosystems conservation, 2) to prevent species and ecosystems from becoming at risk, and 3) to maintain the full diversity of native species and ecosystems. Significance criterion “b” is consistent with these goals.

Federal goals for conservation and protection of the productivity of fish and fish habitat are found in the *Species at Risk Act* and the *Fisheries Act*, respectively. The *Species at Risk Act* provides useful regulatory context and objectives for supporting the conservation of wild fish populations (i.e., criterion “a” above). The intent of the *Species at Risk Act* is to prevent loss of indigenous species of wildlife in Canada and to prevent species of special concern from becoming extirpated, endangered, or thoureatened. Currently there are no fish species in the Peace River listed under the provisions of the *Species at Risk Act*; therefore, the criterion “a” is intended to provide an objective threshold for assessing the degree to which conservation goals of preventing species from becoming at risk.

The provisions of the *Fisheries Act* provide mechanisms to allow development of projects to occur while providing for the protection of fish and fish habitat. Criterion “b” acknowledges the public interest in fish and fish habitat, in particular, the interest in maintaining long-term productive capacity of fish habitats and, accordingly, the societal benefits of recreational, commercial, and Aboriginal fisheries. The productive capacity of freshwater fisheries habitats can be maintained or improved through: maintenance of the current productive capacity of habitats, restoration of damaged fish habitats, and development of new habitats. The Project will result in a transformation of fish habitat conditions and potentially alter the productive capacity of fish habitats in the Peace

River. Criterion "b" above is therefore intended to provide an objective threshold for assessing the degree to which the goal of maintaining long-term productive capacity of fish and fish habitat is achieved.

12.6.3 Determination of Significance of Residual Effects

A summary of the potential effects, mitigation, and significance of residuals effects are presented in Table 12.23.

Table 12.23 Summary of Assessment of Potential Significant Residual Adverse Effects on Fish and Fish Habitat

Project Phase	Potential Effect	Key Mitigation Measures	Result in Loss of Distinct Fish Group (criterion a)	Reduction in Long-Term Net Biomass (criterion b)	Significance Analysis of Residual Effects
Construction	Loss of fish habitat due to construction of dam and generating station, Highway 29 realignment, and Hudson's Hope shoreline protection	Implement Fish and Aquatic Habitat Management Plan (Volume 5 Section 35 Summary of Environmental Management Plans) A 15 m riparian buffer will remain adjacent to watercourses during reservoir clearing Material relocation sites (R5a, R5b, and R6) will be relocated 15 m back from the high water level to avoid affecting Peace River fish habitat. Material relocation sites upstream of the dam will incorporate fish habitat into the final capping design. The spoil area will be contoured and capped with gravels and cobble substrate between elevations 455 m and 461 m to provide productive fish habitat that will be available to fish during the operation phase. 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. Fish habitats affected by Highway 29 watercourse crossings will be compensated in the vicinity of the habitat loss. Fish habitat features will be incorporated into the final designs of the watercourse crossings.	No	No	Not Significant

Project Phase	Potential Effect	Key Mitigation Measures	Result in Loss of Distinct Fish Group (criterion a)	Reduction in Long-Term Net Biomass (criterion b)	Significance Analysis of Residual Effects
		Disturbed riparian areas will be replanted with local vegetation. The Highway 29 roadway that would border the reservoir, east of Lynx Creek, will also have fish habitat features incorporated into the final design of the footprint. The Hudson's Hope shoreline protection will be constructed of large material that will provide replacement fish habitat. Additional fish habitat features (e.g., shear zones and point bars) will be incorporated into the final design of the Hudson's Hope berm. Construction footprints are being finalized to reduce the size of the construction footprint. Temporary structures will be removed as soon as they are no longer required.			
Construction	Loss of habitat due to construction headpond and reservoir filling	Highway 29 borrow sites will be located between the Peace River and the future reservoir shoreline. Borrow sites that are located in the littoral zone of the reservoir will be contoured prior to decommissioning to provide gravel/cobble littoral fish habitat. Material repositioning areas will be capped with gravels and cobbles and contouring will be undertaken to enhance fish habitat conditions. 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.	Yes	No	Significant

Project Phase	Potential Effect	Key Mitigation Measures	Result in Loss of Distinct Fish Group (criterion a)	Reduction in Long-Term Net Biomass (criterion b)	Significance Analysis of Residual Effects
Operations	Altered fish habitat due to transformation of reservoir habitat during reservoir operations	The Site C reservoir operation has been designed to have a minimal reservoir elevation fluctuation during operation of 1.8 m, which minimizes the effects to the shoreline (littoral) fish habitat. Compensation options that are technically and economically feasible will be implemented.	No	No	Not Significant
Operations	Altered fish habitat downstream of Site C Dam	The enhancement of side channel complexes (e.g., Old Fort) in the reach between the dam site and the confluence of the Peace and Pine rivers to increase wetted habitat during low flows. Creation of wetted channels and back channel restoration on the south bank island downstream of the dam to create off channel and back channel habitat.	No	No	Not Significant
Construction	Reduced fish health and survival due to sediment inputs by construction of dam and generating station, Highway 29 realignment, and Hudson's Hope shoreline protection	Erosion prevention and sediment control plan (in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of standard preventive measures such as silt fences or other erosion prevention materials Dust control plan (Air Quality Management Plan Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of dust suppression techniques to prevent airborne deposition into water bodies. Surface water quality management plan (Section 35.2.21 Surface Water Quality Management Plan in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include control, management, and treatment of surface runoff. Adjust the timing construction activities to coincide with	No	No	Not Significant

Project Phase	Potential Effect	Key Mitigation Measures	Result in Loss of Distinct Fish Group (criterion a)	Reduction in Long-Term Net Biomass (criterion b)	Significance Analysis of Residual Effects
		periods of high background sediment levels where feasible. Select clean rock materials or wash rock materials for riprap construction to minimize the amount of sediments that are introduced into the aquatic environment. Reduce equipment production rates to reduce the amount of sediments generated by equipment where required.			
Construction	Reduced fish health and survival due to sediment inputs from construction headpond and reservoir filling	Berm or cap areas with high potential to produce sediments. During reservoir clearing, stumps in the headpond area will be left in place to reduce soil disturbance and potential sedimentation issues where feasible. Soil disturbance during reservoir clearing will be minimized by clearing in winter where feasible.	Yes	No	Significant
Construction	Reduced fish health and survival due to fish entrainment	Large diameter diversion tunnels and associated hydraulics that provide low risk of fish mortality. 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) in the tunnel tailrace area. Operating the modified diversion tunnel for a short duration, as described in Volume 1 Appendix B Reservoir Filling Plan.	No	No	Not Significant

Project Phase	Potential Effect	Key Mitigation Measures	Result in Loss of Distinct Fish Group (criterion a)	Reduction in Long-Term Net Biomass (criterion b)	Significance Analysis of Residual Effects
Construction	Reduced fish health and survival due to increased total dissolved gas	Modify spillway design to reduce total dissolved gas generation. Develop and implement an operational procedure to minimize the number of hold points, and the duration of the reservoir filling and turbine commissioning.	No	No	Not Significant
Operations	Reduced fish health and survival due to fish entrainment	The large and slow-rotating Francis turbines produce high survival relative to other large facilities. 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 finishing. Reducing obstructions (e.g., boulders) from the turbulent zone in spillway and tailrace areas.	No	No	Not Significant
Operation	Reduced fish health and survival due to increased total dissolved gas supersaturation	Modify spillway design to reduce total dissolved gas generation. Develop and implement an operational procedure to initiate spillway discharge operations through multiple gates to reduce the rate of discharge at each gate to reduce dissolved gas generation. Develop and implement an operational procedure to minimize operation of turbines in water discharge ranges that produce ‘rough load operation’ to reduce total dissolved gas concentration in tailwater.	No	No	Not Significant

Project Phase	Potential Effect	Key Mitigation Measures	Result in Loss of Distinct Fish Group (criterion a)	Reduction in Long-Term Net Biomass (criterion b)	Significance Analysis of Residual Effects
Construction	Hindered fish movement due to obstruction to fish passage	Upstream fish passage during operations will be provided by a trap and haul facility. 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.	Yes	No	Significant
Operations	Hindered fish movement due to obstruction to fish passage	Upstream fish passage during operations will be provided by a trap and haul facility. 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.	Yes	No	Significant

12.6.3.1 Discussion of the Significance of Residual Adverse Effects

This assessment was structured to determine the potential of the Project to have an adverse effect on the fish and fish habitat VC. To accomplish this, the assessment was structured to evaluate how categories of effects on the VC (habitat, health and survival, and movement) would be affected by the activities within each phase (Construction and Operation) of the Project. Table 12.24 provides a summary of significant and non-significant residual effects evaluated for each category of effect across the construction and operation phases of the Project. Residual effects have been predicted for each of the three categories of effects on fish and fish habitat. These effects are briefly discussed below.

Table 12.24 Summary of Residual Effects During Construction and Operation Phases of the Project (Significant Residual Effects in Boldface Type)

Category of Effect	Construction Phase	Operations Phase
Habitat	Loss of habitat due to construction of the dam and generating station, Highway 29, and Hudson's Hope shoreline protection Loss of habitat due to construction headpond and reservoir filling	Altered fish habitat due to transformation from river to reservoir habitat Altered fish habitat downstream of Site C Dam
Health and Survival	Reduced fish health and survival due to sediment inputs by dam and generating station construction Reduced fish health and survival due to sediment inputs from construction headpond and reservoir filling Reduced fish health and survival due to fish entrainment Reduced fish health and survival due to increased total dissolved gas	Reduced fish health and survival due to fish entrainment Reduced fish health and survival due to increased total dissolved gas
Movement	Hindered fish movement due to obstruction to fish passage	Hindered fish movement due to obstruction to fish passage

Effect on Habitat

The Project has the potential to affect fish habitat in locations upstream and downstream of the Site C Dam site. Changes to habitat upstream of the dam site would begin during construction phase (loss of habitat due to construction of the dam and generating station, Highway 29, and Hudson's Hope shoreline protection; loss of habitat due to construction headpond and reservoir filling) and a complete alteration of habitat would occur once the reservoir is filled. The residual effects resulting from habitat loss due to the construction headpond and reservoir filling would be adverse and significant, because they would be sufficient to reduce the abundance of fish populations in the river over the spatial extent of the headpond during the diversion period, and would result in an irreversible loss of key riverine habitats required for some distinct groups of fish when the reservoir is filled. Following the construction phase of the Project, a new reservoir ecosystem will develop over time and support a new diverse and productive fish community. The new ecosystem is predicted to support equal or greater levels of long-term standing stock biomass of fish populations, and is expected to change the relative species composition. The change in species composition cannot be reliably predicted with existing information, but it would favour species or distinct groups that persist by exploiting reservoir habitat conditions. The residual change in habitat resulting from operations would not be significantly adverse because the future operation of the reservoir would not result in additional habitat alteration that would either reduce productivity or result in loss of additional distinct groups of fish.

Operation of the Project will result in modest changes to fish habitat downstream of the dam. These changes to habitat have been assessed to be of low magnitude and limited in the proximal reach of the Peace River between the Project and the Pine River confluence. Downstream of the Pine River, changes diminish as a result of flow attenuation and tributary inflows. The changes to habitat would include increases in the range of flow fluctuations, and limited changes to temperature and water quality. These changes are not large enough to cause a loss in distinct groups of fish or to result in a reduction in the long-term standing stock biomass of downstream fish populations. The cool turbid water fish species that inhabit the Peace River would be able to complete their entire life histories downstream of the Project and would not be significantly affected by the Project.

Effects on Health and Survival

The Project has the potential to affect the health and survival of fish in the Peace River due to: 1) suspended sediment inputs resulting from dam and generating station construction, 2) suspended sediment inputs resulting from construction headpond and reservoir filling, 3) entrainment, and 4) exposure to increased dissolved gas concentrations. Suspended sediment inputs resulting from construction of the dam and generating station will cause adverse residual effects, but will not be significant because they are not of sufficient magnitude to either result in the loss of distinct groups of fish or to reduce long-term standing stock biomass of fish. However, suspended sediment inputs resulting from the construction headpond and reservoir filling would be of sufficient magnitude and duration to cause significant adverse effects. These effects would contribute to the loss of distinct groups of fish that exclusively inhabit existing clear water habitats, use the Peace River in the region that would be transformed into reservoir and immediately downstream of the dam. Effects on health and survival resulting from entrainment and total dissolved gas exposure in shallow water will occur during the construction and operation phase, but will not be significant because they are not of sufficient magnitude to either result in the loss of distinct groups of fish or to reduce long-term standing stock biomass of fish.

Effects on Movement

The Project has the potential to affect fish movement in the Peace River and movements to tributaries upstream of the Site C Dam site during the construction and operation phases. The habitat changes from the construction headpond and reservoir creation may alter the movement patterns of fish that are not adapted to reservoir habitats such are Arctic grayling. As well, upstream fish movement will be hindered at the dam site. This effect on fish movement is significant because it contributes to the loss of distinct groups of fish.

12.6.3.2 Conclusion

Based on criteria “a”, 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. These distinct groups include:

Moberly Arctic Grayling: The most prominent of these three groups is the Arctic grayling that spawn in the Moberly River and rear in the Peace River in proximity to the construction headpond and reservoir, and immediately downstream of the project. Peace River Arctic grayling populations have been demonstrated to be sensitive to changes in habitat conditions, particularly those related to the transformation of riverine habitats to reservoirs. The loss of distinct groups of Arctic grayling in the upper Peace River watershed was observed following the construction of the Williston Reservoir. As a result, the maintenance of distinct groups of Arctic grayling in the Peace watershed is a species conservation concern. Arctic grayling are abundant in other Peace River tributaries, which may provide recruitment to the Peace River.

Halfway River Bull Trout: Bull trout that spawn in the Halfway River watershed and rear in the Peace River maybe affected by reservoir creation, and have their movements impeded by the dam. Bull trout that spawn in the Halfway River watershed have two life histories (which form two distinct groups): 1) a migratory life history that rear in the Peace River (i.e., an adfluvial or large river rearing life history), and a resident life history that rear entirely in the Halfway watershed. The migratory life history may rear in the reservoir or continue downstream to rear in the Peace River, downstream of the dam site. There is uncertainty regarding how Halfway River migratory bull trout will inhabit the reservoir; however, evidence from modelling and from other reservoirs in B.C. and elsewhere suggest that bull trout are resilient to this type of habitat change. There is uncertainty in the extent to which bull trout will continue to migrate downstream past the dam site, and whether upstream passage mitigation at the Site C Dam site will be required for bull trout. Given the habitat available in the reservoir, the potential available habitat downstream of the dam site, and the potential for fish passage, the probability of loss of the migratory component of the Halfway bull trout population is low.

Mountain Whitefish: Mountain whitefish are abundant in the Peace River and its tributaries. Mountain whitefish are not adapted to reservoir habitats, which creates a risk for the loss of distinct groups of mountain whitefish that rear in the Peace River and spawn in the Peace River mainstem or tributaries upstream of the Site C Dam.

Based on criteria “b”, the Project is not predicted to have a significant adverse effect on the fish and fish habitat VC as a result of a reduction in the long-term average standing stock biomass of the fish community relative to the existing baseline condition. Short-term reductions in standing stock biomass are predicted to occur during the construction phase. Over the long term, standing stock biomass in the reservoir and Peace River downstream of the Project in the LAA is predicted to be equal to or greater than baseline conditions.

12.7 Cumulative Effects Assessment

The list of projects and activities in the cumulative effects assessment (Table 10.7 in Section 10.7 in Volume 2 Section 10 Effects Assessment Methodology) were reviewed to determine which projects are within the Projects RAA, to assess whether their residual effects extend into the Project’s LAA, and if there would be an overlap in residual effects. The review identified two projects and activities that lie in the Regional Assessment Area for fish and fish habitat where there might be overlap in residual effects (Table 12.24). These project include the Dunvegan Hydroelectric Facility on the Peace River 187 km downstream of the Project, and the Montney Gas Play, which encompasses the northern part of the Peace River watershed from the east slopes of the mountains east into Alberta.

Table 12.25 Other Projects/Activities that Lie with the Regional Assessment Area

Project/Activity	Location	Description
Dunvegan Hydroelectric Project	187 km downstream of the Project near the Highway 2 Bridge crossing	100 MW run-of-river hydro project on Peace River near Dunvegan, Alberta. Project components include a spillway and powerhouse across the Peace River to increase the water level in the river at the headworks by an average of 6.6 m. Headpond would extend up to 26 km upstream of powerhouse and spillway. Permitted, but not constructed.
Montney Gas Play	Northeast B.C. – Fort St. John area and western Alberta	Shale rock deposit containing large quantities of natural gas. Includes multiple projects and activities. Exploration, extraction, processing, and transport (pipeline and truck) currently underway. Expansion of development activities to continue into the foreseeable future.

The Dunvegan Project assessment concluded that a significant residual effect would be restricted to the local project area and limited to three fish species. Dunvegan's local area residual effect is limited to the headpond area, 161 km downstream of the Site C Dam site. Site C has no overlapping residual effects with the Dunvegan Project.

The Montney Gas Play could have point source effects on fish and fish habitat in tributaries to the Site C LAA. However, based on the limited interactions that natural gas exploration has with watercourses, it is anticipated that gas exploration would not interact with Site C residual effects. Therefore, there would be no cumulative effects.

12.8 Follow-Up Programs

In accordance with Section 23.5 of the EIS Guidelines, follow-up programs would be required to verify the accuracy of the effects assessment and to determine the effectiveness of the measures implemented to mitigate the adverse effects of the project on fish and fish habitat. A summary of the follow-up programs is provided in Table 12.25 below.

A fish and fish habitat follow-up plan would be implemented to address key uncertainties about the accuracy of effects assessment and the effectiveness of mitigation. The follow-up program will be implemented as a phased approach to match three discrete time periods associated with the Project. These include:

Construction period (eight years)

The reservoir transformation period following reservoir filling (15 years)

The reservoir post-transformation period (15 years)

The scope of the program would be to address:

Uncertainty in effects assessment in each stage

Uncertainty in mitigation effectiveness

Uncertainty in both effect and mitigation effectiveness

The plan would be to include provisions to address five key uncertainties:

Effectiveness of environmental protection measures undertaken during construction to mitigate effects on fish and fish habitat

Effects of total dissolved gas supersaturation on the health and survival of fish

Effects of the dam on the movement of fish

The effects of river to reservoir transformation on fish and fish habitat

The effect of altered flow regime on fish and fish habitat in the river downstream of the dam

Following reservoir filling and commencement of operation, follow-up monitoring will be required to test the hypothesis used to predict the temporal development of the new reservoir, and changes in the downstream river physical environment and productivity. Follow-up monitoring would be organized in four discrete programs:

1. Fish and fish habitat productivity monitoring program for reservoir and reservoir tributaries

Fish and fish habitat productivity monitoring program for downstream Peace River

Fish passage management program

Total dissolved gas monitoring program

The information collected during the follow-up monitoring programs will be used to verify assessment predictions. Depending on the verification, additional adaptive programs may be required including:

Confirm specific adaptive management plans based on follow-up monitoring results

Implement directed studies to address specific uncertainties (e.g., what is the kokanee population in the reservoir?)

As part of the habitat compensation program, funding will be available to verify uncertainty in the effects and will be used on technically feasible, cost-effective, and environmentally sound projects to compensate for unforeseen adverse effects

Table 12.26 Follow-up Monitoring Programs for Fish and Fish Habitat

Project Phase	Category of Effect	Potential Effect	Follow-Up Program
Construction	Habitat (Residual)	Loss of habitat due to construction of the dam and generating station, Highway 29 and Hudson's Hope shoreline protection	Construction Environmental Monitoring Program Habitat Compensation Program
Construction	Habitat (Residual)	Altered fish habitat due to construction headpond and reservoir filling	Habitat Compensation Program
Operations	Habitat (Residual)	Altered fish habitat due to transformation of reservoir habitat during reservoir operations	Fish and Fish Habitat Productivity Monitoring Program (Reservoir) Habitat Compensation Program
Operations	Habitat (Residual)	Altered fish habitat downstream of Site C Dam	Fish and Fish Habitat Productivity Monitoring Program (River) Habitat Compensation Program
Construction	Health and Survival (Not Residual)	Reduced fish health and survival due to stranding in construction headpond	Construction Headpond Fish Salvage and Monitoring Program
Construction	Health and Survival (Residual)	Reduced fish health and survival due to fish entrainment	Fish Passage Management Program
Construction	Health and Survival (Residual)	Reduced fish health and survival due to increased total dissolved gas	Total Dissolved Gas Monitoring Program
Operations	Health and Survival (Residual)	Reduced fish health and survival due to fish entrainment	Fish Passage Management Program
Operations	Health and Survival (Residual)	Reduced fish health and survival due to increased total dissolved gas	Total Dissolved Gas Monitoring Program
Construction	Movement (Residual)	Hindered fish movement due to obstruction to fish passage	Fish Passage Management Program
Operations	Movement (Residual)	Hindered fish movement due to obstruction to fish passage	Fish Passage Management Program

Site C fish and fish habitat baseline study designs were developed with follow-up monitoring in mind. Follow-up fish and fish habitat productivity monitoring programs would use established sampling methodology and sampling site locations in the Peace River and tributaries for consistency. Specific sampling designs would be developed for individual reservoir studies.

The environmental monitoring and follow-up program details and reporting requirements will be part of the *Fisheries Act* 35 (2) Authorization.

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13 VEGETATION AND ECOLOGICAL COMMUNITIES

13.1 Approach

Vegetation and ecological communities includes rare and sensitive ecological communities and ecological communities at risk – including wetlands, rare plants, and a description of the composition, distribution, and abundance of terrestrial flora associated with the distribution of ecosystems within the assessment area. Vegetation and ecological communities were selected as a valued component (VC) due to:

- An interaction with Project components and activities resulting in land clearing and water impoundment
- Aboriginal concerns of potential changes to plants used for food, medicine, and cultural purposes
- Public and stakeholder concerns of potential changes to plants used for food, agriculture, and timber harvesting
- Federal and provincial regulations on vegetation and biodiversity

Potential changes to vegetation can also have indirect interactions on wildlife resources that are used by Aboriginal groups, the public, or are managed by provincial and federal regulations. Potential effects of the Project on wildlife resources are discussed in Volume 2 Section 14 Wildlife Resources, the potential effects on the current use of vegetation by Aboriginal groups are discussed in Volume 3 Section 19 Current Use of Land and Resources for Traditional Purposes, and potential impacts of the Project on the exercise of asserted or established Aboriginal and treaty rights are discussed in Volume 5 Section 34 Asserted or Established Aboriginal Rights and Treaty Rights, Aboriginal Interests and Information.

13.1.1 Regulatory and Policy Setting

The following is a summary of federal and provincial legislation governing vegetation and ecological communities.

13.1.1.1 Species at Risk Act

The Government of Canada proclaimed the federal *Species at Risk Act* (SARA) in June 2003 as part of a three-part strategy for the protection of species at risk in Canada. The other two parts of the strategy include the Accord for the Protection of Species at Risk and the Habitat Stewardship Program for Species at Risk. The *Species at Risk Act* was developed following the implementation of the Canadian Biodiversity Strategy in response to the United Nations' Convention on Biological Diversity. The purpose of SARA is "to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct, to provide for the recovery of endangered or threatened species, and encourage the management of other species to prevent them from becoming at risk" (Government of Canada 2012).

13.1.1.2 Forest Range and Practices Act

The *Forest and Range Practices Act* (FRPA) and its regulations govern the activities of B.C. forest and range licensees, including requirements for planning, road building, logging, reforestation, and grazing. It took effect January 31, 2004, and any activities already approved prior to this time under the existing Forest Practices Code may continue and are governed by the *Forest Practices Code of British Columbia Act* and its regulations.

In 2004, the B.C. Ministry of Water, Land, and Air Protection – now the B.C. Ministry of Environment (BCMOE) – established a category of species at risk by order made under FRPA. This category represents those species that may be affected by forest or range management on Crown land and are listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Identified wildlife are selected from the provincially red- or blue-listed species. Red-listed plants or plant communities are also included. An inter-agency committee – composed of individuals with environment or forestry backgrounds – consults with species experts to determine which of these species and plant communities should be recommended for designation as Identified Wildlife.

In relation to ecosystems and rare plants, under the FRPA, the Lieutenant Governor-in-Council may make regulations authorizing the Minister of Environment to establish under Section 149.1 (a):

> "an area as a wildlife habitat area and objectives for the wildlife habitat area"

Wildlife Habitat Areas are areas managed for selected species and plant communities that have been designated as Identified Wildlife. These areas are mapped and approved by the chief forester and deputy Minister of Environment.

General wildlife measures direct what forest and range management practices can occur within a Wildlife Habitat Area. They may restrict forest or range activities to minimize disturbance or may restrict activities entirely within an area in order to maintain the integrity of the habitat.

13.1.2 Key Issues and Identification of Potential Effects

Issues, concerns, and interests identified during consultation with the public, Aboriginal groups, and government agencies guided the scope of the vegetation and ecological communities' assessment (see Volume 1 Section 9 Information Distribution and Consultation).

Discussions during the Wildlife Technical Advisory Committee (TAC) and concerns identified in various Traditional Land Use Studies were also considered.

13.1.2.1 Wildlife Technical Advisory Committee

A summary of the TAC process is provided in Section 9.3 Agency Information Distribution and Consultation in Volume 1 Section 9 Information Distribution and Consultation. Key discussions, issues, and concerns raised by the Wildlife TAC are summarized in Table 9.3.3 in Section 9.3.

Participants observed a potential limitation in assessing effects to rare plants where it was difficult to assess the importance in a regional context. Three ideas to address the issue included:

- Using sampling along the transmission line as a 'random sample' of the surrounding region
- Investigating soil characteristics and chemistry to predict locations of other plants
- Visiting herbariums to see if there are other records of rare plants found within the region

Subsequent sampling did look along the transmission line, and various herbariums were visited. Soil characteristics, geology, and ecosystem unit were all considered during field studies for rare plants.

13.1.2.2 Traditional Use Studies

Traditional Land Use Studies were prepared for a number of Aboriginal group communities. These included Blueberry River First Nation Traditional Land Use Study (Bouchard and Kennedy 2011); Duncan's First Nation Ethnohistorical Review (Bouchard and Kennedy 2012a); Horse Lake First Nation Ethnohistorical Overview (Bouchard and Kennedy 2012b); Doig River First Nation, Prophet River First Nation, Halfway River First Nation, and West Moberly First Nation Traditional Land Use Study (Candler 2012), Saulteau First Nation Culture and Traditions Study (Nesoo Watchie Resource Management Ltd. 2011), Kelly Late Métis Settlement Society Aboriginal Traditional Knowledge Assessment (KSDavidson & Associates and KCD Consulting Incorporated 2012), Dene Tha' Traditional Land Use with Respect to BC Hydro's Proposed Site C Dam (Stevenson 2012), and Fort Nelson First Nation Background and Rationale for Involvement in the Site C Project (Wolfenden 2012).

Specific issues and concerns raised by the Aboriginal groups within the various reports, as well as the approach used to address the issues, are presented in Table 13.1. Not all issues identified by Aboriginal groups were included as key indicators. Food plants identified by Aboriginal groups were not included within the assessment as plant species are not being assessed individually; instead, effects to ecosystems that contain described plant assemblages are assessed under terrestrial ecosystems, including those that are rare, sensitive, or of conservation concern. Harvesting of plants for traditional purposes is considered in the assessment of the potential effects of the Project on Current Use of Lands and Resources for Traditional Purposes, which is found in Volume 3 Section 19.

Table 13.1 Key Issues: Vegetation and Ecological Communities

Key Issues	Approach to Addressing Key Issues
Loss of ecosystems important for Aboriginal food resources of interest	The potential changes to terrestrial ecosystems have been assessed, which will account for changes to ecosystems which support particular Aboriginal food species.
Loss of old-growth forests	Considered by assessing the loss of older forest types that are identified as structural Stage 7
Spread of invasive plants	Considered as part of the assessment under habitat alteration
Exposure of plants to contaminants, including dust	Considered as part of the assessment under habitat alteration
Loss of muskegs	Considered within the assessment under wetlands
Change in vegetation and ecological health due to a decrease in the water quality or quantity	Considered as part of the assessment under habitat alteration
Bank erosion	Considered as part of the assessment under habitat alteration – specifically, operations

13.1.2.3 Project Interactions

Potential project interactions with vegetation and ecological communities are summarized in Volume 2 Appendix A Project Interactions Matrix, Table 2. As defined in Volume 2 Section 10 Effects Assessment Methodology, a rank of “2” was given where interactions may result in an adverse effect, and the nature of the effect or the effectiveness of mitigation measures are uncertain.

Project interactions with a ranking of “2” are summarized in Table 13.2. The assessment was completed for both the construction and operational phases of the Project. Since many of the Project activities are similar across all Project components, Table 13.2 is an abbreviated version of Table 2 provided in Volume 2 Appendix A Project Interactions Matrix. These interactions were taken forward through the effects assessment.

Section 11.2.4 of the EIS Guidelines states that the assessment of potential adverse effects to the vegetation and ecological communities VC will take into account the potential for the Project to result in changes to the following key aspects:

- The area of vegetation/ecological community loss, assessed by overlaying the project activity zone on the ecosystem maps and conducting a GIS-based analysis of the area lost due to project activities
- The area of vegetation/ecological community fragmentation, identified through GIS analysis
- The area of temporary vegetation/ecological community disturbance will be assessed by overlaying the project activity zone on the ecosystem maps and conducting a GIS-based analysis of the area disturbed
- Long-term effects of maintenance of vegetation/ecological communities in an early seral stage along the transmission line and around the dam site
- Wetlands

These key aspects are considered under one general effect category – habitat alteration and fragmentation – which covers both the temporary and permanent loss, and the fragmentation of vegetation and ecological communities, including wetlands.

Table 13.2 Interactions of the Project with Vegetation and Ecological Communities

Project Activities and Physical Works	Key Aspects: Habitat Alteration and Fragmentation – Includes Temporary or Permanent Loss and Fragmentation of Vegetation and Ecological Communities (Including Wetlands)
Construction	
Dam, Generating Station, and Spillways	
• Site clearing and preparation	✓
• Temporary and permanent access roads	✓
• Waste treatment and management facilities	✓
• Hazardous materials storage and refuelling sites	✓
• Truck washing sites	✓
• Relocation of surplus excess material	✓
• Temporary construction access bridge across the Peace River	✓
• Sand and gravel source pits	✓
• Stage 1 and 2 channelization and diversion works	✓
• Existing infrastructure relocation	✓
Reservoir	
• Existing infrastructure inventory, protection, and relocation	✓
• Hudson's Hope shoreline protection	✓
• Road upgrade and winter road construction	✓
• Clearing of vegetation and timber	✓
• Post-harvest terrestrial debris management	✓
• Access deactivation and reclamation	✓
• Aquatic debris management during inundation	✓
• Water management during diversion, reservoir filling, and commissioning	✓

Project Activities and Physical Works	Key Aspects Habitat Alteration and Fragmentation – Includes Temporary or Permanent Loss and Fragmentation of Vegetation and Ecological Communities (Including Wetlands)
Quarried and Excavated Materials	
• Site preparation and earthworks, drainage, railway construction	✓
• 85th Avenue Industrial Lands conveyor belt	✓
Construction Access Road Development	
• Site preparation and earthworks, drainage, railway construction	✓
Highway 29 Realignment	
• Realign highway sections	✓
Worker Accommodation	
• Temporary accommodation	✓
Transmission System	
• Clearing and preparation	✓
• Access construction and right-of-way improvement	✓
• Tower installation	✓
• Construction site decommissioning and reclamation	✓
• Upgrades to Peace Canyon substation	✓
Operations	
Dam, Generating Station, and Spillways	
• Reservoir and downstream water management	✓
• Maintenance of powerhouse and substation	
Reservoir	
• Debris management	✓
• Hudson's Hope shoreline protection maintenance	✓
Transmission line	
• Right-of-way vegetation maintenance	✓
• Maintenance of access roads	✓

13.1.3 Standard Mitigation Measures and Effects Addressed

A rank of "0" means there is no interaction between the Project components and the VC. Volume 2 Appendix A Project Interactions Matrix, Table 2 provides a rationale for why some activities were ranked "0". These were not carried forward through the effects assessment.

A rank of "1" means that an interaction would occur, but that it is well understood and can be avoided or mitigated through the application of standard mitigation measures and would be negligible. No Project activities were assigned a ranking of "1".

13.1.4 Selection of Key Indicators

Section 11.2.3 of the EIS Guidelines states that the key indicators for the vegetation and ecological communities VC will include:

- Total area (hectares) of each ecosystem type, including wetlands, within the mapped area
- Area (hectares) of each ecosystem by structural stage will be calculated for each of the mapped ecosystems using the final map databases. The seven class structural stage classification system will be used (B.C. Ministry of Environment, Lands and Parks and B.C. Ministry of Forests 1998).
- Number of unique ecosystems mapped, and their distribution within the technical study area described
- Number of and distribution of rare plant species observed within the technical study area

Section 11.2.3.1 of the EIS Guidelines further states that the EIS will describe ecological communities at risk that are "currently designated on the provincial Red and Blue lists, communities that are ranked 1 or 2 for Goal 2 of the Conservation Framework, and sensitive communities that are communities that are less resilient to disturbance such as wetlands."

The key indicators include the requirements as stipulated within the EIS Guidelines. Many of these requirements are duplicated and for assessment purposes are provided under a general category: terrestrial ecosystems. As such, the key indicators have been grouped as follows:

- Terrestrial ecosystems – including structural stages – that are vulnerable to environmental effects of the Project, are a management concern, and have been identified as important by Aboriginal groups, communities, or public stakeholders. All terrestrial ecosystems within the Local Assessment Area (LAA) are reported (see Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report), but the focus of the effects assessment is on rare and sensitive ecological communities. Rare communities include current provincial red- and blue-listed and communities ranked 1 or 2 for Goal 2 (to prevent species and ecosystems from becoming at risk) of the Conservation Framework. Sensitive ecological communities include wetlands, tufa seeps, marl fens, grasslands, and old-growth forests.
- Rare plants that include red- and blue-listed vascular plants, mosses, and lichens.

The list of key indicators and the rationale for selection are summarized in Table 13.3.

Table 13.3 Key Indicators for Vegetation and Ecological Communities

Key Aspects	Key Indicators	Rationale for Selection of the Key Indicators
Habitat alteration and fragmentation – includes temporary or permanent loss and fragmentation of vegetation and ecological communities (including wetlands)	Terrestrial ecosystems	Provincial ecosystems at risk
		Provincial and federal ecosystems of interest
		Biodiversity
	Rare plants	Provincial species at risk and of conservation concern

13.1.5 Spatial and Temporal Boundaries

13.1.5.1 Spatial Boundaries

The spatial boundaries used in the assessment include the:

- **Local Assessment Area (LAA):** the area within which the potential adverse effects of the Project are assessed. The LAA encompasses the Project activity zone, buffered by an additional 1,000 m. This buffer is larger than was suggested in Table 11.2 of the EIS Guidelines. A 1,000 m buffer, which was selected to allow adequate characterization of the terrestrial environment surrounding the Project activity zone, extends far enough to include all potential direct and indirect effects at all construction sites and during operations. This includes new roads, roads requiring sizable upgrades, quarries, the dam site, and the transmission line. For the proposed reservoir, the erosion impact line has a 1,000 m buffer.

The LAA also extends downstream from the dam to the Alberta border, and includes a 1,000 m buffer on both the south and north banks of the Peace River (Figure 13.1). This considers potential effects to riparian vegetation that could be affected by reductions in the magnitude of peak flows, and more frequent high and low flows from the dam downstream to the Pine River confluence (see Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

- **Regional Assessment Area (RAA):** the area within which projects and activities – the residual effects of which may combine with residual effects of the Project – are identified and taken into account in the cumulative effects assessment. The proposed dam, reservoir, transmission line, Highway 29 realignment, temporary access roads, and quarries occur within five Wildlife Management Units that are designated 7-31, 7-32, 7-33, 7-34, and 7-35 (Figure 13.1). The Wildlife Management Unit boundaries provide a larger RAA boundary than what was suggested in Table 11.2 of the EIS Guidelines. The updated boundary includes most of the Peace Lowlands ecosection and incorporates all Project components and activities.

13.1.5.2 Temporal Boundaries

The temporal boundaries of the effects assessment of the Project include short- and medium-term (construction phase; Year 0 - 8) and long-term (operations phase; begin in Year 8 and may continue throughout the life of the Project) time frames.

13.2 Baseline Conditions

The following section provides a summary of the baseline conditions for terrestrial ecosystems and rare plants. This section is supported by more detailed information presented in Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report.

13.2.1 Terrestrial Ecosystems

For a detailed description of the baseline work completed for terrestrial ecosystem, including rare and sensitive ecosystems, see Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report, Part 1 Vegetation and Ecological Communities.

13.2.1.1 Terrestrial Habitats

<u>Biogeoclimatic zones</u>

The Peace River from Hudson's Hope to the Alberta border lies within the Peace River Basin ecoregion, one of the three ecoregions that make up the Boreal Plains ecoprovince. The Peace Lowland ecosection is the only ecosection occurring within the Peace River Basin. The Halfway Plateau ecosection makes up a small area of the LAA. The proposed West Pine Quarry site lies within the Hart Foothills ecosection, with a small portion in the Northern Hart Ranges ecosection.

The Peace River Valley lies within the Peace moist, warm Boreal White and Black Spruce (BWBSmw) subzone variant. Other subzone variants present in the LAA include the Murray wet, cool Boreal White and Black Spruce (BWBSwk1), the Finlay-Peace wet, cool Sub-boreal Spruce (SBSwk2), and the Bullmoose moist, very cold Engelmann spruce-subalpine fir (ESSFmv2).

Habitat Mapping Approach

The terrestrial ecosystems in the LAA were mapped using a combination of two methodologies – Terrestrial Ecosystem Mapping (TEM), and a broader habitat mapping technique that used inputs from existing biophysical mapping, Predictive Ecosystem Mapping (PEM), and Vegetation Resource Inventory (VRI) mapping.

Over 30% of the LAA was mapped as seral ($) 01 forest (Table 13.4). This well-drained, mesic, aspen-dominated forest covers much of the valley slopes of the BWBSmw variant. Moister ecosystems such as the $05 aspen unit were most commonly found on lower slopes, as were smaller amounts of moist balsam poplar forest ($07). The Fm02 poplar floodplain unit is present in the valley bottom adjacent to the Peace River and its larger tributaries. Dry aspen forest ($03) was mapped on warm aspects, mainly on the north side of the river. Shrubby aspen forest (AS) complexed with grassland slopes (WW) and eroding cutbanks (CB) were mapped in gullies and on the steepest, driest warm aspect slopes.

Table 13.4 Mapped Ecosystem Areas in the Local Assessment Area

Ecosystem type	Site Series	Amount in LAA (ha)
Dry coniferous forest	02, 03	3,117
Dry deciduous forest	$02, $03	6,482
Mesic coniferous forest	01, 04, 06	11,372
Mesic deciduous forest	$01, $04	27,269
Moist coniferous forest	05, 07	2,971
Moist deciduous forest	$05, $07	4,394
Wet coniferous forest	08	2,126
Floodplain forest	Fm02	2,699
Grassland	WW	2,667
Wetland	TS, SE, WS, WH Wf02, Wf13	3,965
Nonvegetated	CB, ED, GB	2,057
Anthropogenic	CF, GP, MI, RN, RW, RY, RZ, UR	10,758
Water	RI, RE, OW, PD	6,517
Other (avalanche path)		31
Grand Total		**86,424**

Lodgepole pine forests (02) were rare and generally occurred only on coarse-textured, gently-sloped terraces. The riparian wetland (WH) was the most common wetland type, and was mapped along the shores and backchannels of the Peace River. Sedge and willow wetlands (SE, WS) were rare in the river valley.

Approximately 10% of the LAA was mapped as cultivated field (CF). One per cent was mapped as gravel bar (GB), but neither the extent nor the location of this unit can be specified at any moment, as it varies with the level of the river at any particular time and is subject to movement from one year to the next.

Polygons mapped as structural Stage 5 (young forest) made up over 29% of the LAA (based on a broad review using a mapped polygons first decile only). Deciles are the percentage assigned to the components of a map polygon on the habitat maps. A polygon can have up to three deciles, which add up to 100%. A summary of structural stages mapped – based on the first decile – is presented in Table 13.5. More detailed summaries for all deciles are in Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report.

Table 13.5 Mapped Structural Stage Area in LAA – First Decile

Subzone Variant	Structural Stage[a]	Total in LAA (ha)	Percent of LAA (%)
BWBSmw1	None	7,674	8.9
	1	2,082	2.4
	2	12,315	14.3
	3	11,647	13.5
	4	9,174	10.6
	5	24,672	28.5
	6	16,667	19.3
	7	1,126	1.3
	Total	**85,357**	**98.8**
BWBSwk1	3	2	<0.1
	5	191	0.2
	Total	**193**	**0.2**
ESSFmv2	3	30	<0.1
	5	111	0.1
	6	44	0.1
	Total	**185**	**0.2**
SBSwk2	None	44	0.1
	1	4	<0.1
	2	3	<0.1
	3	90	0.1
	4	29	<0.1
	5	290	0.3
	6	221	0.3
	7	9	0.0
	Total	**689**	**0.8**
Grand Total		**86,424**	**100.0**

NOTE:
[a] None – river, lake, pond, open water, urban, railway, reservoir, road, and rural that are mapped without structural stages

13.2.1.2 Rare and Sensitive Ecological Communities

For a detailed description of the baseline work completed for rare plant see Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report, Part 1 Vegetation and Ecological Communities.

Two red-listed and 15 blue-listed communities are defined for the BWBSmw, BWBSwk1, ESSFmv2, and SBSwk2 subzone variants. Some of the communities occur in more than one variant. Of the 17 communities, 12 potentially occur in the BWBSmw subzone, four in the SBSwk2, one in the ESSFmv2, and six in the BSBSwk1 subzone. The site series associated with each listed community was correlated with the corresponding ecosystem unit mapped in the LAA. Ten ecosystem units associated with 16 rare ecological communities were identified. They occupy 10,696 ha within the LAA.

Ecological communities that are not red- or blue-listed by the B.C. Conservation Data Centre but are ranked as priority 1 or 2 under Goal 2 of the Conservation Framework are considered as sensitive communities for this assessment. Two communities – both associated with site series in the SBSwk2 – are ranked as priority 2 under Goal 2 of the Conservation Framework. These include communities associated with the 01 and 05 site series. The area of those two site series mapped within the LAA is 305 ha.

Other sensitive communities within the LAA are broader habitats that are rare on the landscape or are sensitive to changes in hydrology or to anthropogenic interactions. These include grasslands, old-growth forest, wetlands, marl fens, and tufa seeps. In total, 2,667 ha are mapped as grassland within the LAA. Old-growth forest – forest mapped as structural Stage 7 within the LAA – totals 1,131 ha. Wetlands mapped in the LAA occur in six vegetated ecosystem units and two water units, and total 4,074 ha. Seven tufa seeps and one marl fen were also located in the LAA during field studies.

13.2.2 Rare Plants

For a detailed description of the baseline work completed for rare plant see Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report, Part 1 Vegetation and Ecological Communities.

For this assessment, rare plants were defined to include the following vascular plants, mosses, and lichens:

- Taxa listed on Schedule 1 of SARA as amended (Government of Canada 2008)
- Taxa assigned a status of Extinct, Extirpated, Endangered, Threatened, or Special Concern by COSEWIC (COSEWIC 2012)
- Taxa on the BCMOE provincial red or blue lists (B.C. Conservation Data Centre 2011)

Thirty-nine B.C. red- or blue-listed vascular plant taxa are known to occur within the LAA. This includes occurrences found during the 2008, 2011, and 2012 site-specific surveys, as well as records from previous botanical work in the area. Of these 39 taxa, 11 are red-listed and 28 are blue-listed. No SARA Schedule 1 plant taxa were found, and no plant species ranked by COSEWIC as Extinct, Extirpated, Endangered, Threatened, or Special Concern were observed.

Three blue-listed moss species were identified during the 2008 field surveys. The three species were found in five occurrences. No SARA Schedule 1 mosses were reported, nor were any listed by COSEWIC as Extinct, Extirpated, Endangered, Threatened, or Special Concern.

The 2008 surveys documented 29 occurrences of 10 BCMOE-listed lichen species. The 29 occurrences were primarily in non-wetland habitats. No SARA Schedule 1 lichens were found, and no lichens listed by COSEWIC as Extinct, Extirpated, Endangered, Threatened, or Special Concern were located.

13.2.3 Vegetation Use by Aboriginal Groups

Traditional Land Use studies prepared for the Project indicate that Aboriginal groups currently harvest plants and earth resources in the LAA for medicinal, subsistence and cultural purposes (Candler 2012; Bouchard and Kennedy 2011; Bouchard and Kennedy 2012a; Bouchard and Kennedy 2012b; Nesoo Watchie Resource Management Ltd 2011). Table 13.6 lists the species harvested by Aboriginal groups and the ecosystem in which they are found. Harvesting of plants for traditional purposes is considered in the assessment of the potential effects of the Project on Current Use of Lands and Resources for Traditional Purposes, which is found in Volume 3 Section 19.

Table 13.6 Aboriginal Plant Species of Interest Occurrence in Terrestrial Ecosystems

Plant species	Terrestrial Ecosystem
Bearberry	This species was not recorded during ecosystem mapping surveys
Blackberry	This species was not recorded during ecosystem mapping surveys.
Blueberry	Upland and riparian forests
Bulrush	This species was not recorded during ecosystem mapping surveys.
Chokecherry	Upland forests, grasslands
Cloudberry	Forested wetland
Cow parsnip	Moist forests and Avalanche tracks
Cranberry	Upland and riparian forests and forested wetland
Huckleberry	Upland forests
Labrador Tea	Westland
Mint	This species was not recorded during ecosystem mapping surveys
Peppermint	This species was not recorded during ecosystem mapping surveys
Raspberry	Upland forest, riparian forests and forested wetlands
Rat root	This species was not recorded during ecosystem mapping surveys
Rose	Upland and riparian forests and forested wetland
Saskatoon berry	Upland forest
Sage	Cutbanks
Soapberry	This species was not recorded during ecosystem mapping surveys
Nettle	Floodplain forests and Avalanche tracks
Wild strawberry	Upland forest
Wild onion	Grasslands
Wild potatoes	This species was not recorded during ecosystem mapping surveys

13.3 Effects Assessment

Section 11.2.4 of the EIS Guidelines states that the assessment of potential adverse effects to the vegetation and ecological communities VC will take into account the potential for the Project to result in changes to the following key aspects:

- The area of vegetation/ecological community loss, assessed by overlaying the project activity zone on the ecosystem maps and conducting a GIS-based analysis of the area lost due to project activities
- The area of vegetation/ecological community fragmentation, identified through GIS analysis
- The area of temporary vegetation/ecological community disturbance will be assessed by overlaying the project activity zone on the ecosystem maps and conducting a GIS-based analysis of the area disturbed
- The long-term effects of maintenance of vegetation/ecological communities in an early seral stage along the transmission line and around the dam site
- Wetlands

These key aspects are considered under one general effect – habitat alteration and fragmentation – which covers both the temporary and permanent loss, and the fragmentation of vegetation and ecological communities, including wetlands.

An analysis based on the Geographical Information System (GIS) provides a quantitative assessment, measuring change within the LAA by overlaying the Project activity zone with ecosystem mapping and known spatial locations of ecosystems and specific rare plant populations (see Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report).

Vegetation and ecological communities and rare plant populations in the LAA adjacent to any Project components may still be changed through edge effects associated with fragmentation, spread of invasive species, or changes in hydrology, but the exact spatial extent of any change is difficult to quantify. A qualitative assessment of changes in the condition of a community and rare plants due to these stresses – including long-term maintenance of the transmission line right-of-way – is considered.

13.3.1 Effects Assessment – Habitat Alteration and Fragmentation during Construction and Operations

Habitat alteration for vegetation is defined as a temporary or permanent removal or loss of habitat or a reduction in habitat suitability. Fragmentation involves the ‘separation’ of habitat patches into one or more pieces – a process that requires some portion of the original habitat patch or rare plant occurrence to be lost or transformed into a less favourable or inhospitable habitat.

For the Project, the greater potential for changes to terrestrial ecosystems and rare plants would be expected to occur during the construction phase. Habitat alteration through clearing of vegetation and grubbing during site preparation would be predominant during the early stages. As construction proceeds, water diversion associated with dam construction has the potential to change flow regimes on the Peace River (see Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background for more details), which may change occurrences along the river margins. In the final stages of construction, reservoir filling would change the occurrence of terrestrial ecosystems and rare plants through inundation of existing habitats. Occurrences within the proposed reservoir would be inundated during filling, while those near the new shoreline could experience changes to their supporting habitats.

Clearing activities have the potential to indirectly change nearby occurrences and habitat not directly located within the Project activity zone. These include:

- Increased competition with invasive plant species introduced or dispersed by site clearing activities
- Contamination from road salt, herbicide, silt, or accidental spills of industrial fluids
- Changes to hydrologic regimes – drying of wetlands, flooding of uplands – due to vegetation clearing, road building, and ground disturbance nearby
- Increased dust deposition on leaves and floral parts due to vegetation clearing and grubbing activities
- Increased incidental human disturbance with foot and vehicle traffic

During the operations phase, most of the adverse changes to terrestrial ecosystems and known rare plant occurrences would have already occurred. Maintenance of the various Project components could alter adjacent occurrences or sites where new populations have become established. Some Project components – such as the transmission line right-of-way – will be maintained in a grass-shrub successional stage. Periodic brushing and herbicides will be used to limit tree growth. Elimination of the tree layer will prevent development or recovery of forested rare ecosystems.

Operation of the dam is expected to result in changes to the surface water regime downstream. These conditions would be similar to the conditions currently experienced downstream of the Peace Canyon Dam (see Volume 2 Appendix D Surface Water Regime Technical Memos), and would be dampened by flow attenuation and tributary inputs – especially from the Pine River. The operational releases of the Peace Canyon Dam are bounded by the minimum flow requirement of 283 m^3/s and the maximum licensed discharge of 1,982 m^3/s. The proposed minimum flow for the Project is 390 m^3/s and the proposed maximum turbine discharge capacity is about 2,520 m^3/s. The range of operational releases is 1,699 m^3/s under existing conditions, and would be approximately 2,130 m^3/s with the Project. The measurable changes are greatest in the approximate 16 km section of the Peace River between the proposed Site C dam and the Pine River confluence. With more frequent high and low flows, and associated wetted and dewatered areas, shoreline occurrences of rare plants and rare and sensitive ecosystems could be changed. See Section 12.4.2.2 in Volume 2 Section 12 Fish and Fish Habitat for a comparison of Peace River wetted surface areas from the proposed Site C dam to the Pine River confluence. For rare plants, it is difficult to predict in what manner a particular species will be affected, since the disturbance responses for most rare plants have not been documented. Certain rare plant species will tolerate a high level of ground or vegetation disturbance; other rare plant taxa require an undisturbed environment and quickly decline when the habitat is degraded or disturbed. Because no empirical data on disturbance response for any of the rare plants could be located, it was assumed any Project-related activity that would change any environmental parameter within an occurrence would have an interaction. While this is likely a conservative assumption, the analysis takes a precautionary approach in the absence of scientific consensus.

13.3.1.1 Terrestrial Ecosystems

Within the LAA there are 86,424 ha of land represented by 60 different ecosystem units, although some of the same nonvegetated-anthropogenic ecosystem units occur in different sub-zone variants. The Project components overlap over 15,000 ha, with the majority of the ecosystem units losing less than 15% of the total available within the LAA. The ecosystems more prominently represented within the LAA, which have the largest proportional loss, are the valley bottom forest and the riparian wetland types that overlap with the reservoir. The total amount of each ecosystem affected is provided in Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report, Part 1 Vegetation and Ecological Communities.

Road construction is often cited as a cause of fragmentation of natural habitat (Reed et al. 1996; Findlay and Bourdages 2000; Carr et al. 2002; Hansen and Clevenger 2005). The construction of the road itself replaces a portion of the original habitat with nonvegetated road surface, roadbed material, and any associated drainage structures. Road construction has other consequences beyond loss of habitat. Corridors such as roads are colonization sites and dispersal routes for exotic species – in part because of reduced competition from native species not adapted to the conditions of disturbed habitat (Vankat and Roy 2002). Weed seeds are carried by vehicles and distributed along roadsides (Hansen and Clevenger 2005; Parendes and Jones 2000; Watkins et al. 2003). Habitat edges close to roadsides may function like corridors to facilitate further spread of exotics away from roads and into undisturbed areas (Vankat and Roy 2002).

Fragmentation as a result of the Project has been assessed by quantifying the amount of new permanent road to be constructed (Table 13.7).

Table 13.7 Length of New Permanent Road Associated with the Project

Description	Linear Length (km)
Highway 29 realignment	30.2
Jackfish Lake Road extension	32.6
Old Fort Road	1.0
Total	**63.7**

Most of the linear disturbances associated with the Project are located along existing roadways, an existing railway line, an existing transmission line corridor, or within habitat already affected by human activities – such as Cultivated Field – so the extent of new fragmentation is limited. Of the 64 km of new permanent roads that would be constructed by the Project, nearly half is associated with the realignment of Highway 29 where the new alignments would pass through a number of cultivated fields, thereby limiting further habitat fragmentation. The remaining sections of new permanent roads would be located to the south of the Peace River along an extension of the Jackfish Lake Road. This new segment would be built adjacent to the existing corridor for the transmission line and railway. It passes through a variety of terrestrial habitats – including a number of wetlands in the eastern portion – as it approaches the dam site, thereby contributing to fragmentation of these habitats.

Rare Ecological Communities

Summaries of the area affected within Project activity zone that were mapped as ecosystem units associated with rare communities are presented in Table 13.8. Losses of rare ecological communities due to construction in forested sites within the BWBSmw in the LAA, include: 27% of the blue-listed 05/SO – White spruce/Oak fern – Wild sarsaparilla; 44% of the blue-listed 07/SH – White spruce/Red swamp currant/Horsetails; and 42% of the blue-listed 09/Fm02 – Balsam poplar – White spruce/Mountain alder – red-osier dogwood. In addition, construction activities have the potential to affect over 12% of the available Sedge wetland (00/SE) in the BWBSmw, which is associated with four listed ecological communities, and 13% of the Willow sedge wetland (00/WS), which is associated with one listed ecological community. A portion of this potential loss would be caused by the construction of the transmission line. Losses may be mitigated if transmission towers were placed to avoid wetland habitat. Potential interactions may still occur if construction results in changes in hydrology or sediment runoff.

Additional ecological community loss would also occur during operation, with bank erosion along the reservoir.

Table 13.8 Areas of Ecosystem Units Associated with Rare Communities Potentially Affected by the Project

Ecosystem Unit (Associated Rare Community)	Total Area in LAA (ha)	Area (ha) Within the Project Activity Zone							Phase
		Dam	Reservoir	Transmission Line	Highway 29	Roads	Quarry	Total	
BWBSmw1									
00/SE (Arctic rush - Nuttall's alkaligrass – Seablite) (Mat muhly - Arctic rush - Nevada bluegrass) (Common cattail marsh) (Scrub birch /Water sedge)	1,169	40	47	35	0	19	1	142	Construction
		0	< 1	54	0	0	0	55	Operations
00/WS (Scrub birch /Water sedge)	363	3	28	14	0	5	0	50	Construction
		0	0	16	0	0	0	16	Operations
05/SO (White spruce/Oak fern – Wild sarsaparilla)	1,215	22	296	4	<1	5	0	328	Construction
		0	117	4	0	0	0	121	Operations
07/SH (White spruce/Red swamp currant/ Horsetails)	1,699	18	716	5	< 1	3	< 1	743	Construction
		0	18	5	0	0	0	23	Operations

Ecosystem Unit (Associated Rare Community)	Total Area in LAA (ha)	Area (ha) Within the Project Activity Zone							Phase
		Dam	Reservoir	Transmission Line	Highway 29	Roads	Quarry	Total	
08/BT (White spruce - Black spruce /Labrador tea/Glow moss) (Black spruce/ Common horsetail/ Peat-mosses) (Black spruce/ Lingonberry/ Peat-mosses)	2,051	7	13	54	0	19	< 1	93	Construction
		0	< 1	58	0	0	0	58	Operations
09/Fm02 (Balsam poplar – White spruce /Mountain alder – red-osier dogwood)	2,664	36	1,080	0	1	< 1	0	1,117	Construction
		0	18	0	0	0	0	18	Operations
10/TS (Tamarack/ Water sedge /Golden fuzzy fen moss)	1,405	13	13	32	0	9	< 1	68	Construction
		0	0	47	0	0	0	47	Operations
BWBSwk1									
04/SW (White spruce – Lodgepole pine/ Soopolallie/ Showy aster)	52	0	0	0	0	0	23	23	Construction
SBSwk2									
00/Wf13 (Narrow-leaved cotton-grass – Shore sedge)	9	0	0	0	0	< 1	< 1	< 1	Construction
02/LH (Lodgepole pine/Black huckleberry/ Reindeer lichens)	70	0	0	0	0	0	25	25	Construction

Sensitive Ecological Communities

Tufa Seeps and Marl Fens

Five of the seven tufa seeps within the LAA would be directly affected. The marl fen at Watson Slough would be inundated by the reservoir and lost. Of the two remaining tufa seeps, one would be crossed by the proposed transmission line and the other would be immediately outside the reservoir.

Old Growth

A summary of area in hectares of structural Stage 7 forest within the LAA and potentially affected by the Project is presented in Table 13.9. Project construction and operations would remove less than 5% of the old growth mapped in the LAA. During operations, losses of old growth may result from bank erosion.

Table 13.9 Area of Structural Stage 7 Affected by the Project

Total Area (ha) in LAA	Hectares in Project Activity Zone							
	Dam	Reservoir	Transmission Line	Highway	Roads	Quarry	Total	Phase
1,135	0	39	0	0	0	4	43	Construction
		3	0	0	0	0	3	Operations

Grasslands

A summary of area in hectares of grassland within the LAA and potentially affected by the Project is presented in Table 13.10. Slightly over 10% of the grassland mapped in the LAA would be lost due to the Project, during filling of the reservoir – 86 ha – with an additional 101 ha expected to be lost during operations, due to bank erosion.

Table 13.10 Area of Grassland Affected by the Project

	Hectares in Project Activity Zone							
Total Area (ha) in LAA	Dam	Reservoir	Transmission Line	Highway	Roads	Quarry	Total	Phase
2,667	44	86	8	27	4	0	169	Construction
	0	101	7	0	0	0	108	Operations

Wetlands

A summary of the total area in hectares of wetlands within the LAA and potentially affected by the Project is presented in Table 13.11. The total area of wetlands directly affected due to Project construction would be 675 ha. The greatest proportional loss of vegetated wetlands is to the WH riparian wetland, primarily found along the margins and backchannels of the Peace River. An additional 121 ha of wetland has the potential to be affected during operations, but this would depend on vegetation maintenance activities where the transmission line right-of-way already exists. It should be noted that a portion of this change is due to the transmission line. If the line is constructed to pass over the wetlands and towers are not placed within them, there may be little direct change, although indirect changes from changes in hydrology or sediment runoff are still possible.

Table 13.11 Wetland Area Affected by the Project

Ecosystem Unit	Total Area (ha) in LAA	Hectares in Project Activity Zone							Phase
		Dam	Reservoir	Transmission Line	Highway 29	Roads	Quarry	Total	
BWBSmw1									
00/OW Open water	75	2	14	< 1	0	< 1	0	17	Construction
		0	0	1	0	0	0	1	Operations
00/PD Pond	34	0	4	< 1	0	< 1	< 1	5	Construction
		0	< 1	2	0	0	0	2	Operations
00/SE Sedge Wetland	1,169	40	47	35	0	19	1	142	Construction
		0	< 1	54	0	0	0	55	Operations
00/WH Willow - Horsetail - Sedge - Riparian Wetland	1,010	1	391	< 1	0	0	0	392	Construction
		0	<1	< 1	0	0	0	1	Operations
00/WS Willow-Sedge Wetland	363	3	28	14	0	5.0	0	50	Construction
		0	0	16	0	0.0	0	16	Operations
10/TS Tamarack - Sedge - Fen	1,405	13	13	32	0	9	<1	68	Construction
		0	0	47	0	0	0	47	Operations
SBSwk2									
00/Wf13 Narrow-leaved cotton-grass-Shore Sedge	9	0	0	0	0	< 1	< 1	< 1	Construction

13.3.1.2 Rare Plants

In total, 142 BCMOE-listed vascular plant occurrences have the potential to be changed by the Project. The large majority – 122 – are expected to be lost during construction (Table 13.12).

Table 13.12 Rare Vascular Plant Occurrences Potentially Affected During Construction

Species	Dam	Reservoir	Transmission Line	Highway 29	Roads	Quarry	Total
Anemone virginiana var. cylindroidea (riverbank anemone)	2	8	0	2	0	1	**13**
Arnica chamissonis ssp. incana (meadow arnica)	0	2	2	0	0	0	**4**
Artemisia herriotii (western mugwort)	0	15	0	0	0	0	**15**
Calamagrostis montanensis (plains reedgrass)	3	0	0	0	0	1	**4**
Carex heleonastes (Hudson Bay sedge)	0	1	0	0	0	0	**1**
Carex sychnocephala (many-headed sedge)	0	1	0	0	0	0	**1**
Carex tenera (tender sedge)	0	5	0	0	0	0	**5**
Carex torreyi (Torrey's sedge)	0	0	0	0	0	1	**1**
Carex xerantica (dry-land sedge)	0	0	0	0	0	1	**1**
Chrysosplenium iowense (Iowa golden-saxifrage)	0	1	1	0	0	0	**2**
Cicuta virosa (European water-hemlock)	1	0	2	0	3	0	**6**
Cirsium drummondii (Drummond's thistle)	2	4	1	0	0	0	**7**
Epilobium halleanum (Hall's willowherb)	0	1	0	0	0	0	**1**
Epilobium saximontanum (Rocky Mountain willowherb)	0	1	0	0	0	0	**1**
Galium labradoricum (northern bog bedstraw)	0	1	2	0	0	0	**3**
Glyceria pulchella (slender mannagrass)	0	1	0	0	0	0	**1**
Helictotrichon hookeri (spike-oat)	2	0	0	0	0	1	**3**
Juncus arcticus ssp. alaskanus (arctic rush)	0	4	0	0	0	0	**4**
Malaxis brachypoda (white adder's-mouth orchid)	0	0	1	0	0	0	**1**
Muhlenbergia glomerata (marsh muhly)	0	1	0	0	0	0	**1**
Oxytropis campestris var. davisii (Davis' locoweed)	0	8	0	0	0	0	**8**
Pedicularis parviflora ssp. parviflora (small-flowered lousewort)	0	0	1	0	0	0	**1**
Polypodium sibiricum (Siberian polypody)	0	0	0	0	0	2	**2**
Salix serissima (autumn willow)	0	1	0	0	0	0	**1**
Schizachyrium scoparium (little bluestem)	0	1	0	0	0	0	**1**

Species	Dam	Reservoir	Transmission Line	Highway 29	Roads	Quarry	Total
Silene drummondii var. drummondii (Drummond's campion)	0	1	0	0	0	2	**3**
Sphenopholis intermedia (slender wedgegrass)	1	2	0	0	0	0	**3**
Symphyotrichum puniceum var. puniceum (purple-stemmed aster)	2	3	14	0	7	0	**26**
Trichophorum pumilum (dwarf clubrush)	0	1	0	0	0	0	**1**
Utricularia ochroleuca (ochroleucous bladderwort)	0	0	0	0	1	0	**1**
Total	**13**	**63**	**24**	**2**	**11**	**9**	**122**

The reservoir would remove 63 known rare vascular plant occurrences. Many species were principally found in this area and include riverbank anemone (*Anemone virginiana* var. *Cylindroidea)*, western mugwort (*Artemisia herriotii)*, tender sedge (*Carex tenera)*, arctic rush (*Juncus arcticus* ssp. *Alaskanus)*, and Davis' locoweed (*Oxytropis campestris* var. *Davisii)*. The Watson Slough wetland complex is the only known location in the LAA of six rare taxa that includes Hudson Bay sedge (*Carex heleonastes)*, many-headed sedge (*Carex sychnocephala)*, slender mannagrass (*Glyceria pulchella)*, marsh muhly (*Muhlenbergia glomerata)*, autumn willow (*Salix serissima)*, and dwarf clubrush (*Trichophorum pumilum)*.

The dam site would affect 13 known rare plant occurrences. Two of the species – spike-oat (*Helictotrichon hookeri*) and plains reedgrass (*Calamagrostis montanensis*) – are restricted to grassland habitats, while the other five species were found in varied habitats. It is expected that habitat alteration would result in the extirpation of most of the rare plant occurrences within the dam site. Depending on the extent and intensity of the vegetation clearing in this area, some occurrences may survive. As construction proceeds, changes due to dust deposition, additional vegetation clearing, and other construction-related activities would further reduce the viability of these remaining occurrences.

Nine rare vascular plant occurrences are known from the proposed quarry locations. Specifically, the occurrences are located at the 85th Avenue Industrial Lands, Area E, and Portage Mountain sites. One of the species – Siberian polypody (*Polypodium sibiricum)* – was not found anywhere else in the LAA. The species was found only on cliffs at the Portage Mountain site. The total area affected by quarry developments is considered to be an overestimate, as the Project activity zone associated with some of the quarries is larger than what is anticipated.

Only two known rare vascular plant occurrences are situated along the Highway 29 realignment sections. These are both riverbank anemone occurrences associated with upland habitats. Other road developments could affect 11 known rare plant occurrences. The 11 occurrences were of three different wetland species: European water-hemlock (*Cicuta virosa)*, purple-stemmed aster (*Symphyotrichum puniceum* var. *Puniceum)*, and ochroleucus bladderwort (*Utricularia ochroleuca)*. Direct changes to rare plant occurrences in these areas would begin with vegetation clearing and grubbing to prepare the highway realignment sections. Construction activities could alter adjacent suitable rare plant habitat due to increased dust, altered hydrology, and increased competition from invasive plants. Finally, revegetation and reclamation efforts may alter community structure, affecting the quality of rare plant habitat.

Twenty-four BCMOE-listed vascular plant occurrences are known along the transmission line right-of-way. The majority of these are located in wetland habitats within and adjacent to the existing cleared right-of-way. Over half of the 24 occurrences are purple-stemmed aster, which occurs in large numbers within the existing right-of-way. Two species – white adder's-mouth orchid (*Malaxis brachypoda)* and small-flowered lousewort (*Pedicularis parviflora* ssp. *parviflora*) – were found nowhere else in the LAA. Construction interactions with rare plants along the transmission line are particularly complex and difficult to predict, due to the diffuse and transitory nature of the activities. It is expected that many of the rare plant occurrences will be affected during the initial vegetation clearing and widening of the right-of-way. Many of the existing occurrences are located in the currently cleared right-of-way and would be expected to at least partially survive clearing if it is similar to the current ongoing maintenance along the line.

Tower placement and line stringing activities could interact with existing rare plant occurrences and potential habitat both directly (e.g., trampling, hydrologic modification) and indirectly (e.g., increased invasive species potential, increased dust deposition). The level of interaction depends on where the activities occur. Reclamation and restoration activities post-construction would alter community structure, thereby altering the suitability of the rare plant habitat and affecting the viability of some occurrences. Only two additional known rare plant occurrences are located along the existing transmission line right-of-way, but are outside the construction zone of influence. These two species are Hall's willowherb (*Epilobium halleanum*) and northern bog bedstraw *(Galium labradoricum)*.

The 20 additional rare plant occurrences potentially interacting with the Project during operations are mostly located downstream of the dam along the river margin. Eight occurrences are western mugwort and three are riverbank anemone. Seven occurrences are composed of six other river corridor-associated species. Rare plant changes downstream are primarily related to changes in the hydrologic regime. Changes to daily and seasonal flow patterns could alter downstream vegetation, potentially altering the viability of rare plant occurrences and changing the suitability of the habitat. In addition, indirect changes to downstream rare plant occurrences could result from sedimentation, increased competition with invasive species, and changes to water quality. These indirect changes are expected to lessen with distance downstream from the dam site. Table 13.13 summarizes the rare plant occurrences potentially affected during operations.

Table 13.13 Rare Vascular Plant Occurrences Potentially Affected During Operations

Species	Transmission Line	Downstream	Total
Anemone virginiana var. cylindroidea (riverbank anemone)	0	3	3
Artemisia herriotii (western mugwort)	0	8	8
Atriplex gardneri var. gardneri (Gardner's sagebrush)	0	1	1
Eleocharis elliptica (elliptic spike-rush)	0	1	1
Epilobium halleanum (Hall's willowherb)	1	0	1
Epilobium saximontanum (Rocky Mountain willowherb)	0	1	1
Galium labradoricum (northern bog bedstraw)	1	0	1
Juncus confusus (Colorado rush)	0	2	2
Oxytropis campestris var. davisii (Davis' oxytrope)	0	1	1
Penstemon gracilis (slender penstemon)	0	1	1
Total	**2**	**18**	**20**

As a result, the construction and operation of the Project has the potential to cause an effect on vegetation and ecological communities by the e alteration and fragmentation of habitat, for the terrestrial ecosystems and rare plants discussed above.

13.3.2 Mitigation Measures – Habitat Alteration and Fragmentation

To reduce adverse Project effects to terrestrial ecosystems and rare plants, three general categories of mitigation were applied: 1) avoidance, 2) reduction, and 3) compensation.

Avoidance of habitat loss is the avoidance of direct or indirect effects to known rare plant occurrences and rare and sensitive ecosystems through changes to the design of the Project (see Section 4.2 Project Evolution in Volume 1 Section 4 Project Description) or of construction and operations methods. Through the implementation of avoidance measures – discussed in more detail below – effects to a specific occurrence are eliminated within the site-specific areas where they are applied. Complete avoidance of a rare plant occurrence or habitat is feasible for the placement of select new temporary access roads; some existing access road sections where vegetation disturbance is planned; areas along the transmission line corridor; and some limited-activity areas at the dam site.

Effect reduction is the lessening of direct and indirect effects to rare and sensitive occurrences through the targeted modification of construction and operations methods, and possibly translocation. Translocation, which is the removal of live rare plant individuals or propagules – e.g., seeds, spores, shoots – from the Project activity zone, and their subsequent re-establishment at another location. This can occur directly – the individual is removed and then immediately transplanted to the new habitat, or indirectly – through an intermediary nursery or seed bank.

Compensatory mitigation is the protection and enhancement of off-site suitable rare and sensitive occurrences as compensation for habitat lost or degraded due to the Project. This can be in-kind – off-site habitat that is similar to that lost within the Project activity zone, or out-of-kind – off-site habitat that is different from that lost within the Project activity zone. Compensatory mitigation is most appropriate for areas where avoidance and reduction are not feasible, such as the reservoir, intensive work areas at the dam site, and quarries. Within compensatory mitigation, basic research into the distribution or taxonomy of rare plant species that are affected by the Project can also be explored. The additional knowledge gained will assist in the development of more effective protection and recovery strategies for these rare plant species throughout their range.

The B.C. Ministry of Environment's Conservation Framework program provides a set of tools that prioritize and select appropriate conservation actions for rare species and ecosystems in the province (BCMOE 2012a). The relevant Conservation Framework outputs for the vascular plant species that are expected to be directly affected by the Project are presented in Table 13.14. The Conservation Framework priorities and action groups will be considered when applying mitigation.

Table 13.14 Rare Vascular Plant Occurrences and Conservation Framework Priorities

Species	Total [a]	Provincial List	Conservation Framework Priority [b]	Conservation Framework Action Groups [c]
Atriplex gardneri var. gardneri (Gardner's sagebrush)	1	Red	1	Plan; Private Land; Habitat Protect; Habitat Restore; COSEWIC; *Wildlife Act*; Status Report; Inventory
Cirsium drummondii (Drummond's thistle)	7	Red	1	Inventory; Status Report; Plan; *Wildlife Act*; COSEWIC; Habitat Restore; Habitat Protect; Private Land
Juncus confusus (Colorado rush)	2	Red	1	Inventory; Status Report; *Wildlife Act*; COSEWIC; Plan; Private Land; Habitat Protect; Habitat Restore
Schizachyrium scoparium (little bluestem)	1	Red	1	Inventory; Status Report; *Wildlife Act*; COSEWIC; Plan; Private Land; Habitat Protect; Habitat Restore
Anemone virginiana var. cylindroidea (riverbank anemone)	16	Blue	2	Inventory
Carex sychnocephala (many-headed sedge)	1	Blue	2	Monitor Trends
Carex torreyi (Torrey's sedge)	1	Blue	2	Inventory
Chrysosplenium iowense (Iowa golden-saxifrage)	2	Blue	2	Inventory
Epilobium halleanum (Hall's willowherb)	2	Blue	2	Inventory
Epilobium saximontanum (Rocky Mountain willowherb)	2	Red	2	Inventory
Galium labradoricum (northern bog bedstraw)	4	Blue	2	Inventory

Species	Total [a]	Provincial List	Conservation Framework Priority [b]	Conservation Framework Action Groups [c]
Helictotrichon hookeri (spike-oat)	3	Blue	2	Inventory
Oxytropis campestris var. davisii (Davis' locoweed)	9	Blue	2	No New Action
Penstemon gracilis (slender penstemon)	1	Red	2	Inventory; Status Report; *Wildlife Act*
Polypodium sibiricum (Siberian polypody)	2	Red	2	Inventory
Salix serissima (autumn willow)	1	Blue	2	Inventory
Symphyotrichum puniceum var. puniceum (purple-stemmed aster)	26	Blue	2	Inventory
Arnica chamissonis ssp. incana (meadow arnica)	4	Blue	3	No New Action
Carex heleonastes (Hudson Bay sedge)	1	Blue	3	No New Action
Carex tenera (tender sedge)	5	Blue	3	No New Action
Carex xerantica (dry-land sedge)	1	Red	3	Inventory
Cicuta virosa (European water-hemlock)	6	Blue	3	No New Action
Eleocharis elliptica (elliptic spike-rush)	1	Blue	3	No New Action
Glyceria pulchella (slender mannagrass)	1	Blue	3	No New Action
Juncus arcticus ssp. alaskanus (arctic rush)	4	Blue	3	No New Action
Malaxis brachypoda (white adder's-mouth orchid)	1	Blue	3	No New Action
Trichophorum pumilum (dwarf clubrush)	1	Blue	3	No New Action
Utricularia ochroleuca (ochroleucous bladderwort)	1	Blue	3	Taxonomy
Calamagrostis montanensis (plains reedgrass)	4	Blue	4	Inventory
Muhlenbergia glomerata (marsh muhly)	1	Blue	4	Inventory
Pedicularis parviflora ssp. parviflora (small-flowered lousewort)	1	Blue	4	No New Action

Species	Total [a]	Provincial List	Conservation Framework Priority [b]	Conservation Framework Action Groups [c]
Silene drummondii var. drummondii (Drummond's campion)	3	Blue	4	No New Action
Sphenopholis intermedia (slender wedgegrass)	3	Blue	4	No New Action
Artemisia herriotii (western mugwort)	23	Red	6	No New Action
Total (34 species)	**142**			

NOTES:

[a] Total number of occurrences potentially affected during construction or operation

[b] Highest assigned priority of the three B.C. Conservation Framework goals

[c] Conservation action(s) required for the species according to the B.C. Conservation Framework (BCMOE 2012a)

COSEWIC (Send to COSEWIC): Send to COSEWIC for assessment as a first step to listing under the federal *Species at Risk Act* as Extirpated, Endangered, Threatened, or Special Concern or for assessment at a higher or lower risk category

Habitat Protect (Ecosystem and habitat protection): Use legislation, policies and guidelines to protect the ecological community or species' habitat. For example, *Forest & Range Practices Act*, protected areas, land use orders, stewardship, and best management practices. For species, may require research on habitat needs or inventory to determine suitable areas for protection.

Habitat Restore (Ecosystem and habitat restoration): Apply management and/or restoration techniques to maintain or restore the ecological community or species' habitat. Includes invasive species control, maintaining or restoring natural processes and key structures, fire suppression, and prescribed burnin

Inventory: Inventory the species or ecological community to confirm or determine status rank. May require research on inventory techniques.

Monitor trends: Monitor the species, its habitat, or the ecological community at an interval appropriate to the life history of the organism, or the successional development of the ecological community. May require research on monitoring techniques.

No new action: Existing management is effective; no additional conservation action is warranted. Assess whether ongoing programs need to be maintained. May require effectiveness evaluation of existing activities and monitoring of the species, habitat, or ecological community.

Plan (Planning): Includes preparing a Management Plan or Recovery Strategy and Action Plan, landscape planning, or updating an existing plan; also includes implementing and monitoring effectiveness of the plan and monitoring the effect on the species' population or habitat or an ecological community. May require research on threats, habitat use, mitigation or recovery techniques.

Private Land (Private land stewardship): This group contains a subset of ecosystems and species from the ecosystem and habitat protection and restoration action groups that are of conservation concern, but occur on private land and /or in situations outside the scope of more traditional legislation, policies, and formal guidelines

Status Report (Compile status report): Compile or update a status report. May require research on threats, trends, habitat use, life history, or demography.

Taxonomy (Review taxonomy and classification): Invest in taxonomic studies to determine taxonomic validity for species or invest in classification and correlation of newly identified ecological communities

***Wildlife Act* (List under *Wildlife Act*):** List under *Wildlife Act* as an Extirpated, Endangered or Threatened species. Includes describing residences as per the provisions of the act where warranted.

Table 13.15 describes specific mitigation measures for avoiding, reducing, and compensating for, the potential for the Project to alter and fragment habitat for terrestrial ecosystems and rare plants.

1 **Table 13.15 Mitigation Measures to Reduce Habitat Alteration and Fragmentation**

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
		Avoidance		
Construction	Habitat alteration and fragmentation: old growth, grasslands, and wetlands	Project design to date has located new proposed roads and other linear disturbances along existing disturbed areas as much as possible to minimize the effects of habitat loss. During final design, transmission towers and temporary roads will be placed away from wetlands and known rare plant occurrences where feasible. All known occurrences will be provided as inputs during the final design phase for consideration. If there is limited or no existing data to help facilitate avoidance measures, then supplemental pre-construction surveys will be conducted. If avoidance is not feasible, other mitigation measures will be considered, including effect reduction and compensation.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro
	Tufa seep, wetlands, and rare plants	An Environmental Protection zone will be established to protect occurrences located adjacent to construction areas. Signage will be added where necessary to indicate the boundaries of the exclusion area. Construction personnel will be required to attend a field-based orientation session where the exclusion areas will be explained, and the importance of avoiding disturbance within them will be stressed. This will form part of the Environmental Training Management Plan (Section 35.2.2.8 in Volume 5 Section 35 Summary of Environmental Management Plans).		
Construction	Habitat alteration and fragmentation: grasslands, wetlands, and rare plants	A Soil Management, Site Restoration, and Revegetation Plan (Section 35.2.2.19 in Volume 5 Section 35 Summary of Environmental Management Plans) will be developed. The plan will take into account the location of known occurrences, and will suggest the seed mixes and methods to avoid indirect loss or alteration to nearby occurrences.	Effective – these are standard measures that have been applied successfully in the past	BC Hydro
	Old growth, wetlands, and rare plants	Temporary construction access roads will be closed and reclaimed following construction. During construction, access roads will be controlled to limit use.		

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
Operations	Habitat alteration and fragmentation: wetlands and rare plants	A spatial database of known rare plant occurrences in the vicinity of Project components will be maintained and searched to avoid effects during operations and maintenance activities. The database will be actively updated as new information becomes available.	Effective – this process is currently used by BC Hydro	BC Hydro
		Reduction		
Construction	Habitat alteration and fragmentation: old growth, grasslands, wetlands, and rare plants	Efforts have been made during Project design to use existing access corridors, plan for deactivation of temporary access roads, and minimize disturbance to help limit additional fragmentation. Project components where this has occurred are listed below. • **Substation and Transmission Lines to Peace Canyon Dam:** Constructing the new transmission lines adjacent to the existing line, and using the existing corridor and maintenance access roads. • **Highway 29 Realignment:** Using portions of existing roads and selecting borrow sites that already exist or that would be eventually covered by the reservoir. • **Quarried and Excavated Construction Materials:** Further developing existing quarry sites (e.g., Wuthrich, Del Rio, and West Pine) and using a site that has already been affected by development (85th Avenue Industrial Lands). • **Construction Access Roads:** Use of existing infrastructure for moving material, upgrading existing access roads, and deactivation of temporary roads used for reservoir clearing, and placing the south bank access to the Dam Site along the existing transmission line corridor.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro
Construction	Habitat alteration and fragmentation: wetlands and rare plants	The construction methods used will take into account the location of known occurrences and high-suitability habitat. Where complete avoidance is not feasible, effect reduction will be considered. This can include timing construction activities to winter months, and surface protection measures such as placing ramps to reduce vehicle compaction within occurrences, or using rubber-tired versus tracked equipment to minimize ground disturbance.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Habitat alteration and fragmentation: grasslands, wetlands, and rare plants	The indirect effects associated with increased dust deposition are expected to be diffuse, and are not considered to threaten the continued viability of any known rare plant occurrences. Fugitive dust from construction activities will be minimized through the application of an Air Quality Monitoring and Dust Control Plan (Section 35.2.2.7 in Volume 5 Section 35 Summary of Environmental Management Plans).	Effective – these are standard measures that have been applied successfully in the past	BC Hydro
Construction and Operations	Habitat alteration and fragmentation: wetlands	Construction and maintenance activities in and around watercourses and wetlands will conform to BC Hydro's regulator-accepted practices including Approved Work Practices for Managing Riparian Vegetation (BC Hydro et al. 2003). An Agreement between BC Hydro, the B.C. Ministry of Environment, and Fisheries and Oceans Canada (BC Hydro et al. 2009) identifies other accepted work practices that are to be developed and available for use in the near future. Additional guidance will be used from Standards and Best Practices for Instream Works (B.C. Ministry of Water, Land and Air Protection 2004) and the Land Development Guidelines for the Protection of Aquatic Habitat (Chilibeck et al. 1992), which are designed to reduce sedimentation and avoid introduction of deleterious substances to aquatic environments. Maintaining surface flow patterns is important in the retention of functioning wetlands. Construction activities will be designed and carried out in a manner that seeks to maintain the hydrology of adjacent wetlands, particularly where known rare plant occurrences are present. Measures will be implemented to maintain existing hydrological patterns as much as possible, if roads cannot avoid wetlands. Culverts will be installed under access roads to maintain hydrological balance, and sedimentation barriers will be installed as needed.	Effective – these are standard measures that have been applied successfully in the past	BC Hydro

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Habitat alteration and fragmentation: wetlands	Stormwater management will be designed to control runoff and direct it away from work areas where excavation, spoil placement, and staging activities occur. Consideration for maintaining recharge levels to wetlands will be given when diverting water around work sites, providing there is not expected to be a measurable increase in sediment transport to these sensitive areas. Surface water quality management will be addressed in the Erosion Prevention and Sediment Control Management Plan (Section 35.2.2.9), Fisheries and Aquatic Habitat Management Plan (Section 35.2.2.10) and Emergency Response Plan (Section 35.2.1.1), all in Volume 5 Section 35 Summary of Environmental Management Plans.	Effective – these are standard measures that have been applied successfully in the past	BC Hydro
	Old growth, rare plants	A hierarchal decision matrix has been developed for reservoir clearing to reduce erosion potential along steep, unstable slopes and along riparian zones for all defined watercourses. Specifically the decision matrix includes: • Retention of all trees in on steep, unstable slopes that would be highly susceptible to landslides if the vegetation was removed • Retention of non-merchantable trees and vegetation in riparian areas within a 15 m buffer from the high water mark. Merchantable trees may still be removed using clearing practices to maintain a 15 m machine-free zone. These same standards will be employed in other work areas, and will follow BC Hydro's approved work practices.		

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction and Operations	Habitat alteration and fragmentation: old growth, grasslands, wetlands, and rare plants	All activities that involve potentially harmful or toxic substances such as oil, fuel, antifreeze, and concrete will follow approved work practices and consider the provincial BMP guidebook Develop with Care (BCMOE 2012b). All construction machinery and vehicles will be properly maintained to ensure that harmful fluids do not leak into aquatic environments or other sensitive areas. Prior to initiating construction activities in proximity to any water body, the hydraulic, fuel, and lubrication systems of all equipment will be checked to ensure that systems are in good condition and free of leaks. Biodegradable hydraulic fluids will be considered for machines used for in-stream works. All machines will have a spill kit, and operators will be educated its use. Maintenance and refuelling will be conducted at a designated area at an approved distance from watercourses. BC Hydro's fuel handling and storage management plan (Section 35.2.2.11 in Volume 5 Section 35 Summary of Proposed Environmental Management Plans) will include appropriate planning for fuel handling and storage, spill prevention, and emergency response.	Effective – these are standard measures that have been applied successfully in the past	BC Hydro
	Tufa seeps, grasslands, wetlands, and rare plants	A Vegetation and Invasive Plant Management Plan (Section 35.2.2.22 in Volume 5 Section 35 Summary of Proposed Environmental Management Plans) will be developed and implemented during the entire construction phase (including restoration) and integrated during operations. The plan will be designed using the locations of known rare plant or sensitive site occurrences and locations of high-suitability habitats as inputs. Weed control efforts will be coordinated with the rare plant botanists to ensure that effects to occurrences are avoided or reduced.		

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
	Grasslands, wetlands, and rare plants	Disturbed sites will be replanted quickly with ground cover, shrubs, or trees that are regionally appropriate once erosion concerns have been addressed. This will be part of BC Hydro's Soil Management, Site Restoration and Revegetation Plan (Section 35.2.2.19 in Volume 5 Section 35 Summary of Environmental Management Plans). Additional mitigation measures to reduce the spread of invasive species are described below. Prior to work commencing, surveys will be conducted to identify invasive species populations. Treatment will be initiated as required. All vehicles entering and leaving work sites will be washed thoroughly, with special attention to wheel wells, tire treads, and tracks where mud and seeds of noxious weeds may be lodged. Wash areas will be located away from any water body and riparian areas. Used wash water will be treated to prevent seed dispersal.		
	Old growth, wetlands and rare plants	BC Hydro has considerable experience managing and maintaining an extensive transmission line network within the province, including the existing transmission corridor along which the new lines will be constructed. The Integrated Vegetation Pest Management Plan for Transmission Line Rights-of-Way (BC Hydro 2010) will be followed in order to reduce or avoid the spread of invasive species during the operations phase of the transmission line and the Pest Management Plan For Management of Vegetation at BC Hydro Facilities (BC Hydro 2012b) will be used to manage invasive species at other Project facilities.		
Construction	Habitat alteration and fragmentation: rare plants	An experimental rare plant translocation program will be considered for suitable rare plant species found within the reservoir and other areas where Project components are certain to remove the populations. The translocation program will follow the B.C. Ministry of Environment's Guidelines for Translocation of Plant Species at Risk in British Columbia (Maslovat 2009). Translocation of endangered plants is generally thought to have a low likelihood of success and should be considered a follow-up monitoring opportunity, rather than a means to relocate occurrences to prevent their loss.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project; not practical for all species	BC Hydro

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
		Compensation		
Initiated during Construction	Habitat alteration and fragmentation: wetlands and rare plants	With the creation of the Project, BC Hydro will fund a compensation program. This program would include: • A survey of habitat enhancement projects in the RAA will be conducted to identify projects that might provide compensation for rare and sensitive habitats and protect occurrences of rare plants (e.g., wetlands). If suitable habitat enhancement projects can be found, BC Hydro will provide assistance (financial or in-kind) to the managing organization. The inventories will also identify areas that are under threat from development or in need of habitat enhancement. Where opportunities exist, BC Hydro will consider direct purchase – if offered for sale – and management of these lands to enhance or retain rare plant values. BC Hydro will also consider contributing to other protection options where direct purchase is not feasible. BC Hydro will fund or undertake targeted surveys in the RAA to locate additional occurrences of the 18 directly affected rare plant species that the Conservation Framework identifies as requiring additional inventories (Table 13.14). Full element occurrence data will be collected and transmitted to the B.C. Conservation Data Centre for each additional occurrence found.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project. but effective where practicable	BC Hydro
		The proponent will fund or undertake a study in an attempt to clarify the taxonomy of ochroleucus bladderwort. This is the only species of the 34 directly affected taxa for which the Conservation Framework identifies further taxonomic research as being required for its conservation. The study plan will be developed in consultation with the B.C. Conservation Data Centre and may include field, herbaria, and genetic work.	Effectiveness is low for the Project during construction. but knowledge gained could be beneficial if applied during operations or could be applied to other future projects	

13.3.2.1 Other Mitigation Options Considered

Avoidance and reduction measures have been employed to reduce wetland loss but removing Watson's Slough and the associated marl fen from the reservoir is not technically or economically feasible. Protection of Watson's Slough from inundation from the reservoir would have required a large berm several metres in height. The effectiveness of such a berm would be uncertain, and seepage from the reservoir and input from natural springs may have affected the slough.

13.4 Residual Effects

13.4.1 Characterization of Residual Effects

Although the mitigation measures summarized above would reduce the effect to vegetation and ecological communities, a residual adverse effect remains. This is particularly the case with the reservoir, dam site, and quarries, where the direct effect of habitat alteration and fragmentation cannot be avoided or reduced.

As a result, the construction and operation of the Project is likely to result in a residual adverse effect on vegetation and ecological communities by the alteration and fragmentation of habitat for the terrestrial ecosystems and rare plants discussed above, specifically:

- Loss of riparian forests, specifically loss of 44% of the blue-listed 07/SH – White spruce/Red swamp currant/Horsetails and 42% of the blue-listed 09/Fm02 – Balsam poplar – White spruce/Mountain alder – red-osier dogwood in the LAA
- Loss of rare and sensitive ecosystems such as tufa seeps – five of seven occurrences will be lost, and marl fens
- Loss of 675 ha of wetlands
- Loss of 122 rare plant occurrences

The characterization of the residual Project effect assumes that the specific mitigation measures described above are all implemented.

The criteria used to characterize residual adverse effects are provided in Table 13.16.

Table 13.16 Characterization Criteria for Residual Effects on Vegetation and Ecological Communities

Criterion	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The ultimate long-term trend of the effect relative to baseline case.	**Negative:** Condition of the VC is worsening in comparison to baseline conditions
		Positive: Condition of the VC is improving in comparison to baseline conditions
Magnitude	The amount of change in a key indicator or variable relative to baseline case.	**Low:** Less than 10% change
		Moderate: Between 10% and 20% change
		High: Greater than 20% change
Geographical Extent	The geographic area in which an environmental effect of a defined magnitude occurs.	**Site-specific:** The extent of the effect will have sub-local implications to key indicators
		Local: The extent of the effect will have sub-population implications to key indicators within the LAA
		Regional: The extent of the effect will have broader population implications to key indicators
Duration	The period of time required until the VC returns to its baseline condition, or the effect can no longer be measured or otherwise perceived.	**Short-term:** Effect is limited to <1 year
		Medium-term: Effect occurs >1 year but only during construction
		Long-term: Effect lasts into operation but dissipates during the life of the Project
		Permanent: Effect lasts during the life of the Project and possibly beyond
Frequency	The number of times during a project or a specific project phase that an environmental effect may occur.	**Once:** Occurs once
		Continuous: Occurs on a regular basis and at regular intervals
		Weekly: Occurs on a regular basis within one month but is sporadic throughout a year
		Monthly: Occurs on a regular basis for more than a month but is sporadic throughout a year
Reversibility	The degree or likelihood to which existing baseline conditions can be regained after factors causing the effect are removed.	**Reversible** with reclamation and/or over time
		Irreversible over time, even with reclamation
Context	The extent to which the area effected has already been adversely affected by human activities, and is ecologically fragile with little resilience and resistance to imposed stresses.	**High resilience:** Area or key indicator persists when it is subjected to frequent natural or anthropogenic disturbances
		Low resilience: Area is relatively pristine with little or no recent disturbance, or the key indicator requires long-term ecosystem stability in order to thrive
Level of Confidence	An evaluation of the scientific certainty in the review of Project-specific data, relevant literature, and professional opinion.	**Low:** The effectiveness of mitigation or scale of the effect is poorly understood; follow-up monitoring is recommended
		Moderate: Greater certainty in understanding an effects outcome but reflective of modelling confidence and an understanding of effect pathways
		High: Detailed mapping and an understanding of effect pathways are well understood
Probability	The likelihood that an adverse effect will occur	**Low:** An effect is unlikely to occur
		High: An effect is likely to occur

The duration of the residual adverse effect on vegetation and ecological communities ranges from long term to permanent. This reflects the fact that changes in riparian forests will likely extend beyond the life of the Project while changes to some rare plant populations—those currently occurring in disturbed areas such as the transmission line—are expected to dissipate during the life of the Project. The magnitude of the effect of habitat alteration and fragmentation on terrestrial ecosystems, rare and sensitive ecological communities and rare plants occurrences varies depending on the indicator, with some changes greater than 20% and some less than a 10% resulting in a characterization of low to high magnitude. Geographic extent of the residual effect ranges from local to regional. The extent of the change to terrestrial ecosystems and wetlands is local, that is, within the LAA. The change to rare ecological communities and rare plants may extend outside the LAA because of their limited range and low number of occurrences, the consequences of which are of regional importance. There is a low level of confidence about the scale of the effect and effectiveness of measures to mitigate the potential loss of rare plants. Context varies between low and high depending on the species. Some rare plant populations are highly resilient and can exist in disturbed areas such as the transmission line while others are less resilient to disturbance. Similarly the level of confidence ranges from low to moderate reflecting the varying degree of knowledge and understanding of how rare and sensitive ecological communities and rare plant populations will respond to the initial habitat alteration and fragmentation and subsequent mitigation.

Characterization of potential effects on the agricultural land base is shown in Table 13.17.

1 **Table 13.17 Characterization of Residual Effects on Vegetation and Ecological Communities**

Key Indicator	Residual Environmental Effect								
	Direction	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Context**	**Probability**	**Level of Confidence**
Habitat alteration and fragmentation	Negative	High-Low	Regional-Local	Permanent-Long-term	Once-Continuous	Irreversible-Reversible	Low and High resilience	High	Moderate-Low

13.4.2 Thresholds for Determining Significance

The significance of each residual environmental effect is evaluated, taking into consideration the above criteria, existing knowledge about the VC key indicators, and the expected effectiveness of the mitigation. The residual environmental effect of habitat alteration and fragmentation is significant if the effect could threaten extirpation of a key indicator, or result in considerable reductions to habitats associated with a key indicator that may in turn further elevate provincial or federal listings and cause the key indicator to be a management concern. This means that species or ecosystems that are:

1. Currently provincially or federally designated as, or considered candidates for, threatened or endangered status (e.g., provincially red-listed or SARA Schedule 1) and have a residual effects Magnitude characterized as High, or
2. Currently a lower listing (e.g., provincially blue-listed or SARA Schedule 1 special concern) and have a residual effects Magnitude characterized as High, which may result in the key indicator being elevated to a threatened or endangered status listing.

A number of rare plants and ecosystems are listed provincially but not federally. This could be solely based on the delineation of jurisdictional boundaries, or may be a result of provincial strategies for managing species and ecosystems at risk. So that both provincial and federal decision-makers appreciate the full context of any significance ranking, the determination of significance is provided for both federal and provincial consideration.

13.4.3 Determination of Significance of Residual Effects

The available measures to mitigate the potential effects on rare plants and ecological communities may not be fully effective. Therefore, the residual effect of the Project on certain ecological communities and rare plants would be significant because the sustainability of the regional population of these communities and plants, all of which are of provincial management concern, would be threatened.

All of the rare plants and rare ecological communities occurring within the LAA are provincially listed. None are federally listed. Table 13.18 provides a summary of Potential Significant Residual Adverse Effects.

Table 13.18 Summary of Assessment of Potential Significant Residual Adverse Effects

Valued Component	Project Phase	Potential Effects	Key Mitigation Measures	Significance Analysis of Residual Effects (Summary Statement)
Vegetation and Ecological Communities	Construction	Habitat alteration and fragmentation	• Minimize project footprint • Establish Environmental Protection Zones to protect occurrences adjacent to construction sites • Maintain a spatial database of rare plant occurrences within LAA • Time, as feasible, construction activities to reduce effects to rare plants and sensitive and rare ecological communities • Follow approved work practices and environmental management plans • Maintain surface flow patterns • Manage invasive species within the Project activity zone • Translocate rare plants that would otherwise be lost due to the Project • Provide funding to existing suitable habitat enhancement projects or land purchase to protect areas under threat or in need of enhancement	Significant

Of the provincially red-listed rare plant species that would be potentially affected, Drummond's thistle and little bluestem occur within the area that would be inundated by the reservoir. Within B.C., Drummond's thistle is known only from the Peace River area (see Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report, Part 1 Vegetation and Ecological Communities). Not all known occurrences within the LAA of both species will be lost if the Project is completed.

Blue-listed ecosystem communities with sizable losses include old and mature riparian and floodplain forests. While these communities will continue to persist downstream of the reservoir and in other areas removed from the LAA, there will be a reduced provincial representation of those habitats within the province. As such, the provincial status may be elevated from blue to red.

The federal government has an interest in preserving wetlands as habitat for wildlife, notably migratory birds and SARA-listed species, but the residual effect is not considered significant due to wetland loss, since the magnitude is not High and numerous wetland complexes occur in upland forests and plateaus removed from the Project.

13.5 Cumulative Effects Assessment

13.5.1 Identification of Cumulative Effects

With the Project likely to result in residual adverse effects to vegetation and ecological communities, the potential cumulative effects of the Project have been assessed. The cumulative effects assessment follows methods explained in Volume 2 Section 10 Effects Assessment Methodology and includes a review of projects and activities, the residual effects of which may interact cumulatively with potential residual effects to vegetation and ecological communities as a result of the Project.

13.5.2 Description of Potential Cumulative Effects on VCs

For each project or activity that could cumulatively contribute to habitat alteration and fragmentation, an overview of the project or activity, project status, spatial and temporal boundaries, and potential residual effects is provided below, based on the information that is available. To generate the Future Case without the Project, foreseeable future projects and activities are prioritized to assess how they may interact with the Baseline Case. Projects recently constructed or operational (in the last few years) are included in the summary, as their recent status would not be reflected in the habitat mapping that was prepared for the assessment, or would yet to be fully incorporated in the provincial and federal governments' current understanding of the status of the key indicators associated with the VC. Many of the projects and activities listed below that occur within the defined RAA are well removed from the LAA for which residual effects of the Project are anticipated. The projects and activities have been included, as they may still remove rare plants and terrestrial habitats that are the same as those affected by the Project.

Figure 13.2 shows the locations of all of the projects and activities occurring in the RAA for which spatial information is available.

Alliance Pipeline Sunrise Meter Station Relocation

The project has been in operation since 2010 and involved the relocation of an existing meter station to a new 50 m by 50 m site closer to Huron Energy's Sunrise Compressor Station (TERA 2010), approximately 27 km northwest of Dawson Creek. The relocated meter station was constructed to accommodate the receipt of natural gas originating in the Sunrise producing area of northeastern B.C. The goal was to minimize natural gas liquids dropping out from the rich incoming natural gas stream before reaching the desired location.

One listed plant species was found within 5 km of the site: meadow willow (*Salix petiolaris*). As outlined in the environmental assessment report (TERA 2010), residual environmental effects for vegetation include the introduction and spread of weeds. Given the location of this Project, a cumulative effect is not expected.

Groundbirch East Receipt Meter Station

The project, by NOVA Gas Transmission Ltd., has been in operation since 2011. It involved the construction and operation of a new meter station approximately 45 km west of Dawson Creek to provide an interconnect between Westcoast Energy Inc.'s pipeline system – downstream of the Sunset Creek compressor station – and Groundbirch Mainline (National Energy Board 2012).

Potential residual environmental effects identified were the introduction and spread of weeds (National Energy Board 2012). Given the location of this Project, a cumulative effect is not expected.

Groundbirch Mainline

NOVA Gas Transmission Ltd. operates a 24 km pipeline, of which 5 km parallels existing rights-of-way and roads, and the remaining 19 km was newly cut (TERA 2010a). A construction right-of-way of 39 m was required for the Project, with 20 m being a permanent right-of-way and 19 m being temporary workspace. The pipeline is located 40 km northwest of Dawson Creek and 33 km southwest of Fort St. John. Construction of the project was completed in 2012.

Identified Residual Effects on vegetation included:

- Alteration of wetland habitat and hydrologic function
- Alteration of water quality function in wetlands activities
- Potential reduction of wetland function in the event of a spill
- Loss or alteration of native vegetation
- Loss or alteration of local rare plant populations or a portion of a rare ecological community
- Introduction and spread of invasive weeds
- Disturbance to vegetation from a spill and its associated clean-up and reclamation (TERA 2010a)

Loss or alteration of native vegetation and loss or alteration of rare plant populations and rare ecological communities may combine with those of the Project and result in a cumulative effect.

Moberly River Pipeline Replacement

Westcoast Energy Inc. replaced a section of the Fort Nelson natural gas mainline, with work finished in 2011. A 14 m long section of pipe became exposed due to southward migration of the Moberly River along an outside bend at the pipeline crossing location. The exposed section of pipe was replaced, and a new 50 m by 600 m right-of-way was created adjacent to the northwest edge of the existing right-of-way, as well as additional workspace to accommodate all equipment and machines used on the project.

No Environmental Assessment for this project could be located, but effects are expected to be similar to other pipeline projects. Rare plant populations and rare ecological communities may be affected. These may combine with those of the Project and result in a cumulative effect.

Provident Beatton River Replacement Project

This project involved the replacement of portions of the approximately 53 km long Taylor to Boundary Lake Pipeline, which carries sweet, high vapour pressure hydrocarbon products from the city of Taylor to Boundary Lake, Alberta. A 36 km long section of the pipeline required replacement to ensure safe and reliable operation. The majority of the replacement work occurred within the existing right-of-way under operations and maintenance activities; a new right-of-way – approximately 16 km long – was required for the construction of a more suitable crossing of the Beatton River (National Energy Board 2011).

Potential effects include the introduction and spread of non-native invasive species, disturbance to vegetation due to spills or product releases, or a loss or alteration of native vegetation, rare plants, riparian areas, and forested areas (National Energy Board 2011). The project would cross two wetlands, and two listed rare plant species – meadow arnica (*Arnica chamissonis*) and spike-oat (*Helictotrichon hookeri*) – were observed on the proposed right-of-way. A cumulative effect is expected, as the Project is would remove four occurrences of meadow arnica and three occurrences of spike-oat.

Septimus Pipeline Project

This project has been in operation since 2010 and involved the construction of 21 km of a rich gas pipeline between the Septimus Gas Plant and Alliance Pipeline. The route was within B.C.'s Agricultural Land Reserve and primarily traverses private cultivated agricultural land and some forested land. The start of the pipeline is located approximately 16 km directly south of Fort St. John.

No Environmental Assessment for this project could be located, but effects are expected to be similar to other pipeline projects. Rare plant populations and rare ecological communities may be effected and may combine with those of the Project and result in a cumulative effect.

Dawson Creek Processing Plant

The project involves the construction and operation of a raw natural gas processing facility 16 km west of Dawson Creek, and consists of a natural gas processing plant and the associated access road, approximately 1 km of gas pipeline, a liquid handing loop, and the acquisition of a segment of the Spectra Energy Midstream Bissette Pipeline. The processing capacity of the Dawson Plant is to be installed in two phases. The initial phase is complete and has been in operations since 2011. The second phase of this project, which includes the installation of additional processing equipment, has a planned in-service date of February 1, 2013.

Residual environmental effects on vegetation associated with construction and operation include:

- Alteration of vegetation
- Loss or alteration of local rare plant populations
- Loss or alteration of a portion of a rare ecological community or wetland
- Introduction and propagation of weeds
- Disturbance of vegetation could occur as a result of an inadvertent spill or product release (TERA 2010b)

Loss or alteration of native vegetation and loss or alteration of rare plant populations and rare ecological communities may combine with those of the Project and result in a cumulative effect.

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Transmission North 2011 Expansion Project

The project provides incremental firm service from the outlet of the Fort Nelson Processing Plant to a new point of interconnection between the Transmission North system and NOVA Gas Transmission Ltd.'s Groundbirch Pipeline. The project was comprised of two primary components in different locations. The first component involved the installation of a new compressor unit, upgrades at existing stations, and the construction of approximately 24 km of pipeline (Fort Nelson Mainline). The second component involved the construction of a new pipeline and associated facilities, construction of approximately 20 km of pipeline (Stewart Lake Pipeline), and the construction of a new compressor station. The project was operational in 2011.

Residual effects to vegetation identified include loss of highly and very highly vulnerable rare ecosystems and loss of wetlands, riparian areas, and old forest. These may combine with those of the Project and result in a cumulative effect.

Dokie Wind Project

Preliminary modelled layout comprises 200 turbines of 1.5 MW each. Phase 1 of the project (144 MW) has been operational since 2011. Phase 2 would include the construction of the remaining towers, to produce 156 MW.

Residual effects on vegetation included loss of plant species, reduction in the availability of key black huckleberry habitat, reduction in available wetland and riparian ecosystems and old forest, and non-reversible reduction of rare ecosystem availability (Hélimax et al. 2006). These may combine with those of the Project and result in a cumulative effect.

Farrell Creek 88-I South Gas Plant Project

Talisman Energy Inc. is proposing to construct and operate a natural gas processing plant 25 km north of Hudson's Hope (Stantec Consulting Ltd. 2012). The proposed plant, which will be adjacent to its existing Farrell Creek Central Production Facility (88-I Plant), will remove water and natural gas liquids from the raw gas to meet the pipeline requirements. The project is to be developed in two or more stages, and will eventually build to a processing capacity of approximately 14 million m^3/day.

No detailed analysis of effects is available, as this project is still in the application phase. Possible effects on vegetation from this project are expected during the construction stage and could include effects to rare plants and rare ecological communities (Stantec Consulting Ltd. 2012). These losses may combine with those of the Project and result in a cumulative effect.

Wolverine Secure Landfill Project

Tervita Corporation, formerly CCS Landfills Services, is proposing to develop a secure landfill approximately 48 km northwest of Dawson Creek (CCS Corporation 2011). The proposed location is on Crown land, and will accommodate industrial activities in northeastern British Columbia. The project is currently in the Environmental Assessment stage, with the goal of an Environmental Assessment Certificate to be issued in March 2013.

For vegetation, some effects were noted, including disturbance and alterations to habitat and displacement of native vegetation by introduction of new vegetation (CCS Corporation 2011). A cumulative effect may occur.

Dawson Creek/Chetwynd Area Transmission Project

BC Hydro is planning to build a new substation 19 km east of Chetwynd, approximately 60 km of overhead transmission line from Sundance Substation to Bear Mountain Terminal, expansion of existing substations, 12 km of transmission line from Bear Mountain Terminal to Dawson Creek substation, and a passive reflector near Chetwynd substation for communication purposes (BC Hydro 2011).

Residual effects identified to vegetation include:

- Alteration of ecosystems, including rare and sensitive ecosystems
- Vegetation removal and maintenance to a shrub/herb stage

Losses of rare and sensitive ecosystems may combine with those of the Project and result in a cumulative effect.

Transmission North 2012 Expansion Project

This proposed pipeline is designed to provide incremental firm service from receipt points along Westcoast's Fort Nelson Mainline and the NOVA Gas Transmission Ltd. Groundbirch Pipeline (TERA 2011). The proposed 24 km route parallels the existing Fort Nelson Mainline pipeline right-of-way for most of its length, with the exception of small localized diversions at Mackie and Lynx creeks, to optimize the watercourse crossings. In addition to the construction right-of-way, temporary workspace will also be required at crossings, sidebends, log decks, and where grading is necessary.

Potential residual effects on vegetation identified include:

- Alteration of native vegetation
- Loss or alteration of rare plants or rare ecological communities
- Introduction and spread of invasive weeds
- Disturbance due to a spill, fire or association cleanup and reclamation (TERA 2011)

Losses of rare and sensitive ecosystems may combine with those of the Project and result in a cumulative effect.

Gething Coal Mine Project

The project involves Canadian Dehua International Mines Group Inc. constructing a new underground coal mine and on-site coal preparation plant approximately 25 km west of Hudson's Hope (Rescan Environmental Services Ltd. 2006).

This project is currently in the Environmental Assessment stage. The estimated construction start-up is 2013. Current status of the proposal is unknown, and no specific residual effects are available for review. Possible cumulative effects on vegetation will be the removal or change in vegetation and ecosystem communities.

Carbon Creek Coal Mine

This project involves the development of an open-pit surface and underground metallurgical coal mine. The mine will be designed to achieve a production rate of 2.9 million tonnes of clean coal/year with an estimated mine life of 30 years (Rescan Environmental Services Ltd. 2012). Currently, the project is in the environmental assessment stage, with construction of project tentatively planned to begin in 2014 and surface mine coal production beginning in same year.

The Project Description is available, but no residual effects have yet been identified. Possible cumulative effects on vegetation will be the removal or change in vegetation and ecosystem communities.

Hackney Hills Wind Project

The proposed wind power project is located west of Fort St. John and directly northwest of Hudson's Hope (Aeolis Wind Power Corporation 2008). The wind farm will have an estimated generation capacity of up to 1,000 MW, with the intent to sell electricity to BC Hydro. The wind farm falls on Crown land and is surrounded by all-season petroleum developments and forestry service roads.

Residual effects have not yet been identified. Possible effects to vegetation include loss from the direct effects of clearing, disturbance, and effects to rare plants and communities (Aeolis Wind Power Corporation 2008). These may interact with the effects of the Project.

This project is currently in the pre-Application stage of the Environmental Assessment process.

Wartenbe Wind Energy Project

The project site is located on Mount Wartenbe, southeast of Chetwynd. The project originally received its Environmental Assessment Certificate in 2006, but subsequently changed ownership. An application to extend the deadline of the certificate was submitted in 2011, as construction had not commenced and the certificate was set to expire. In 2012 the name of the holder of the Environmental Assessment Certificate was changed. The preliminary modelled layout includes 47 turbines of 1.5 MW each.

Substantive project interactions were noted for wetlands and riparian ecosystems, and loss of rare ecosystems (AXYS Environmental Consulting Ltd. 2006). The environmental assessment concluded that cumulative effects on rare ecosystems would be significant both with and without the project. These may combine with those of the Project and result in a cumulative effect.

Wildmare Wind Energy Project

This project involves Finavera's construction of a 74 MW wind park, connector roads, electrical connections, access roads, substation, operations centre, and an overhead transmission line (Finavera Wind Energy Inc. 2011). It will be located 5 km west of Chetwynd. The project is currently under review.

Residual effects identified include loss of rare plants, rare ecosystems and wetlands, habitat fragmentation, soil disturbance and compaction, water quality degradation, and introduction of exotic species (Finavera Wind Energy Inc. 2011). Losses of rare plants, rare and sensitive ecosystems, and wetlands may combine with those of the Project and result in a cumulative effect.

General Oil and Gas Activities

There are many oil and gas-related activities found throughout the northeast portion of the province; collectively, there are a number of environmental effects that result from the exploratory stage as well as the drilling and development stage. As new extraction technologies become available, additional sites will be more attractive for exploration and development. The timing and level of development will likely be set by market prices, but recent plans for liquefied natural gas should continue interest in the regions gas sector.

During exploration, activities that take place that may have adverse effects to vegetation and ecosystem communities, include drilling exploration, construction of access roads, and seismic exploration.

During the drilling/development phase, larger areas are required that involve the construction of well pads, access roads, pipelines, and other ancillary facilities and the drilling of wells. Habitat loss would be the largest effect, although indirect effects such as associated dust, erosion, and the spread of invasive weeds could also occur.

According to information available, a total of 32 oil and gas facilities are approved or under review within the RAA. Facilities are where water, hydrocarbon liquids or natural gas are processed, measured, upgraded, or stored (Ministry of Labour – Citizens' Services and Open Government 2012).

A total of 344 Pipeline projects (from 2004 to present) are approved within the RAA, with another 23 under review. Linear length of pipeline, which was estimated from available spatial information, totals 377 km within the RAA.

Petroleum Access Roads are applications for roads over any Crown land. A total of 1,422 approved or proposed access road applications are within the RAA, with a total length of 823 km. In addition, there are 37 approved or proposed Petroleum Development Road applications, totalling 163 km within the RAA. Petroleum Development Roads applications are for construction, to apply for use of existing non-status tenured roads over any Crown land, or to apply for use of non-status, unencumbered existing access roads on Crown land.

Losses of rare plants, rare and sensitive ecosystems, and wetlands associated with these activities may combine with those of the Project and result in a cumulative effect.

General Forestry Activities

A more detailed review of the forestry activities is provided in Section 21 Forestry. Information provided in that section has been summarized below.

The RAA for vegetation and ecological communities overlaps portions of the Fort St. John and Dawson Creek Timber Supply Areas, as well as Tree Farm Licence 48. The current Timber Harvesting Land Base for all three areas combined is 2,152,127 ha. Of this total area, the Annual Allowable Cut is presently set at 4,875,000 m^3 of both coniferous and deciduous forest. The government will be reviewing the amount cut and possibly setting new limits for both Timber Supply Areas in the near future, and in 2017 for Tree Farm Licence 48.

Timber harvesting replaces mature forest with early seral stage plant communities. The construction of logging roads for access provides opportunities for stream sedimentation and habitat fragmentation. Roads also act as vectors for the persistence and spread of invasive plants.

Losses of rare plants, rare and sensitive ecosystems, and effects to wetlands associated with these activities may combine with those of the Project and result in a cumulative effect.

Land Tenures

Over 11,000 ha have been identified within recent land tenure applications within the RAA (Table 13.19). Commercial recreation tenure applications account for the largest percentage of land use. Activities associated with commercial recreation include camps for hunting and fishing, trail riding, cat skiing, heli-hiking, guided nature viewing, and multiple other uses. The activities typically have considerably less disturbance, compared to other industrial activities, but habitat alteration can still occur with habitat loss, and indirect effects associated with the spread of invasive species may interact with those of the Project and result in a cumulative effect.

Table 13.19 Total Number of Land Tenure Applications Within the RAA

Tenure Purpose	Number of Applications	Total Area (ha)
Agriculture	22	1,631
Commercial	1	< 1
Commercial recreation	17	9,411
Communication	3	1
Community	2	5
Energy production	8	9
Industrial	35	98
Institutional	1	< 1
Quarrying	18	293
Residential	3	1
Utility	24	43
Total	**134**	**11,492**

Parks and Protected Areas

The Peace River Boudreau Lake proposed protected area comprises a portion of the south bank of the Peace River valley, Boudreau Lake, the lower Moberly River Valley, and the islands near the confluences of the Moberly River and Maurice Creek with the Peace River. The proposed protected area is 6,750 ha in size and partially overlaps BC Hydro's flood reserve for the Project (Dawson Creek LRMP Inter-Agency Planning Team 1999). The protected area has not been officially established.

The protected area would be a positive effect and protect representative portions of the BWBSmw biogeoclimatic subzone, including habitats for a number of rare species and ecosystems.

13.5.3 Cumulative Effects Mitigation Measures

The projects summarized above will result in the alteration and fragmentation of habitats through the conversion of natural habitats. These conversions are mostly long term or even permanent. It is anticipated that the residual effects of the Project will act cumulatively with the residual effects of these other project and activities.

Rare species recovery could be undertaken at the regional level collaboratively with other projects. BC Hydro has limited authority to guide regional initiatives to support the diversity and persistence of rare plant populations and rare and sensitive ecological communities. This would be better guided by the provincial government.

13.5.4 Characterization of Residual Cumulative Effects

Past land use has shaped much of the region's vegetation and ecological community composition. Many rare plants and ecological communities are currently under threat of loss and extirpation due to past and present land development (Baseline Case). Some of the listings are simply a result of the geographic distribution and provincial boundaries that restrict occurrences to a small portion of the province. In other instances, populations or habitats are simply unique and rare on the landscape (e.g., tufa seeps and marl fens).

In the future, many of the same activities associated with the Baseline Case will continue (e.g., forestry, and oil and gas development) and residual effects of habitat alteration and fragmentation are expected, regardless of the Project proceeding (Future Case without the Project). Most of these activities are removed from the Peace River valley, affecting areas of adjacent plateau and mountainous sites within the RAA. Some are within the LAA – notably forestry, and oil and gas, and some land tenure applications.

The majority of the Project disturbance is within the Peace River valley, affecting riparian habitats that are generally removed from most other developments (Project Case). Other Project components situated in upland areas removed from the Peace River (e.g., the transmission line and some quarry sites) may overlap with future projects and activities – especially with forestry, and oil and gas development. As such, the Project is likely to result in a residual cumulative effect. The characterization of the effect is listed below (Table 13.20).

Table 13.20 Characterization of Residual Cumulative Effects

Effects Criteria	Project Case
Direction	Negative
Magnitude	High
Geographic Extent	Regional
Duration	Permanent
Frequency	Continuous
Reversibility	Irreversible
Context	Low and High resilience
Level of Confidence	High
Probability	High

13.5.5 Determination of Significance of Residual Cumulative Effects

Due to past and continuing activities, and planned future projects and activities, the cumulative effect for the Project Case is considered significant – based on the expectation of a significant residual effect (see Section 13.4). The anticipated residual effects to vegetation and ecosystem communities from all other future projects and activities combined are also considered significant, even if the Project is not constructed. This occurs because effects associated with other projects and activities that involve road construction, forestry, land clearing are not fully mitigable, and the future loss of rare plants and rare and sensitive ecosystems is expected to further elevate provincial or federal listings.

13.6 Monitoring and Follow-Up Programs

The confidence in the characterization of the residual Project effect to rare plants was considered to be low. Although general predictions of adverse rare plant effects are sound, the specific disturbance responses for the rare plants in the LAA are unknown; the prediction of important habitats for rare plant occurrence is subject to limitations; certain mitigation measures – principally translocation – are considered experimental, and the success rate is difficult to predict; and distribution data within B.C. are incomplete for many of the affected rare plant taxa. As such, it is difficult to fully appreciate the scale of the effect to all rare plants that could be affected by the Project.

Rare plant translocation and understanding responses to disturbance will need to be monitored and reported to provide an understanding of success. Rare plants that will be lost would be good candidates for translocation, and species that persist in disturbed areas – e.g., the transmission line right-of-way – may be better suited for understanding tolerance to disturbance. The scope of the monitoring program should be discussed further with specialists to select candidate species, identify suitable sites, and further establish study design. The length of the monitoring program may be species specific, and would depend on observed early success rates (for translocation) or changes to adaptive mitigation strategies. At a minimum, the monitoring program should continue through the first 10 years of operations.

Follow-up will also be considered to document adequacy of habitat enhancement and possible compensation programs to document their progress in meeting expectations. Measuring success will be developed further with stakeholders but could include a measure of desired vegetation growth, persistence of rare plant occurrences, or the reduction in invasive species.

Follow-up programs are summarized in Table 13.21.

Table 13.21 Follow-up Programs for Vegetation and Ecological Communities

Project Phase	Monitoring Program Objective	Monitoring Program Frequency	Monitoring Program Duration
Operations	Rare plant translocation and understanding responses to disturbance will need to be monitored and reported to provide an understanding of success	Annually	Being after translocation and continue for first 10 years of operations
Operations	To document adequacy of habitat enhancement and possible compensation programs to document their progress in meeting expectations.	Annually	Dependent on habitat compensation programs established

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14 WILDLIFE RESOURCES

14.1 Approach

Wildlife resources was selected as a valued component (VC) due to:

- An interaction with Project components and activities resulting in the loss or fragmentation of feeding, breeding, or winter habitat from dam construction and reservoir filling
- Aboriginal concerns of effects on biodiversity, loss of habitat, changes in animal populations and their distribution, and effects on traditional land use practices
- Public and stakeholder concerns of effects on biodiversity, loss of habitat, and changes in animal populations and their distribution
- Federal and provincial regulations on wildlife, biodiversity and conservation

The wildlife resources VC includes the following key species groups: butterflies and dragonflies, amphibians and reptiles, migratory birds, non-migratory game birds, raptors, bats, fur-bearers, ungulates, and large carnivores.

14.1.1 Regulatory and Policy Setting

The following is a summary of federal and provincial legislation governing wildlife resources.

14.1.1.1 *Canadian Wildlife Act*

The *Canadian Wildlife Act* outlines the powers of the federal government to protect wildlife, in cooperation with provinces and territories. The Act enables the Canadian Wildlife Service (CWS), in cooperation with provincial and territorial governments, to take measures to protect endangered wildlife species and acquire land for wildlife research, conservation, and interpretation.

14.1.1.2 *Migratory Birds Convention Act*

The *Migratory Birds Convention Act, 1994* is administered by the Wildlife Enforcement Division of Environment Canada, in cooperation with provincial and territorial governments. The Act is enforced and regulated by CWS, the Royal Canadian Mounted Police and provincial or territorial law enforcement authorities. A “migratory bird” referred to in the Convention includes the sperm, eggs, embryos, juveniles, adults, tissue cultures, and parts of the bird. This includes waterfowl, cranes, rails and coots, shorebirds – including gulls and terns, pigeons and doves, insectivorous songbirds (excluding blackbirds), seabirds, loons, grebes, herons, egrets, and bitterns.

The Migratory Birds Regulations exist under the *Migratory Birds Convention Act*, and are in place to carry out the purposes and provisions of the Act. The Migratory Birds Regulations concern the conservation and protection of migratory birds. The Migratory Birds Regulations control hunting and possession of migratory game birds; the sale, purchase, or shipment of migratory birds, their nests, or their eggs; scientific collection, aviculture, and taxidermy; activities designed to reduce the damage that migratory birds cause to crops or other property and the danger they pose to aircraft; and requirements for hunters to use non-toxic shot for most migratory game bird species.

The following prohibition applies to land development projects, under the Migratory Birds Regulations:

> "Section 6. No person shall:
>
> *(a) Disturb, destroy or take a nest, egg, nest shelter, eider duck shelter or duck box of a migratory bird, or*
>
> *(b) Have in his possession a live migratory bird, or a carcass, skin, nest or egg of a migratory bird*
>
> except under authority of a special permit or as provided in the Migratory Bird Sanctuary Regulations."

14.1.1.3 *Species at Risk Act*

The Government of Canada proclaimed the federal *Species at Risk Act* (SARA) in June 2003 as part of a three-part strategy for the protection of species at risk in Canada. The other two parts of the strategy include the Accord for the Protection of Species at Risk and the Habitat Stewardship Program for Species at Risk. SARA was developed following the implementation of the Canadian Biodiversity Strategy, in response to the United Nations Convention on Biological Diversity. The purpose of SARA, per the Species at Risk Public Registry, is to "to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct, to provide for the recovery of endangered or threatened species, and encourage the management of other species to prevent them from becoming at risk".

SARA-listed wildlife species occur within the Peace River valley. The Peace River valley is defined as a linear area incorporating the Peace River and its associated gravel bars, terraces, and side slopes, extending to the top of the slope at the level of the surrounding plateau.

14.1.1.4 *British Columbia Wildlife Act*

In the B.C. *Wildlife Act*, "wildlife" refers to "raptors, threatened species, endangered species, game or other species of vertebrates prescribed as wildlife". Birds are protected under Section 34 (see below); this includes "birds described in the American Ornithologists Union Checklist of North American Birds, 6th edition or its supplements, which are native to Canada or the United States of America and were not introduced by man". Some species, including Eurasian Skylarks (*Alauda arvensis*), all raptors, and some native and some introduced upland game birds, have additional protection. Some species that are exempt for management reasons include crows, European Starlings (*Sturnus vulgaris*), Rock Pigeons (*Columba livia*), Brown-headed Cowbirds (*Molothrusater*), House Sparrows (*Passer domesticus*), and Black-billed Magpies (*Pica hudsonia*).

Provisions of the B.C. *Wildlife Act* are reviewed below.

Section 4 provides for the power to designate Wildlife Management Areas as follows:

> "With the consent of the Lieutenant Governor in Council, the minister may, by regulation, designate as a wildlife management

> area land that is under the minister's administration and is not in a park, a conservancy or a recreation area
>
> Despite any other enactment, a person may not use land or resources in a wildlife management area without the written permission of the regional manager."

Section 5 provides for the creation of Critical Wildlife Areas and wildlife sanctuaries as follows:

> "If the minister requires land for habitat for a species of wildlife designated as an endangered species or threatened species, the minister may, by regulation, designate land in a wildlife management area as a critical wildlife area."

Section 6 provides for the designation of species as 'endangered' or 'threatened' as follows:

> 1) "If the Lieutenant Governor in Council considers that a species of wildlife is threatened with imminent extinction throughout all or a significant portion of its range in British Columbia because of the action of humans, the Lieutenant Governor in Council may, by regulation, designate the species as an endangered species.
>
> 2) If the Lieutenant Governor in Council considers that a species of wildlife is likely to become endangered in British Columbia if the factors affecting its vulnerability are not reversed, the Lieutenant Governor in Council may, by regulation, designate the species as a threatened species."

Section 7 states:

> "(1) A person commits an offence if the person
>
> a) alters, damages, or destroys wildlife habitat, or
>
> b) deposits on land or water a substance or manufactured product or by-product
>
> in a manner that is harmful to
>
> (c) wildlife, or
>
> (d) wildlife habitat
>
> in a wildlife management area, except as permitted under section 4 (4) or by the regulations or a permit.
>
> (4) A regional manager may make orders prohibiting a person from:
>
> (a) entering,
>
> (b) cutting, picking, removing, altering, destroying or damaging vegetation in,
>
> (c) disturbing or harassing wildlife in,
>
> (d) releasing or abandoning an animal in, and
>
> (e) allowing an animal to enter

> a wildlife management area, a critical wildlife area or a wildlife sanctuary."

Section 9 states:

> "(1) A person commits an offence if the person disturbs, molests or destroys
>
> (a) a muskrat house or den, except on diked land, or
>
> (b) a beaver house or den or beaver dam."

Section 9(1) does not apply to a licensed trapper, if the action is taken to provide irrigation or drainage under lawful authority for the protection of property, or if the action is authorized by regulation.

Section 11 states that hunting of wildlife is an offence unless the person holds a hunting license or permit

> 8) "Trapping of fur bearing animals is only allowed if the person holds a trapping license
>
> 9) First Nations residing in British Columbia do not require a hunting licence"

Section 30 provides that it is an offence to hunt, take, kill or wound big game while it is swimming.

Section 33 provides that it is an offence to have in one's personal possession live or dead wildlife, except as authorized under a licence or permit or as provided by regulation (not applicable to persons acting under a licence under the *Fur Farm Act* or the *Game Farm Act*).

Section 33.1 provides that it is an offence to intentionally feed or attempt to feed dangerous wildlife, subject to certain exceptions.

Section 34 provides that it is an offence to (except as provided by regulation) possess, molest, take, injure, or destroy:

> (a) a bird or its egg,
>
> (b) the nest of an eagle, peregrine falcon, gyrfalcon, osprey, heron or burrowing owl, or
>
> (c) the nest of a bird not referred to in paragraph (b) when the nest is occupied by a bird or its egg.

14.1.1.5 *Forest Range and Practices Act*

The *Forest and Range Practices Act* (FRPA) and its regulations govern the activities of forest and range licensees in B.C., including requirements for planning, road building, logging, reforestation, and grazing. It took effect on January 31, 2004, and any activities already approved prior to this time under the existing Forest Practices Code may continue and are governed by the *Forest Practices Code of BC Act* and its regulations.

In 2004 the Minister of Water, Land and Air Protection (now the Ministry of Environment) established a category of species at risk by order made under FRPA. This category represents those species that may be affected by forest or range management on Crown land and are listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). “Identified Wildlife” are predominantly selected from the provincially Red- or Blue-listed wildlife species. An inter-agency committee (comprised of individuals with environment or forestry backgrounds) consults with species experts to determine which of these species should be recommended for designation as Identified Wildlife.

Under the FRPA, the Lieutenant Governor-in-Council may make regulations authorizing the Minister of Environment to establish one or more of the following under Section 149.1 (a):

i. “an area as an ungulate winter range and objectives for the ungulate winter range;

ii. an area as a wildlife habitat area and objectives for the wildlife habitat area;

iii. a general wildlife measure;

iv. categories of wildlife for the purposes of subparagraphs (i) to (iii)”

Wildlife Habitat Areas are managed for selected species and plant communities that have been designated as Identified Wildlife. These areas are mapped and approved by the chief forester and the Deputy Minister of Environment.

General wildlife measures direct what forest and range management practices can occur within a Wildlife Habitat Area. They may restrict forest or range activities during sensitive periods (e.g., the breeding season) to minimize disturbance or may restrict activities entirely within an area to maintain the integrity of the habitat.

14.1.2 Key Issues and Identification of Potential Effects

Issues, concerns and interests identified during consultation with the public, Aboriginal groups, and government agencies guided the scope of the wildlife resources assessment (see Volume 1 Section 9 Information Distribution and Consultation).

Input from: management considerations described within the Peace Moberly Tract Sustainable Resource Management Plan (SRMP), Fort St. John Land and Resource Management Plan (LRMP), and Dawson Creek LRMP; discussions during the Wildlife Technical Advisory Committee (TAC); and concerns identified in various Traditional Use Studies were also considered. A brief summary of each of these inputs is provided below.

Resource Management Planning

LRMPs and SRMPs are strategic land use plans designed to help stakeholders identify and manage economic opportunities provided by natural resource development, as well as conserve cultural and environmental values. LRMPs are a higher-level plan than SRMPs, encompassing a much larger area and generally taking more resource development/environmental protection into effect. Both plans are meant to provide a long-term plan for Crown land resource development, and are established as a combined effort by private citizens, stakeholders (e.g., industrial sector, environmental groups), government agency representatives, and local Aboriginal groups.

Three specific management plans have been completed that overlap the Project, including the Peace Moberly Tract Draft SRMP (West Moberly and Saulteau First Nations 2006), Dawson Creek LRMP (Dawson Creek LRMP Inter-Agency Planning Team 1999), and Fort St. John LRMP (Fort St. John LRMP Working Group 1997). Species identified for management in these plans include ungulates, grizzly bear (*Ursus arctos*), fur-bearers, trumpeter swans (*Cygnus buccinator*), Red- and Blue-listed songbirds, Red- and Blue-listed plant communities, and berries.

Wildlife Technical Advisory Committee

A summary of the Technical Advisory Committee (TAC) process is provided in Section 9.3 Agency Information Distribution and Consultation in Volume 1 Section 9 Information Distribution and Consultation. Key discussions, issues, and concerns raised by the TAC are summarized in Table 9.3.3 Key TAC Discussions.

Traditional Use Studies

Traditional Land Use Studies (TLUS) were prepared for a number of Aboriginal group communities. These included Blueberry River First Nation Traditional Land Use Study (Bouchard and Kennedy 2011); Duncan's First Nation Ethnohistorical Review (Bouchard and Kennedy 2012a); Horse Lake First Nation Ethnohistorical Overview (Bouchard and Kennedy 2012b); Doig River First Nation, Prophet River First Nation, Halfway River First Nation, and West Moberly First Nation Traditional Land Use Study (Chandler 2012); Saulteau First Nation Culture and Traditions Study (NesooWatchie Resource Management Ltd. 2011), Kelly Lake Métis Settlement Society Aboriginal Traditional Knowledge Assessment (KSDavidson & Associates and KCD Consulting Incorporated 2012), Dene Tha' Traditional Land Use with Respect to BC Hydro's Proposed Site C Dam (Stevenson 2012), and Fort Nelson First Nation Background and Rational for Involvement in the Site C Project (Wolfenden 2012).

Specific issues and concerns raised by the Aboriginal groups within the various reports, as well as the approach used to address the issues, are presented in Table 14.1.

Table 14.1 Aboriginal Key Issues: Wildlife Resources

Key Issues	Approach to Addressing Key Issues
Reservoir creating a barrier to movement for grizzly bear, black bear (*Ursus americanus*), moose (*Alces alces*) snowshoe hare (*Lepus americanus*), and grey wolf (*Canus lupus*).	Effects on movement are considered for large carnivores and ungulates. Snowshoe hare and black bear are not specifically addressed.
Erosion and bank sloughing will impede wildlife movement in and out of the reservoir.	The erosion impact line has been calculated and the potential extent of bank sloughing during operations has been included within the assessment.
Elimination of calving sites for moose, mule deer (*Odocoileus hemionus*), and elk (*Cervus canadensis*) on islands within the Peace River.	Calving sites for ungulates is part of the assessment under habitat alteration and fragmentation.
Decrease in population and loss of habitat and associated hunting areas for white-tailed deer (*Odocoileus virginianus*), mule deer, moose, and woodland caribou (*Rangifer tarandus*).	Effects on ungulate habitats are part of the assessment under habitat alteration and fragmentation.

Key Issues	Approach to Addressing Key Issues
Decrease in population of fur-bearers – specifically, squirrel, rabbit, common muskrat (*Ondatra zibethicus*), American marten (*Martes americana*), fisher (*Martes pennanti*), wolverine (*Gulo gulo*), Canada lynx (*Lynx canadensis*), and American beaver (*Castor canadensis*).	Effects on fisher and beaver are part of the assessment. A detailed assessment of effects on other fur-bearers is not included – rationale provided in Table 14.2.
Loss of rare and important ecosystems for Red- and Blue-listed neo-tropical migrant birds, fur-bearers, wolves.	The loss of suitable habitats is part of the assessment of effects on migratory birds and fur-bearers. General effects on wolves are considered under large carnivores.
Forced relocation and drowning of smaller wildlife with the filling of the reservoir.	Forced relocation and drowning is considered under effects associated with disturbance and displacement, and mortality.
Effects on bats.	Effects on bats are part of the mammal assessment.
Effects on cougars (*Puma concolor*).	Cougar is not part of the assessment – rationale provided in Table 14.2.
Effects on ptarmigan.	Ptarmigan is not part of the assessment – rationale provided in Table 14.2.
Effects on bison (*Bos bison*).	Bison is not part of the assessment – rationale provided in Table 14.2.
Effects on wildlife from the increase in noise and other sensory disturbances, including increased public access.	Effects from noise are considered under effects associated with disturbance and displacement.
Exposure of animals to contaminants, including dust.	The effects of dust are considered within the effects assessment.
Loss of ungulate rutting grounds.	The focus of the assessment on habitat use by ungulates is on winter use.
Loss of lek sites for Sharp-tailed Grouse (*Tympanuchus phasianellus*).	The potential loss of lek sites is included for Sharp-tailed Grouse as part of the assessment under habitat alteration and fragmentation.
Loss of animal den and nesting sites.	The potential loss of nesting and denning sites has been included for a number of species as part of the assessment under habitat alteration and fragmentation.
Destruction of moose mineral licks.	Mineral licks observed were recorded in baseline but are not specifically addressed in the assessment.
Change in water temperatures and ice formation patterns, which may negatively affect wildlife.	Water temperature and ice formation has been reviewed and is considered as part of the assessment.
Relocation of moose, American beavers, ducks, and geese due to a reduction in water levels downstream	The effect of changes to the downstream surface water regime is considered as part of the assessment.
Decrease in water leading to limited new growth, resulting in a reduced amount of moose browse.	A decrease in water is not anticipated. The loss of seasonal moose forage as a result of the Project is considered within the assessment under habitat alteration and fragmentation.
Potential for increased predation of grey wolves on moose, and Canada lynx on American beaver.	Potential mortality risks are considered for both American beaver and moose.
Increase in hunting pressure from other Aboriginal groups on northern Aboriginal territories due to a loss of key ungulate winter ranges.	The loss of designated ungulate winter ranges is part of the assessment.

Not all issues suggested by Aboriginal groups were included as key indicators (Table 14.2). This was because some species had no expected interaction with the Project, they are common across the landscape and a change to the population in the LAA is not expected, or they could be effectively assessed under another key indicator.

Table 14.2 Rationale for the Exclusion of Suggested Species

Species	Rationale for exclusion
Ptarmigan	No interaction with the Project is expected.
Muskrat	Strongly associated with aquatic and riparian habitats. The species shares similar habitat needs with American beaver, which has been selected as a key indicator.
Squirrel	Considered to be abundant and a forested habitat generalist. Resilient to disturbance. The Project is not expected to result in a change in the population in the LAA.
Snowshoe hare	A common species with cyclical population fluctuations. Tends to prefer younger forest types for forage and security, which is not limited on the landscape. The Project is not expected to result in a change in the regional population.
American marten	Not as a selective of habitats as fisher, but does have some similar habitat needs. Fisher has been selected as a key indicator.
Wolverine	Individuals are rare or not occurring within much of the LAA. The Project is not expected to have a result in a change in the population in the LAA.
Canada lynx	A species whose population and density is strongly linked to cyclical fluctuations in prey (especially snowshoe hare). Since changes to snowshoe hare are not expected, the same is assumed for Canada lynx.
Bison	No interaction with project is expected.
Caribou	Caribou are not found in the Peace River valley, so they will not be directly affected by the proposed reservoir or dam. Where Project components do occur in recognized caribou herd ranges (e.g., West Pine Quarry), a review of existing data has determined that there will be no direct Project interactions on caribou, and that sites can be operated in such a way as to have no indirect interactions on caribou. The West Pine Quarry has been in operation by the B.C. Ministry of Transportation and Infrastructure since 2001. Operations will expand the existing quarry, but will not encroach upon important habitats noted in recovery planning and activities will continue to follow practices currently used by the B.C. Ministry of Transportation and Infrastructure.
Black bear	A common species with high resilience. It uses a wide variety of habitats. Bear-human interactions are addressed under grizzly bear, which has been selected as a key indicator.
Cougar	There have been few reported observations by landowners, and Conservation Officers have not dealt with the species within the Peace region between 2003 and 2012 (based on the B.C. Wild Predator Loss Control and Compensation Program). The species was not observed during any study since detailed fieldwork began in 2005. No interaction within the LAA is anticipated.

14.1.2.1 Project Interactions

Potential project interactions with wildlife resources are summarized in Volume 2 Appendix A Project Interactions Matrix, Table 2. As defined in Volume 2 Section 10 Effects Assessment Methodology, a rank of “2” was given where interactions may result in an adverse effect and the nature of the effect and/or the effectiveness of mitigation measures are uncertain. These interactions were taken forward through the effects assessment.

Project interactions with a ranking of “2” are summarized in Table 14.3. The assessment was completed for both the construction and operational phases of the Project. Since many of the Project activities are similar across all Project components, Table 14.3 is an abbreviated version of Table 2 provided in Volume 2 Appendix A Project Interactions Matrix.

Section 12.2.4 of the EIS Guidelines states that the assessment of potential adverse effects on the VC will take into account the potential for the Project to result in changes to the following key aspects:

- Permanent and temporary habitat alteration and fragmentation
- Disturbance and/ or displacement
- Potential for direct and indirect mortality to individuals

Table 14.3 Interactions of the Project With Wildlife Resources

Project Activities and Physical Works	Key Aspects		
	Habitat Alteration and Fragmentation	Disturbance or Displacement	Mortality
Construction			
Dam, Generating Station and Spillways			
Site clearing and preparation	✓	✓	✓
Temporary and permanent access roads	✓	✓	✓
Waste treatment and management facilities	✓		
Installation and operation of temporary facilities		✓	
Hazardous materials storage and refueling sites	✓		✓
Truck washing sites	✓		
Aggregate and filter processing plants		✓	
Relocation of surplus excess material	✓	✓	✓
Temporary construction access bridge across the Peace	✓	✓	✓
Transportation of construction materials and supplies		✓	✓
Sand and gravel source pits	✓	✓	✓
Stage 1 and 2 channelization and diversion works	✓	✓	✓
Existing infrastructure relocation	✓	✓	✓
Quarried and Excavated Material Source Development			
Site preparation, earthworks and operations	✓	✓	✓
85th Avenue conveyor belt		✓	
Construction Access Road Development			
Site preparation and earthworks, drainage, railway construction	✓	✓	✓
Highway 29 Realignment			
Realign highway sections	✓	✓	✓
Worker Accommodation			
Supply and transportation of goods and services for the camp		✓	✓
Temporary accommodation		✓	✓
Reservoir			
Existing infrastructure inventory, protection and/or relocation	✓	✓	✓
Hudson's Hope shoreline protection	✓	✓	✓
Road upgrade and winter road construction	✓	✓	✓
Clearing of vegetation and timber	✓	✓	✓
Transport of merchantable timber		✓	✓

Project Activities and Physical Works	**Key Aspects**		
	Habitat Alteration and Fragmentation	**Disturbance or Displacement**	**Mortality**
Post-harvest terrestrial debris management	✓	✓	✓
Access deactivation and reclamation	✓	✓	✓
Aquatic debris management during inundation	✓	✓	
Water management during diversion confinement, reservoir filling and commissioning	✓	✓	✓
Transmission Line			
Clearing and preparation	✓	✓	✓
Access construction and right-of-way improvement	✓	✓	✓
Tower installation		✓	
Conductor stringing		✓	
Construction site decommissioning and reclamation	✓	✓	✓
Upgrades to Peace Canyon substation	✓	✓	✓
Site C substation installation		✓	
Operations			
Dam, Generating Station, and Spillways			
Operations includes reservoir and downstream water management	✓	✓	✓
Maintenance of powerhouse and substation		✓	
Reservoir			
Debris management	✓	✓	✓
Hudson's Hope berm maintenance	✓	✓	✓
Transmission Line			
Right-of-way vegetation maintenance	✓	✓	✓
Maintenance of overhead structures		✓	
Maintenance of access roads	✓	✓	✓

14.1.3 Standard Mitigation Measures and Effects Addressed

A rank of "0" means there is no interaction between the Project components and the VC. Volume 2 Appendix A Project Interactions Matrix, Table 2 provides a rationale for why some activities were ranked "0". These were not carried forward through the effects assessment.

A rank of "1" means that an interaction would occur but that it is well understood and can be avoided or mitigated through the application of standard mitigation measures and would be negligible. No Project activities were assigned a ranking of "1".

14.1.4 Selection of Key Indicators

The EIS Guidelines (Section 12.1) state that the "assessment of potential adverse effects on wildlife resources will be based on the following key species groups: butterflies and dragonflies; amphibians and reptiles; migratory birds; non-migratory game birds; raptors; bats; furbearers; ungulates; and large carnivores." The key species groups have been further divided into key indicators, including down to the species level in some instances, following Section 12.2.3 of the EIS guidelines. The list of key indicators is outlined in Table 14.4.

Table 14.4 Key Indicators for Wildlife Resources

Key species group	Key Indicators	Rationale for Selection of the Key Indicators
Butterflies and dragonflies	Butterflies and dragonflies	Provincial species at risk
Amphibians and reptiles	Western toad	Federal and provincial species at risk
	Garter snakes	Regional species of interest
Migratory birds	Songbirds – with a focus on provincially and federally listed species: Bay-breasted Warbler, Black-throated Green Warbler, Canada Warbler, Cape May Warbler, Connecticut Warbler, Rusty Blackbird	Federal and provincial species at risk
		Migratory Bird Convention Act
	Waterfowl and shorebirds: including trumpeter swan	Provincial species at risk
		Migratory Bird Convention Act
	Marsh birds – with a focus on Yellow Rail, American Bittern, Nelson's Sparrow and Le Conte's Sparrow	Federal and provincial species at risk
		Migratory Bird Convention Act
	Woodpeckers	Species of regional interest
		Migratory Bird Convention Act
	Common Nighthawk	Federal species at risk
		Migratory Bird Convention Act
	Swallows	Provincial species at risk (Barn Swallow)
		Migratory Bird Convention Act
Non-migratory game birds	Sharp-tailed and Ruffed Grouse	Species of regional management concern
		Species of interest to Aboriginal groups
Raptors	Bald Eagle	Nests protected year-round under Section 34 of the B.C. *Wildlife Act*
	Northern Goshawk	Regional species of interest
	Broad-winged Hawk	Provincial species at risk
	Northern Harrier	Regional species of interest
	Owls – with a focus on Short-eared Owl, Great Horned Owl, Great Gray Owl, Boreal Owl, and Northern Saw-whet Owl	Short-eared Owl is a federal and provincial species at risk
		Regional species of interest
Bats	Bats	Some species at risk provincially and federally
Fur-bearers	Fisher and American beaver	Harvested species
		Fisher is a provincial species at risk
		Species of interest to Aboriginal groups
Ungulates	Ungulates – with a focus on moose, elk, mule deer, and white-tailed deer	Regional species of management concern
		Harvested species
		Species of interest to Aboriginal groups

Key species group	Key Indicators	Rationale for Selection of the Key Indicators
Large carnivores	Grey wolf	Species of regional management concern
		Species of public interest
		Species of interest to Aboriginal groups
	Grizzly bear	Provincial species at risk
		Species of public interest
		Harvested species
		Species of interest to Aboriginal groups

14.1.5 Spatial and Temporal Boundaries

14.1.5.1 Spatial Boundaries

The spatial boundaries used in the assessment include the:

- **Local Assessment Area (LAA):** the area within which the potential adverse effects of the Project are assessed. The LAA encompasses the Project activity zone, buffered by an additional 1,000 m. This buffer is larger than was suggested in Table 11.2 of the EIS Guidelines. A 1,000 m buffer was selected to allow adequate characterization of the terrestrial environment surrounding the Project activity zone, and extends far enough to include all potential direct and indirect effects at all construction sites and during operations. This includes new roads, roads requiring upgrades, quarries, the dam site, and the transmission line. For the proposed reservoir, the erosion impact line has a 1,000 m buffer.

  The LAA also extends downstream from the dam to the Alberta border, and includes a 1,000 m buffer on both the south and north banks of the Peace River (Figure 14.1). This considers potential effects on riparian areas that could be affected by reductions in the magnitude of peak flows, and more frequent high and low flows from the dam downstream to the Pine River confluence (see Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).
- **Regional Assessment Area (RAA):** the area within which projects and activities – the residual effects of which may combine with residual effects of the Project – are identified and taken into account in the cumulative effects assessment. The proposed dam, reservoir, transmission line, Highway 29 realignment, temporary access roads, and quarries occur within five Wildlife Management Units – designated 7-31, 7-32, 7-33, 7-34, and 7-35 (Figure 14.1). The Wildlife Management Unit boundaries provide a larger RAA boundary than what was suggested in Table 11.2 of the EIS Guidelines. The updated boundary includes most of the Peace Lowlands ecosection and incorporates all Project components and activities.

14.1.5.2 Temporal Boundaries

The temporal boundaries of the assessment include short- and moderate-term (construction phase; Year 0-8) and long-term (operations phase; begin in Year 8 and may continue throughout the life of the Project) time frames and seasons, or life history stages of key indicators. In some cases, the effects assessment is limited to one Project phase, due to the timing and duration of the activities causing the effect. Potential effects on some species may be more pronounced, depending on the season or life history stages. For example, potential effects on wetlands are more of a concern for western toads during their breeding season, and migrating songbirds typically are only present in the Project area between May and August.

14.2 Baseline Conditions

Baseline conditions were characterized using information from existing literature and field studies that were conducted from 2005 to 2012. The scope of the work was to collect baseline data of wildlife species presence, distribution, and abundance. Taxa identified in the scope of these studies included butterflies and dragonflies, amphibians and reptiles, migratory birds, non-migratory game birds, raptors, bats, fur-bearers, ungulates, and large carnivores.

The following section provides a summary of the baseline conditions for wildlife resources. This section is supported by more detailed information presented in Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report.

14.2.1 Butterflies and Dragonflies

There are 20 Red- or Blue-listed butterfly taxa that potentially occur in the LAA. There are also two provincially Blue-listed damselfly species and one Blue-listed dragonfly.

In the two years – 2006 and 2008 – of butterfly sampling, 285 sites including replicates were surveyed, and approximately 3,300 specimens were collected. Sixty-five taxa were identified, of which 14 were Red- or Blue-listed.

A total of 155 dragonfly and damselfly specimens were collected in aquatic habitats in the Peace River valley in 2008, and approximately 2,500 specimens of aquatic larvae and exuviae (cast exoskeletons) were collected in 2012. Of the total collected, 28 species in nine genera and five families were identified, including the collection of a Blue-listed prairie bluet (*Coenagrion angulatum*).

Using the area of wetlands in the LAA as a surrogate for potentially suitable dragonfly and damselfly breeding habitat, approximately 4,300 ha occurs within the LAA.

Habitat suitability modelling completed for 10 species of butterflies identified a wide range of potential suitable habitat within the LAA – between 3,474 ha and 26,644 ha, depending on the species.

For a detailed description of the baseline work completed for butterflies and dragonflies, see Part 2 of Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report.

14.2.2 Amphibians and Reptiles

Seven amphibian and reptile species are known to occur in the LAA: boreal chorus frog (*Pseudacris maculata*), Columbia spotted frog (*Rana luteiventris),* long-toed salamander (*Ambystoma macrodactylum),* wood frog (*Lithobates sylvaticus*), western toad, common garter snake – red-sided subspecies (*Thamnophis sirtalis parietalis*), and the terrestrial garter snake (*T. elegans*). Of these seven species, only the western toad is provincially Blue-listed and listed federally as a species of special concern under Schedule 1 of the *Species at Risk Act*.

All five amphibian species were detected during amphibian surveys conducted between 2006 and 2012. Western toads and wood frogs were found in all life stages – adults, juveniles, tadpoles, and eggs. Columbia spotted frogs and boreal chorus frogs were observed as adults and egg clusters. Only one adult long-toed salamander was observed. Western toads were detected at 27 different sites.

Both species of garter snake were detected. Four hibernacula were confirmed in the LAA – two at Bear Flat, one at Tea Creek, and one west of the Clayhurst Bridge. The sites were crevices on steep, warm aspect cliffs or rock outcrops and are outside the proposed reservoir. The hibernacula are small, providing for individuals, rather than groups.

Habitat suitability modelling was completed for western toad breeding habitat and garter snake hibernation habitats. Within the LAA, 13,864 ha of western toad breeding habitat, and 4,084 ha of suitable garter snake hibernation habitat were identified.

For a detailed description of the baseline work completed for amphibians and snakes, see Part 3 of Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report.

14.2.3 Migratory Birds

Migratory bird studies were completed in 2006, 2008, 2011, and 2012 for a variety of bird species and species groups, including: songbirds, swallows, waterfowl and shorebirds, marsh birds, woodpeckers, and Common Nighthawk.

Songbirds include the orders Passeriformes (passerines), Apodiformes (hummingbirds and swifts), Columbiformes (doves and pigeons), and Coraciiformes (kingfishers). There are seven Red- or Blue-listed songbird species known to occur within the LAA. Three of these species – Canada Warbler (*Cardellina canadensis*), Olive-sided Flycatcher (*Contopus cooperi*), and Rusty Blackbird (*Euphagus carolinus*) – are SARA listed. The Canada Warbler and Olive-sided Flycatcher are Schedule 1 Threatened, and the Rusty Blackbird is Schedule 1 Special Concern.

Breeding bird point-counts were completed and resulted in a total of 169 species and 39,635 bird observations recorded. Counts of rare species for all survey years included six Bay-Breasted Warblers (*Setophaga castanea*), 621 Black-throated Green Warblers (*Setophaga virens*), 294 Canada Warblers, six Cape May Warblers (*Setophaga tigrina*), 73 Connecticut Warblers (*Oporornis agilis*), 49 Olive-sided Flycatchers, and 27 Rusty Blackbirds.

Fall migration encounter transects were completed in the fall of 2012, and a total of 129 avian species were detected, with a total count of 9,068 birds. All seven rare species of warblers were documented during the fall surveys.

From the habitat suitability modelling for rare species, the amounts of available suitable habitat identified within the LAA were:

- Bay-breasted Warbler – Red-listed: 15,640 ha
- Black-throated Green Warbler – Blue-listed: 34,776 ha
- Canada Warbler – Blue-listed: 12,033 ha
- Cape May Warbler – Red-listed: 9,749 ha
- Connecticut Warbler – Red-listed: 27,035 ha

- Rusty Blackbird – Blue-listed: 1,698 ha

Habitat modelling for Olive-sided Flycatcher was not completed, as stand-level attributes – e.g., snag density, tree values in a recent cut-block – are difficult to map, and the confidence in the model would be low. A qualitative assessment in the potential change was considered.

Results from swallow nest counts and point-count surveys documented a total of 39 single nests and 89 colonies, representing Bank Swallow (*Riparia riparia*), Northern Rough-winged Swallow (*Stelgidopteryx serripennis*), Cliff Swallow (*Petrochelidon pyrrhonota*), and Violet-green Swallow (*Tachycineta thalassina*). Large Bank Swallow colonies were observed near the Moberly River and Bear Flat, and large colonies of Cliff Swallows were observed near the Peace Canyon Dam.

Cliff Swallows were the most common species observed with 958 detections, followed by Bank Swallows (n = 803) and Violet-green Swallows (n = 648).

Encounter transects were completed for waterfowl and shorebirds in 2006 and 2008, and resulted in observations of 59 species of waterfowl using the Peace River and tributaries – 35 species were observed in backchannels, 24 species in wetlands, and 34 species observed on lakes. Red- and Blue-listed species detected during surveys included Cackling Goose (*Branta hutchinsii*), Caspian Tern (*Hydroprogne caspia*), California Gull (*Larus californicus*), Double-crested Cormorant (*Phalacrocorax auritus*), Great Blue Heron (*Ardea herodias* ssp. *herodias*), Long-tailed Duck (*Clangula hyemalis*), Surf Scoter (*Melanitta perspicillata*), and Upland Sandpiper (*Bartramia longicauda*).

Specific to the Peace River, 13 species of waterfowl were detected only along the river. These included Arctic Tern (*Sterna paradisaea*), Black-bellied Plover (*Pluvialis squatarola*), California Gull, Caspian Tern, Common Tern (*Sterna hirundo*), Greater White-fronted Goose (*Anser albifrons*), Harlequin Duck (*Histrionicus histrionicus*), Mew Gull (*Laruscanus*), Pacific Loon (*Gaviapacifica*), Ring-billed Gull (*Larus delawarensis*), Red-throated Loon (*Gavia stellata*), Sandhill Crane (*Grus canadensis*), and Snow Goose (*Chen caerulescens*).

Four bird species are identified as marsh birds, including two from the Order Passeriformes (Le Conte's Sparrow and Nelson's Sparrow) and one from each of the Order Gruiformes (Yellow Rail) and Order Pelecaniformes (American Bittern).

Counts from call-playback surveys and point-count stations resulted in detections of 29 Le Conte's Sparrows, 13 Nelson's Sparrows, and 33 Yellow Rails. No American Bittern were detected.

The species model for American Bittern identified 5,395 ha of low-suitability habitat within the LAA. Modelling for the other three species within the LAA identified:

- 4,534 ha of suitable habitat for Le Conte's Sparrow
- 4,534 ha of suitable habitat for Nelson's Sparrow
- 2,043 ha of suitable habitat for Yellow Rail

Call-playback surveys and nest searches were completed for seven woodpecker species that occur in the Peace Region. All seven species were detected during targeted surveys. A total count of 1,021 woodpeckers was recorded, with 998 identified to species. Sixteen woodpecker nests were observed during woodpecker surveys, including one Downy Woodpecker (*Picoides pubescens*), two American Three-toed Woodpecker (*Picoides dorsalis*), and 13 Yellow-bellied Sapsucker (*Sphyrapicus varius*).

Three species models were completed to act as surrogates for all seven species. The species model for American Three-toed Woodpecker identified 21,581 ha of suitable habitat within the LAA; the Pileated Woodpecker (*Dryocopus pileatus*) model identified 14,463 ha of suitable habitat; and the species model for Yellow-bellied Sapsucker identified 40,274 ha of habitat suitable within the LAA.

The Common Nighthawk is federally listed as Threatened and is on Schedule 1 of the *Species at Risk Act*. A total of 69 Common Nighthawk were recorded from call-playback surveys. The species model prepared for Common Nighthawk nesting habitat identified 14,462 ha of suitable habitat within the LAA.

For a detailed description of the baseline work completed for migratory birds see Part 4 of Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report.

14.2.4 Non-Migratory Game Birds

Species-specific surveys for Ruffed Grouse were completed in 2011, with a total of 69 Ruffed Grouse detections recorded. An additional 275 detections of Ruffed Grouse were observed during breeding bird point-counts, completed over multiple years. The model for Ruffed Grouse identified 52,659 ha of suitable habitat within the LAA.

Information on 21 Sharp-tailed Grouse leks documented by the B.C. Ministry of Environment (BCMOE) was obtained and assessed. An additional 34 point-count stations within Area E were completed for Sharp-tailed Grouse. One lek was identified during point-count surveys at Area E and a total of eight Sharp-tailed Grouse were observed. Additional incidental observations during surveys over multiple years for other taxa resulted in 72 Sharp-tailed Grouse detections.

Two habitat suitability models for Sharp-tailed Grouse were completed – during the growing season (June through September) and the winter season (October through March) – as Sharp-tails are partially migratory and some may shift between summer and winter ranges. The habitat models identified 22,920 ha of suitable habitat during the growing season and 9,697 ha of suitable habitat during the winter season in the LAA.

For a detailed description of the baseline work completed for non-migratory game birds, see Part 5 of Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report.

14.2.5 Raptors

Raptor studies were completed for Bald Eagle, Broad-winged Hawk, Northern Goshawk, Northern Harrier, and five species of owls: Great Horned, Great Gray, Boreal, Northern Saw-whet, and Short-eared Owls.

Raptor survey work included aerial nest surveys for Bald Eagles. The most recent surveys in 2011 identified 59 active and inactive nests, 53 of which were along the Peace River. Balsam poplar (*Populus balsamifera*) was selected for nesting by Bald Eagles the majority – 85% – of the time.

Standwatches, call-playback surveys, and nest searches were completed for Broad-winged Hawk. A total of nine Broad-winged Hawk detections were made, all during call-playback surveys. Four Broad-winged Hawk nests were observed. All were platform stick-nests. The species model prepared for Broad-winged Hawk identified 25,927 ha of suitable nesting habitat within the LAA.

Call-playback surveys and nest searches were completed for Northern Goshawk**.** Eleven detections were recorded, along with three confirmed active nests and one possible nest. The species model for Northern Goshawk identified 38,820 ha of suitable nesting habitat within the LAA.

Encounter transects, standwatches, and nest surveys completed for Northern Harrier resulted in a total of 19 detections. No nests were documented. The habitat model prepared for the Northern Harrier identified 13,105 ha of suitable nesting habitat within the LAA.

Call-playback transects were completed for Boreal Owl, Great Gray Owl, Great Horned Owl, and Northern Saw-whet Owl. A total of 27 observations of Boreal Owl, 102 observations of Great Gray Owl, 267 of Great Horned Owl, and 319 of Northern Saw-whet Owl were made. Nest searches for Boreal Owl, Great Gray Owl, and Great Horned Owl did not locate any nests.

Twelve detections of Short-eared Owl were recorded during targeted encounter transects in one of the three years that surveys were completed.

Habitat suitability modelling identified a total amount of suitable habitat within the LAA of:

- 16,010 ha for Boreal Owl
- 16,207 ha for Great Gray Owl
- 15,257 ha for Great Horned Owl
- 12,917 ha for Northern Saw-whet Owl
- 14,156 ha for Short-eared Owl

For a detailed description of the baseline work completed for raptors, see Part 6 of Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report.

14.2.6 Bats

Bat surveys – including mist-net capture surveys, radio-telemetry and acoustic surveys with bat detectors – were conducted in order to document the bat species present and their use of roosting habitat. A total of 189 bats of at least six species were captured with an overall capture success of 0.0102 bats/m^2-hr or 0.471 bats/net-night. Species captured included little brown myotis (*Myotis lucifugus*), a long-eared myotis complex, long-legged myotis (*Myotis volans*), big brown bat (*Eptesicusfuscus*), silver-haired bat (*Lasionycteris noctivagans*), and hoary bat (*Lasiuruscinereus*). All captured species are breeding in the LAA. One additional species – the Red-listed eastern red bat (*Lasiurus borealis*) – was detected acoustically, but not captured.

The long-eared myotis complex includes both the Blue-listed northern myotis (*Myotis septentrionalis*) and the Yellow-listed long-eared myotis (*Myotis evotis*), as these two species are very difficult to distinguish from external characteristics. All remaining species captured are provincially Yellow-listed. Little brown myotis and northern myotis have both received emergency listings as Endangered by COSEWIC due to the impacts of a fungal disease in eastern Canada. At the time of report preparation, December 2012, the two species had not been included on SARA.

Thirty-four bats were radio-tagged and 56 roosts were identified, including 46 within live trees or snags, six within cutbanks, and four within building structures. Bats most frequently used Balsam poplar–Spruce-Red-osier dogwood floodplain habitats (site series Fm02), in structural stages 3 (shrub) through 6 (mature) for day roosts. Radio-tagged bats of all species that roosted in trees were most often relocated in young to mature forest. Bats found roosting in shrub and pole-sapling forest were using remnant balsam poplar snags.

Bat detectors recorded very high levels of bat activity in late summer and early fall at a number of cliff sites within the Peace River valley, including cliffs at Tea Creek, Bear Flat, and Alwin Holland Municipal Park. Recorded activity at these sites indicates the cliffs are used as winter hibernacula, growing season roost sites, and fall swarming sites. Winter use appears to be big brown bats, based on limited capture data.

Detectors deployed on Portage Mountain in 2012 recorded the Blue-listed northern myotis, little brown myotis, and either big brown bat or silver-haired bat. The pattern of activity at this site is consistent with bats using the area for hibernation.

Habitat suitability modelling for bats identified 31,451 ha of suitable foraging habitat and 33,759 ha of reproducing habitat within the LAA.

For a detailed description of the baseline work completed for bats, see Part 7 of Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report.

14.2.7 Fur-Bearers

14.2.7.1 Beaver

Low-level aerial reconnaissance surveys and surveys by boat were conducted along the Peace River in 2005 and 2011. Aerial surveys flown in 2005 recorded 67 active and 61 inactive lodges on the Peace River between the Moberly River and Hudson's Hope, and 75 active and 52 inactive lodges downstream of the Moberly River to the Alberta border. These observations were used to estimate the beaver population to be 335 animals upstream and 375 animals downstream, based on five beaver per active lodge.

Surveys in 2011 located 59 active and 31 inactive beaver lodges on the Peace River between the Moberly River and Hudson's Hope. An additional 53 active and 16 inactive lodges were recorded downstream of the Moberly River to the Alberta border. A follow-up boat survey, conducted after the aerial survey, recorded an additional 10 active and six inactive lodges downstream of the Moberly River not readily confirmed during the aerial survey, resulting in population estimates of 295 animals upstream and 315 animals downstream, based on five beaver per active lodge.

14.2.7.2 Fisher

Baseline surveys were undertaken to determine the size and orientation of the resident fisher home ranges, to characterize habitat use (particularly denning and resting habitat), to estimate the number of fishers in the Peace River valley and surrounding areas, to determine the population structure and persistence, and to estimate the density and distribution of den trees within the Peace River valley and surrounding area. Live-capture, subsequent ground- and aerial-based radio-telemetry, genetic analysis of hair samples, and habitat transects identifying suitable denning sites were completed.

Live trapping for radio-telemetry was completed in winter 2010/2011 and winter 2011/2012. A total of 7,352 trap nights – each night that a trap remained open and able to catch an animal – at 489 different sites resulted in 52 captures of 16 individual fishers.

Despite the greater effort and apparently larger amount of suitable habitat south of the Peace River, more fishers were captured on the north side of the river, with 11 captures on the north side and five on the south. Density estimates varied by year and between the two study areas – north and south of the Peace River. The north study area averaged 7.7 fishers/1,000 km^2 over both years, and the south study area averaged 2.6 fishers/1,000 km^2.

A total of 463 radio-telemetry locations were used to determine the home range analysis using two methods: 95% fixed kernel and 100% minimum convex polygon. Based on the 95% fixed kernel method, aggregate home ranges for seven radio-tagged fishers averaged 36.3 km^2 for females and 469.1 km^2 for males. Home ranges of resident fishers were sporadic and clumped across landscape on the south side of the Peace River; overlap was common among the study animals on the north side. Three fishers – one female and two males – crossed the Peace River at least once.

Hair samples were obtained from collected bait stations, captured animals, and fishers taken by trappers. In total, 519 hair samples were collected; 259 samples had sufficient deoxyribonucleic acid (DNA) for extraction. Results indicate that the animals on the north and south sides of the Peace River form one continuous population.

A total of 114 habitat plots were completed in 2011 and 2012. The density of trees with attributes important to fishers was similar between used and unused sites. Five female fishers were tracked to 11 reproductive dens on 37 occasions. All dens were found in balsam poplar (n = 5) or trembling aspen (n = 6) trees.

Stratified sampling for identifying potential cavity-bearing trees was conducted in 2009 and 2011. Twenty different combinations of ecosystem unit and structural stage were sampled, with a total of 162 suitable maternal den trees tallied in 134 km of fixed-area transects. These trees were highest in density in moist mature habitats, with 90% balsam poplar.

Habitat suitability based on tree density was calculated for fishers. An estimated 14,143 ha of suitable habitat is available within the LAA.

For a detailed description of the baseline work completed for fur-bearers, see Part 7 of Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report.

14.2.8 Ungulates

Between 2010 and 2011, a total of 81 individual ungulates were captured, including 20 moose, 23 elk, and 38 mule deer. The provincial government provided data on 10 white-tailed deer tracked using radio-collars from January 2006 to March 2007. For ungulates caught in the first year – excluding mortalities – moose were monitored for an average of 766 days, elk for an average of 783 days, and mule deer for an average of 765 days. Ungulates caught and monitored in the second year averaged 331 days. The white-tailed deer data set indicated an average monitoring period of 328 days. The total number of locations recorded was 94,336 for moose, 93,867 for elk, 68,730 for mule deer, and 12,428 for white-tailed deer.

Home range sizes averaged 37 km^2 for moose cows and 68 km^2 for bulls; 120 km^2 for elk cows and 506 km^2 for bulls; and 18 km^2 for white-tailed deer. All were classified as non-migratory. Mule deer were classified as non-migratory, short-movement individuals, and long-migration individuals. Average home range size for non-migratory individuals was 15 km^2 for does and 20 km^2 for bucks, 69 km^2 for short-movement does, and 147 km^2 for the one short movement buck, and 526 km^2 for long-migration does and 638 km^2 for bucks. All species crossed the Peace River; only a few crossings were recorded during the winter season by elk or mule deer.

A total of 90 potential birthing sites – 19 within the Peace River valley – were identified and visited between 2010 and 2011. Of the 90 potential sites, equal numbers of sites were suspected to be moose or elk (n = 38 each) and 14 were suspected to be mule deer birthing sites. Habitat types observed at birthing sites were highly variable. The majority of birthing sites were located in deciduous-dominated seral units – 31 ap:At, 11 in ac:Ac, and six in Balsam poplar –White spruce/Mountain alder–red-osier dogwood – Fm02. Of the 19 birthing sites identified in the Peace River valley, three sites – two moose and one mule deer – were identified on islands in the Peace River completely surrounded by flowing water. In general, moose sites were mostly on the plateau, elk favoured valley slopes, and mule deer used the plateau, slopes, and riparian habitats equally.

Habitat use by moose was within the mesic deciduous forest most – 30 to 40% – of the time. Other forested habitats were used at similar rates in proportion to their availability. Moist shrublands were selected year-round; moist coniferous and deciduous forest showed increased use in fall and winter. Riparian habitats were used in proportion to their availability in summer and fall, with increased selection in winter and spring. Anthropogenic habitats, cultivated fields, and open water were avoided year-round. Bulls and cows showed similar habitat use patterns, and few differences were noted between day and night periods.

Elk spent most – 20 to 40% – of their time in the flat mesic deciduous forest. Habitat selection was most evident in winter, when elk increased use of moist deciduous and coniferous forests, riparian forests, and shrublands on warm aspects. Elk avoided anthropogenic habitats and open water year-round, although use of cultivated fields at night increased in fall and winter, compared to daytime. This shift coincided with the hunting season.

Habitat use by buck and doe mule deer was similar for most categories, except does tended to use riparian habitat more than bucks. Mesic broadleaf forest and cultivated fields received the highest use by mule deer in all seasons, and accounted for 40 to 50% of all locations. These two habitats were also the most common habitats available within the mule deer composite home range, at 55% of the area.

Although white-tailed deer spent most time in mesic deciduous forests and shrublands, they only had a clear preference for moist deciduous forests.

All ungulates captured upstream of the proposed dam site were classified based on the proportion of time they spent in the proposed reservoir area. Of the study animals, few – two moose and four mule deer – spent the majority of their time in the proposed reservoir area, most upstream moose (11 of 15) used the proposed reservoir area more than 10% of the time, four of the 21 elk were in the proposed reservoir area greater than 10% of the time, and 16 of 24 mule deer and one of nine white-tailed deer used the proposed reservoir area more than 10% of the time.

Aerial censuses of moose, elk, and mule deer were completed using stratified block counts in 2006, 2009, and 2011 and compared to surveys completed in 1991. The survey area included the Peace River valley and adjacent slopes from Alberta to Hudson's Hope, although the 1991 survey only included blocks upstream of the proposed dam site. The 2011 estimates within the Peace River valley are 900 moose, 1,100 elk, and 3,500 mule deer. Moose numbers have been relatively stable, although 2011 was the highest count of the four surveys. Elk numbers have been steadily increasing. Mule deer numbers were highest in 1991 and – although appearing stable in recent counts – the population was believed to have dropped following the severe winter of 2007. The 2009 and 2011 counts suggest that the population has recovered.

Based on ungulate use during the collaring study, winter habitat use was identified for the four ungulate species. The amount of suitable wintering habitat in the LAA is:

- 75,603 ha for moose
- 71,871 ha for elk
- 27,901 ha for mule deer
- 8,617 ha for white-tailed deer

Portions of four Ungulate Winter Ranges are present within the LAA – SPE-001, 003, 014, and 025 – accounting for 2,578 ha of habitat.

For a detailed description of the baseline work completed for ungulates, see Part 7 of Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report.

14.2.9 Large Carnivores

Habitat values for wolves are dependent on a good supply of ungulate prey, combined with low amounts of human disturbance. Habitats with low road density, little agricultural land, low human presence, and a component of coniferous forest tend to be the most suitable for wolves (reviewed in Milakovic 2008). The threshold level of road density for wolves to persist has been cited as 0.58 km/km^2 (Mech et al. 1988; Thiel 1985), although wolves may use areas with higher road densities if they are adjacent to large roadless areas (Mech 1989).

Mean annual home range sizes of wolves in the mostly undisturbed Besa-Prophet area, north of the Peace River valley and west of Fort Nelson, were 801 km^2 (Milakovic 2008) and varied based on the proportion of dense conifer stands – low productivity ungulate habitat – within the range. Home range size is positively correlated with pack size, but the factors controlling pack size are not well understood (reviewed in Paquet and Carbyn 2003).

Physical and psychological barriers to wolf movement include areas of dense human settlement and linear corridors such as power lines, highways, seismic lines, railways, and gas lines (Paquet and Carbyn 2003). Mortality risks to wolves from deliberate, accidental or incidental killing by people increase greatly in proximity to such features.

The BCMOE estimates that 30 wolves were killed by hunters in 2010 in MU-7-32, which includes the lower reaches of the Moberly River and a portion of the south bank of the Peace River (B.C. Ministry of Environment unpubl. data). An additional 18 animals were estimated killed in MU7-33, which extends from the Blueberry River east to the Alberta border, along both sides of the Peace River, south to Dawson Creek. As a result of predator control actions in the Peace region, a total of 165 wolves were killed between 2003 and 2012 (B.C. Ministry of Environment unpubl. data).

At present, there is no closed season for hunting or trapping wolves below 1,100 m elevation in the Management Units bordering the Peace River (B.C. Ministry of Forests, Lands and Natural Resource Operations 2012a). The provincial government has recently released a draft wolf management plan (B.C. Ministry of Forests, Lands and Natural Resource Operations 2012b). It is reported that wolves are expanding their range across the province and are returning to areas where they were once extirpated. The plan includes provisions for wolf control to protect domestic stock or species at risk, but not for the purposes of increasing ungulate populations for human harvest. The Province is considering eliminating the bag limit for wolves in the Peace region.

The role of wolf predation in the regulation of ungulate populations has been studied frequently (Jones and Mason 1983; Seip 1992; Van Ballenberghe and Ballard 1994; Allison 1998; Peterson 1988; Garrott et al. 2007; Hebblewhite et al. 2010; Griffin et al. 2011), but remains little understood (Gese and Knowlton 2001; Peek et al. 2012). A recent review of long-term data from Yellowstone, Banff National Park, and Isle Royale (Vucetich et al. 2011) concluded that predator and prey ratio accounts for only 56% of observed variance of prey population growth, at best. Stable prey populations may exist at a wide range of predator densities, and predation rate cannot be used reliably to determine whether predation is causing prey population declines. Climate variables, human exploitation levels, and the suite of species present in an area will all influence predator-prey dynamics. The provincial draft wolf management plan also notes that there is no scientific consensus on the role of wolves in prey dynamics, and that wolf abundance and distribution are regulated by ungulate supply, human-caused mortality, territorial behaviour, and disease. Wolves are assessed as part of the large carnivore species group in the effects assessment.

Current provincial management of grizzly bears is within Grizzly Bear Population Units (GBPU) drawn along natural and ecological boundaries. Grizzly Bear Population Units within the Peace River valley include the Rocky, with a population estimated at 538 bears, and the Moberly, with an estimated 71 bears. These units include portions of the Peace River between Hudson’s Hope and Bear Flat. The remainder of the Peace River valley is not included in a GBPU, but is classified as an area where grizzly bears are extirpated.

The frequency of grizzly bear dispersal through the Peace River valley has not been well documented, but is infrequent based on the province’s population and habitat data. Data from DNA studies do not indicate fragmentation within northern grizzly bear populations (Proctor et al. 2012). Patterns of recorded mortalities suggest that there are currently no physical barriers to grizzly bear movements in northeastern B.C., and that movement is instead limited by conflicts with people and associated grizzly bear mortalities (B.C. Ministry of Environment, Large Carnivore Specialist, 2012, pers. comm.). Habitat suitability around the eastern portion of the Peace River valley is relatively low and therefore less likely to attract or support dispersing bears (A. Hamilton, B.C. Ministry of Environment, pers. comm. September 2012).

Grizzly bear mortality risk is often assessed using an analysis of road density (Mattson 1993; Mace et al. 1996; Wakkinen and Kasworm 1997). A road density analysis was completed to evaluate changes in the LAA in road density due to the Project. Permanent roads are generally placed in areas where road density already exceeds a 1.2 km/km^2 threshold, and thus these areas are unlikely to be used by grizzly bears. The large unroaded areas south of the Peace River will remain virtually the same once temporary construction roads are removed. Grizzly bear are assessed as part of the large carnivore species group in the effects assessment.

For a more detailed discussion for large carnivores, see Part 7 of Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report.

14.3 Effects Assessment

Section 12.2.4 of the EIS guidelines states the assessment of potential adverse effects on the VC will take:

> "into account the potential for the Project to result in changes to the following key aspects:
>
> - Permanent and temporary habitat alteration and fragmentation;
> - Disturbance and/or displacement; and
> - Potential for direct and indirect mortality to individuals."

The analysis of the effects of habitat alteration and fragmentation is a GIS-based analysis that provides a quantitative assessment measuring change within the LAA by overlaying the known areas of disturbance with ecosystem mapping, species habitat modelling, and known spatial locations of specific wildlife features, including nest sites, dens, hibernacula, leks, and lodges.

For species where habitat models are not effective – swallows, waterfowl, shorebirds, and Olive-sided Flycatcher – at defining the spatial extent of habitat use, a qualitative assessment in the potential change is considered. Resource Selection Function modelling and tree density modelling were used to analyze the effects of habitat alteration and fragmentation on ungulates and fisher, respectively.

Parts 2 through 7 in Volume 2 Appendix R Terrestrial Vegetation and Wildlife Report provide greater detail of modelling methodologies.

Species for which habitat modelling was completed are provided in Table 14.5.

1 **Table 14.5 Species for Which Habitat Modelling Was Completed**

Key Species group	Indicator Species	Aspect Modelled
Butterflies and dragonflies	Dragonflies	Breeding
	Aphrodite fritillary	Breeding
	Arctic blue	Breeding
	Arctic skipper	Breeding
	Assiniboine skipper	Breeding
	Common ringlet	Breeding
	Common woodnymph	Breeding
	Great spangled fritillary	Breeding
	Old world swallowtail	Breeding
	Tawny crescent	Breeding
	Uhler's arctic	Breeding
Amphibians and Reptiles	Western Toad	Reproducing-eggs
	Garter snake	Winter hibernation
Migratory Birds	Bay-breasted Warbler	Reproducing-eggs
	Black-throated Green Warbler	Reproducing-eggs
	Canada Warbler	Reproducing-eggs
	Cape May Warbler	Reproducing-eggs
	Connecticut Warbler	Reproducing-eggs
	Rusty Blackbird	Reproducing-eggs
	American Bittern	Reproducing-eggs
	LeConte's Sparrow	Reproducing-eggs
	Nelson's Sparrow	Reproducing-eggs
	Yellow Rail	Reproducing-eggs
	American Three-toed Woodpecker	Reproducing-eggs
	Pileated Woodpecker	Reproducing-eggs
	Yellow-bellied Sapsucker	Reproducing-eggs
	Common Nighthawk	Reproducing-eggs
Non-migratory Game Birds	Ruffed Grouse	Living all seasons
	Sharp-tailed Grouse	Living-growing season and Living-winter
Raptors	Boreal Owl	Reproducing-eggs
	Broad-winged Hawk	Reproducing-eggs
	Great Gray Owl	Reproducing-eggs
	Great Horned Owl	Reproducing-eggs
	Northern Goshawk	Reproducing-eggs
	Northern Harrier	Reproducing-eggs
	Northern Saw-whet Owl	Reproducing-eggs
	Short-eared Owl	Reproducing-eggs
Mammals	Bats	Feeding-growing season and Reproducing-birthing habitat

Construction noise and close proximity of people and machinery to suitable habitats can change animal behaviours. The assessment of potential effects on disturbance and displacement of wildlife is both a qualitative assessment of the timing and extent of disturbances in close proximity to suitable habitats.

The number of individuals hunted, poached, hit by vehicles, or lost due to construction and filling of the reservoir is difficult to quantify. A qualitative assessment of the likelihood of mortality based on the timing and frequency of activities and the proximity of roads and other Project components to suitable habitats is included.

14.3.1 Effects Assessment – Habitat Alteration and Fragmentation During Construction and Operations

Habitat alteration is defined as the permanent removal or loss of habitat or a reduction in habitat suitability for a species. Alteration of habitat can also lead to an increase in predation, decrease in security cover, and removal of seasonal forage, roost, nest, birthing, and den sites.

Habitat alteration does not just include direct habitat removal, but can also be a reduction of habitat suitability due to changes in hydrology, increased siltation, and other deleterious substances, and the introduction of invasive species. Changes in hydrology can reduce wetland size or create new areas of ponded water, depending on whether water inputs are decreased or increased. Sedimentation (introduction of sediments) can result in infilling of portions of wetlands, thereby altering water depth and smothering aquatic vegetation.

The proximity of construction sites along the edges of wet areas can increase water temperature in streams, change flows, and increase silt levels. The release of deleterious substances (including concrete, fuel, oil, and other hydrocarbons) can also be detrimental to terrestrial and aquatic environments. These substances, such as petroleum-based organic compounds, sediments, and de-icing agents can often run off paved roads during construction, maintenance and use (Buckler and Granato 1999). Also, as cited in Kociolek et al. 2011: Walker & Everett 1987, and Kalisz & Powell 2003.

The introduction of invasive species is considered habitat alteration. Physical barriers that prevent dispersal define the natural range and distribution of a species. Invasive species have circumvented these physical barriers and have been able to establish in areas where they were not previously known. Continued changes in land use, together with the spread of the human population, have made it possible for invasive species to increase their range, sometimes to the extent that they crowd out native species. The introduction and potential proliferation of the more aggressive invasive species ultimately alters the habitat, often leading to decreases in habitat suitability for native wildlife. Fragmentation of natural areas, especially by roads, provides more opportunities for the dispersal and establishment of non-native species, which in turn continues to alter and fragment natural areas.

Fragmentation involves the 'separation' of habitat patches into one or more pieces – a process that requires some portion of the original habitat patch or rare plant occurrence to be lost or transformed into less favourable or inhospitable habitat. Habitat fragmentation reduces the size and continuity of larger habitats, where the suitable habitats that remain may be too small to be effective at providing for various life stages of a species. These smaller areas are also more susceptible to habitat alteration with continual influences from the activities that led to the fragmentation in the first place.

Specific to the Project, roads are considered to be a leading cause of fragmentation, although other Project components may also isolate smaller patches of suitable habitat. Edge habitat created by roads or other means can lead to a change in vegetation communities, which in turn can lead to a change in the wildlife community. The transmission line will fragment older forests, but could provide for greater amounts of suitable shrub and herb habitat for some species, dependent on operations. Specific to the transmission line, operations activities include mechanical and chemical (herbicide) vegetation maintenance that could cause short-term changes in vegetation and abundance, and potentially long-term changes in vegetation diversity and composition. These changes will benefit some species and be detrimental to others.

Changes due to habitat alteration and fragmentation can affect one or more life stages within or across species. Habitat alteration and loss through clearing of vegetation during site preparation will be the primary issue during the early construction stages. As construction proceeds, water diversions associated with dam construction have the potential to change flow regimes on the Peace River (see Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background for more details), which may affect wildlife and wildlife habitat along the river margins. In the final stages of construction, reservoir filling would constitute the majority of permanent loss of habitat.

Project components and activities during construction and operation have the potential to alter and fragment habitats used by wildlife and were summarized in Table 14.1. These include:

- **Dam, Generating Station and Spillways:** site clearing and preparation, temporary and permanent access roads, relocating surplus excess, sand and gravel source pits, existing infrastructure relocation, Stage 1 and Stage 2 channelization, and diversion works
- **Reservoir:** vegetation removal, flooding, Hudson's Hope shoreline protection, debris management, and bank erosion
- **Transmission Line:** vegetation removal, access construction and vegetation maintenance during operations
- **Highway 29 Realignment:** vegetation removal, temporary and permanent road construction, relocating and removing infrastructure and surplus materials, bridge construction, and shoreline protection
- **Construction Access Roads:** Site preparation, earthworks, drainage, and railway construction
- **Quarried and Excavated Materials:** Site preparation, earthworks, operations

Species with smaller home ranges or that have specific habitat requirements tied to the Peace River valley – especially riparian habitat – would be affected the most.

Suitable habitat, defined as moderate- and high-value habitat, has been selected for key indicators based on needs for sensitive life history requirements. Suitable habitat for most key indicators has been selected for reproduction needs. Winter habitats have also been selected for garter snakes, bats (hibernacula), and Sharp-tailed Grouse. Winter habitat for ungulates is considered the most important habitat for ungulate survival, especially during severe winters, and was chosen for representing suitable habitats for the moose, elk, and mule-deer. The amount of designated Ungulate Winter Range that would be lost as a result of the Project is also included.

14.3.1.1 Butterflies and Dragonflies

Approximately 4,270 ha of potential dragonfly breeding habitat is available within the LAA, based on ecosystem mapping (Table 14.6). The total amount of potential breeding habitat loss during construction and operations is 796 ha, half of which is riparian wetlands (WH) associated with river backchannels. This represents 19% of the available habitat within the LAA. For clarification, the loss due to the reservoir clearing and filling (construction) is based on the full supply level; for operation, it is the additional loss between the full supply level and the erosion impact line.

The total amount lost is considered to be an overestimation, as quarry sites are expected to be smaller than the larger Project activity zone presented in this report and the loss of wetlands along the transmission line right-of-way is not anticipated; although the amount of habitat affected during operations is dependent on the activities planned. This is because wetlands and other non-forested areas would not be cleared unless road construction or tower placement were required. The total of 796 ha is also a duplication of some areas where clearing activities occur both during construction and operations.

The Highway 29 realignment does not overlap any potential dragonfly breeding habitats.

Table 14.6 Potential Habitat Loss – Breeding: Dragonflies

Forested and Non-Forested Ecosystems with Breeding Potential	Available Habitat in LAA (ha)	Phase	Loss of Suitable Habitat by Project Component (ha)						
			Dam Site	Reservoir	Transmission Line	Roads	Quarries	Total (ha)	Percent (%) Lost
Lake	194.4	Construction	0.0	0.0	0.3	0.1	0.0	0.4	0.8
		Operations	0.0	0.0	1.1	0.0	0.0	1.1	
Shallow Open Water	77.0	Construction	1.6	13.6	0.9	0.3	0.0	16.5	22.9
		Operations	0.0	0.0	1.1	0.0	0.0	1.1	
Pond	33.5	Construction	0.0	4.0	0.7	0.1	0.1	4.9	21.2
		Operations	0.0	0.4	1.8	0.0	0.0	2.2	
Sedge Wetland (SE 00)	1,168.9	Construction	39.9	47.0	34.7	19.0	1.1	141.8	16.8
		Operations	0.0	0.5	54.4	0.0	0.0	54.9	
Tamarack Sedge (TS 10)	1,404.5	Construction	12.9	13.1	32.1	9.1	0.4	67.5	8.1
		Operations	0.0	0.0	46.6	0.0	0.0	46.6	
Willow-Horsetail-Sedge riparian wetland (WH 00)	1,009.5	Construction	1.1	390.5	0.5	0.0	0.0	392.1	38.9
		Operations	0.0	0.8	0.3	0.0	0.0	1.1	
Willow Sedge Wetland (WS 00)	363.4	Construction	3.1	27.7	14.1	5.0	0.0	50.0	18.0
		Operations	0.0	0.0	15.5	0.0	0.0	15.5	
Narrow-leaved cotton-grass – Shore sedge (SBSwk2 Wf13)	8.5	Construction	0.0	0.0	0.0	0.4	0.3	0.7	8.2
		Operations	0.0	0.0	0.0	0.0	0.0	0.0	
Total			58.6	497.6	204.1	34.0	1.9	796.4	—

The habitat loss to butterflies differs based on a species' requirements. Of the 10 species for which habitat suitability modelling was produced, the great spangled fritillary loses the most amount of habitat (3,664 ha combined over both phases), whereas the Arctic skipper loses the greatest percentage (20% combined over both phases) from what is available within the LAA (Table 14.7). These numbers are based on potential loss of suitable habitats mapped within the Boreal White and Black Spruce moist, warm (BWBSmw1) biogeoclimatic subzone only. Similar to dragonflies, the amount of loss is considered an overestimate for the quarries and the transmission line.

Table 14.7 Potential Habitat Loss: Butterflies

Common Name	Total Suitable Habitat in LAA (ha)	Project Phase	Loss of Suitable Habitat by Project Component (ha)							
			Dam Site	Reservoir	Transmission Line	Highway 29	Roads	Quarries	Total (ha)	Percent (%)[b]
Aphrodite fritillary	**26,643.9**	Construction	1,136.7	1,027.1	325.9	168.7	155.2	92.7	**2,906.4**	**14.1**
		Operations	0.0	446.7	405.8	0.0	0.0	0.0	**852.5**	
Arctic blue	**3,859.8**	Construction	58.5	124.0	12.0	34.1	5.1	0.0	**233.8**	**9.8**
		Operations	0.0	133.9	10.5	0.0	0.0	0.0	**144.5**	
Arctic skipper	**7,142.3**	Construction	542.0	467.4	92.2	77.7	30.2	14.5	**1,224.0**	**19.7**
		Operations	0.0	86.8	95.0	0.0	0.0	0.0	**181.8**	
Assiniboine skipper	**6,487.4**	Construction	144.0	561.7	70.8	31.4	42.0	1.4	**851.4**	**16.5**
		Operations	0.0	131.6	89.1	0.0	0.0	0.0	**220.7**	
Common ringlet	**4,945.9**	Construction	81.1	190.0	12.0	43.9	5.4	0.0	**332.5**	**10.5**
		Operations	0.0	176.8	10.5	0.0	0.0	0.0	**187.4**	
Common woodnymph	**6,483.2**	Construction	144.0	581.5	70.9	31.4	42.0	1.4	**871.3**	**16.9**
		Operations	0.0	133.6	89.1	0.0	0.0	0.0	**222.7**	
Great spangled fritillary	**20,693.5**	Construction	990.6	1,773.7	164.8	113.2	89.2	52.9	**3,184.5**	**17.7**
		Operations	0.0	301.5	178.2	0.0	0.0	0.0	**479.7**	
Old world swallowtail	**3,473.7**	Construction	65.7	142.3	12.0	31.4	4.3	0.0	**255.8**	**12.1**
		Operations	0.0	153.8	10.5	0.0	0.0	0.0	**164.4**	
Tawny crescent	**25,962.5**	Construction	1,076.6	974.9	278.9	167.1	129.4	91.3	**2,718.3**	**13.7**
		Operations	0.0	476.9	349.5	0.0	0.0	0.0	**826.4**	
Uhler's arctic	**3,893.3**	Construction	58.5	124.0	12.0	34.1	5.1	0.0	**233.8**	**9.7**
		Operations	0.0	133.9	10.5	0.0	0.0	0.0	**144.5**	
Total			**4,297.7**	**8,142.1**	**2300.2**	**733.0**	**507.9**	**254.2**	**16,236.4**	**—**

Changes in hydraulic patterns and water quality and quantity as a result of the Project can alter invertebrate habitat. Suitable habitats can shift from an herbaceous wetland community to a shrub community as a result of a reduction in water. Conversely, increases in water may also contribute to habitat loss as the inundation of smaller wetlands, leading to greater areas of ponded water, may change the vegetation composition, distribution, and abundance to something less favourable (Cannings et al. 2011).

The proximity of Project roads and other construction sites along the edges of wet areas or immediately upstream can increase water temperature in streams, change flows, and increase silt levels which negatively affects larvae (Cannings et al. 2011). Sediments can fill in portions of wetlands, altering water depth, and smothering aquatic vegetation. Inorganic sedimentation can cause a direct effect on aquatic life-stages, as particles of sediment can accumulate on respiratory structures and body surfaces (Lemly 1982). The release of deleterious substances – including concrete, fuel, oil, and other hydrocarbons – can also be detrimental to terrestrial and aquatic environments.

14.3.1.2 Amphibians and Reptiles

Amphibians and reptiles are vulnerable to a variety of habitat alteration and fragmentation, due to reduced ability to move and migrate freely, and there is an increased vulnerability to mortality when moving across roads or through inhospitable environments. The direct loss of habitat is the primary effect of the Project on amphibians and reptiles. This includes the physical removal of vegetation, seasonal flooding due to confinement of the river channel during construction, temporary construction sites including roads, reservoir filling, and continued erosion during reservoir operations.

Approximately 38% of the 13,864 ha of suitable western toad habitat available within the LAA will be lost due to construction and operations (Table 14.8). The majority of this habitat loss will be the result of filling of the reservoir. Similar to above, the amount of loss is considered an overestimate for the quarries and the transmission line. The Highway 29 realignment does not overlap any potential amphibian breeding habitats.

For garter snakes, 15% of suitable hibernation habitat will be lost due to the Project, the majority of which is a result of the filling of the reservoir (Table 14.8).

Table 14.8 Habitat Loss: Amphibians and Reptiles

Species	Total Suitable Habitat in LAA (ha)	Project Phase	Loss of Suitable Habitat by Project Component (ha)						
			Dam Site	Reservoir	Transmission Line	Hwy Realign	Roads	Quarries	TOTAL
Western toad	**13,864**	Construction	208	4,763	102	0	37	2	**5,112**
		Operations		34	137	0	0	0	**171**
Garter snake	**4,084**	Construction	90	228	14	39	4	0	**375**
		Operations	0	222	13	0	0	0	**235**

Project construction activities may alter water quality and quantity, in turn affecting amphibian breeding habitat and some snake foraging sites. Sediments can fill in portions of wetlands, altering water depth and smothering aquatic vegetation, rendering them unsuitable for breeding. Increased turbidity affects amphibian eggs, larvae, and adults by interfering with respiration, forage, and shelter (Matsuda et al. 2006). The release of deleterious substances – including concrete, fuel, oil and other hydrocarbons – can also be detrimental to terrestrial and aquatic environments, and the permeable skin of amphibians makes them particularly susceptible to harmful chemicals in the environment (Blaustein et al. 1995; Stuart et al. 2004). Impacts to western toad can occur throughout all life-history phases from pesticide applications (Zevit and Wind 2010).

Where roads cause a loss of connectivity between breeding areas and upland habitat, the result can negatively impact populations (Zevit and Wind 2010). In altered landscapes, a spatial separation often occurs between terrestrial habitat and breeding sites (Becker et al. 2007). In species with an aquatic larvae life stage, adults leave terrestrial environments to reach bodies of water for reproduction. In fragmented landscapes, adults may have to travel through areas with multiple hazards such as increased predation risk, exposure to chemicals and pollutants, and road traffic. For snakes, a reduction in the ability of males to locate females due to road-induced fragmentation can lead to females not reproducing. This could be the result of obstructions to the effectiveness of trail following by males, resulting in longer distances travelled and longer time to locate a potential mate, which may increase exposure and mortality risk (Shine et al. 2004).

14.3.1.3 Migratory birds

As indicated in Table 14.4, migratory birds include songbirds, waterfowl, shorebirds, marsh birds (specifically Yellow Rail, American Bittern, Nelson's Sparrow, and Le Conte's Sparrow), woodpeckers, swallows, and Common Nighthawk. Over 150 species occur within the LAA, so the determination of effects for each species is not possible. Instead, the assessment of effects focuses on migratory bird species that are provincially Red- and Blue-listed or species listed federally (SARA) (Table 14.4).

Based on habitat suitability mapping, there is a total of 202,822 ha of suitable habitat within the LAA combined for all of the selected migratory bird species (Table14.9). For Black-throated Green Warbler, Canada Warbler, Rusty Blackbird and Common Nighthawk, the life requisites have been rated for all subzone variants within the LAA. All other migratory species with habitat suitability modelling have been rated only within the BWBSmw.

The loss of valley bottom forest that overlaps the proposed reservoir will have an effect on a number of songbird species. The valley has the greater songbird diversity compared to upland habitats and contains some of the rare forested ecosystems that are unique to riparian floodplains (Volume 2 Section 13 Vegetation and Ecological Communities). Some of these communities (e.g., Spruce-Currant-Horsetail – 07/SH and Black cottonwood-Red-osier dogwood – 09/Fm02) are also suitable habitats for rare warblers.

The habitat loss to rare songbirds differs based on species requirements. Of the rare songbird for which habitat suitability modelling was completed, the Canada Warbler, Cape May Warbler, and Bay-breasted Warbler lose the highest percentage of habitat – 21.9%, 20.9% and 20.1% respectively – combined over both Project phases. Nearly 61% of the point count stations with Black-throated Green Warbler detections, 47% of the point count stations with Canada Warbler detections, and 51% of the point count stations with Connecticut Warbler detections are within or immediately adjacent to the Project activity zone.

Table 14.9 Habitat Loss: Migratory Birds

Group	Species	Total Suitable Habitat in LAA (ha)	Project Phase	Loss of Suitable Habitat by Project Component (ha)							
				Dam Site	Reservoir	Transmission Line	Hwy Realign	Roads	Quarries	Total	Total (%)
Songbirds	Bay-breasted Warbler	15,639.8	Construction	101.7	2,243.1	102.3	62.9	36.7	88.2	2,634.9	16.8
			Operations	0.0	523.0	0.0	0.0	0.0	0.0	523.0	3.3
	Black-throated Green Warbler	34,775.9	Construction	459.3	2,789.3	261.1	74.7	120.6	169.9	3,874.9	11.1
			Operations	0.0	760.7	0.0	0.0	0.0	0.0	760.7	2.2
	Canada Warbler	12,032.9	Construction	632.3	1,249.8	72.5	48.0	41.0	3.5	2,047.1	17.0
			Operations	0.0	590.8	0.0	0.0	0.0	0.0	590.8	4.9
	Cape May Warbler	9,748.6	Construction	74.9	1,584.8	47.6	27.3	17.4	67.0	1,819.0	18.7
			Operations	0.0	212.4	0.0	0.0	0.0	0.0	212.4	2.2
	Connecticut Warbler	27,035.1	Construction	571.1	1,054.6	326.5	68.6	163.5	132.9	2,317.2	8.6
			Operations	0.0	484.4	0.0	0.0	0.0	0.0	484.4	1.8
	Rusty Blackbird	1,698.4	Construction	3.0	12.3	54.8	0.0	12.2	0.0	82.3	4.8
			Operations	0.0	0.0	50.2	0.0	0.0	0.0	50.2	3.0
Marsh birds	Le Conte's Sparrow	4,533.6	Construction	88.2	708.9	94.1	0.0	33.6	1.9	926.7	20.4
			Operations	0.0	1.6	128.6	0.0	0.0	0.0	130.2	2.9
	Nelson's Sparrow	4,533.6	Construction	88.2	708.9	94.1	0.0	33.6	1.9	926.7	20.4
			Operations	0.0	1.6	128.6	0.0	0.0	0.0	130.2	2.9
	Yellow Rail	2,043.2	Construction	42.0	295.7	50.5	0.0	23.2	1.4	412.8	20.2
			Operations	0.0	0.2	73.5	0.0	0.0	0.0	73.7	3.6
Woodpeckers	American Three-toed Woodpecker	21,581.3	Construction	69.3	2,009.7	215.7	38.4	77.8	128.1	2,539.0	11.8
			Operations	0.0	479.2	0.0	0.0	0.0	0.0	479.2	2.2
	Pileated Woodpecker	14,463.3	Construction	39.7	1,497.8	134.0	2.0	41.7	92.0	1,807.2	12.5
			Operations	0.0	242.1	0.0	0.0	0.0	0.0	242.1	1.7
	Yellow-bellied Sapsucker	40,274.1	Construction	1,017.6	3,180.1	315.9	136.3	144.4	181.5	4,975.8	12.4
			Operations	0.0	812.4	0.0	0.0	0.0	0.0	812.4	2.0
Common Nighthawk		14,462.3	Construction	178.1	1,630.6	83.7	201.9	28.1	194.1	2,316.5	16.0
			Operations	0.0	135.3	120.0	0.0	0.0	0.0	255.3	1.8

While habitat suitability mapping was not completed for waterfowl and shorebird species the change in general habitat classes (river, backchannel, lake and wetland) are used as a proxy for habitat use. The reservoir will convert approximately 83 km of river and associated backchannel habitat into a reservoir. The waterfowl species assemblage are expected to change, and overall productivity will be dependent on forage potential and the availability of both security cover and nesting substrates (e.g., dense wetland vegetation or older forests with suitable nest cavities).

With the filling of the reservoir, ice formation will now occur on an annual basis, where it has not readily occurred in the past (Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report). This will remove staging habitat for some waterfowl species that have used the ice-free portions of the river in early spring. The extent of the ice sheet and timing of thaw will be dependent on winter severity and early spring temperatures, although modelling typically shows most of the ice gone by late April.

Woodpeckers will lose approximately 12% of suitable habitat within the LAA during construction (for all species modelled). Common Nighthawk will lose 16% of the available habitat within the LAA during construction, although suitable habitat will be temporarily created with vegetation clearing within the proposed reservoir area. If these new cleared areas are used for nesting, then additional effects of displacement and possible mortality could occur with seasonal flooding (see below).

Bank-nesting species such as swallows will also be affected by reservoir filling and bank erosion, and additional nest sites would be lost during dam construction and bridge removal for Highway 29 realignment. Violet-green Swallow and Cliff Swallow nest sites near Hudson’s Hope should mostly persist, as the extent of flooding is minimal in this area. Nesting sites associated with bridges and slopes will be recolonized upon completion of construction and as slopes re-stabilize during operations. Furthermore, the dam and associated power generating facilities should also offer nest sites for a number of species, including Barn Swallow, providing there is minimal human disturbance.

The percentage loss of marshbird habitat is similar for Le Conte’s Sparrow, Nelson’s Sparrow, and Yellow Rail. The loss of Watson’s Slough will affect all three species, although the species were reported in other areas south of the Peace River. Loss from the construction of the transmission line is not anticipated, but this is dependent on tower placement, road alignments, and activities planned during operations.

Additional potential issues associated with the Project that alter habitats, possibly reducing habitat suitability for some species include:

- Changes in hydraulic patterns and surface water regimes that alter habitat by reducing river flow, eliminating seasonal flow variability, sediment movement, and channel stability (McAllister et al. 2001)
- Increased siltation that infill portions of wetlands, thereby altering water depth and smothering vegetation
- The release of deleterious substances (Buckler and Granato 1999); also, as cited in Kociolek et al. 2011: Fay & Kociolek 2009
- Dust; as cited in Kociolek et al. 2011: Walker & Everett 1987, and Kalisz & Powell 2003.

- The introduction and proliferation of invasive species

14.3.1.4 Non-Migratory Game Birds

Based on habitat suitability mapping, there is 52,659 ha of suitable habitat for Ruffed Grouse, 22,920 ha of suitable habitat for Sharp-tailed Grouse in the growing season, and 9,697 ha of suitable habitat for Sharp-tailed Grouse in the winter available within the LAA (Table 14.10).

Clearing of vegetation and filling of the reservoir will result in loss of foraging habitat, security habitat, and possible nesting locations. The potential loss of 15% of the available Ruffed Grouse suitable habitat is considered an overestimation, as quarry sites are to be smaller than the area used in this assessment of potential effects, and the transmission line right-of-way may increase the amount of suitable habitat, with the creation and maintenance of younger forest types. The projected loss of 18% of both suitable habitat types for Sharp-tailed Grouse is also considered an overestimation for similar reasons. The Highway 29 realignment has the potential to affect a known lek site but any interaction is dependent on the selection of the final alignment. The known lek site at Area E is located immediately adjacent to the Project component boundary, but not within the boundary.

Table 14.10 Potential Habitat Loss: Ruffed Grouse and Sharp-Tailed Grouse

Common Name	Total Suitable Habitat in LAA (ha)	Project Phase	Loss of Suitable Habitat by Project Component (ha)						
			Dam Site	Reservoir	TL	Hwy 29	Roads	Quarries	Total
Ruffed Grouse	52,659	Construction	1,307.5	3,919.5	546.5	193.9	243.9	288.0	6,499.3
		Operations	0.0	907.8	651.0	0.0	0.0	0.0	1,558.8
Sharp-tailed Grouse Growing Season	22,920	Construction	344.8	2140.5	211.9	314.5	77.7	209.1	3,298.5
		Operations	0.0	353.6	405.8	0.0	0.0	0.0	759.4
Sharp-tailed Grouse Winter Season	9,697	Construction	122.5	871.5	160.1	51.0	62.1	47.2	1,314.5
		Operations	0.0	159.7	245.7	0.0	0.0	0.0	405.4
Totals			1,774.8	8,352.6	2221	559.4	383.7	544.3	13,835.9

14.3.1.5 Raptors

Based on habitat suitability mapping, there is a combined 152,399 ha of suitable habitat within the LAA for the selected raptor species (Table 14.11). The percentage loss of habitat from the Project activity zone for raptor species varies between 11% (Broad-winged Hawk) and 20% (Northern Saw-whet Owl) of what is available within the LAA. Habitat losses will occur predominately during the initial clearing activities, but additional losses will continue into operations with bank erosion and ongoing vegetation maintenance along the transmission line. Northern Harrier and Short-eared Owl should benefit from the early seral vegetation maintained along the transmission line, as they are more tolerant of this vegetation type.

Table 14.11 Potential Habitat Loss: Raptors

Species	Total Suitable Habitat in LAA (ha)	Project Phase	Loss of Suitable Habitat by Project Component (ha)						
			Dam Site	Reservoir	Transmission line	Highway Realign ment	Roads	Quarries	TOTAL
Boreal Owl	16,010.0	Construction	61.1	1,594.6	160.0	15.5	54.1	89.5	1,974.6
		Operation	0.0	247.8	145.8	0.0	0.0	0.0	393.6
Broad-winge d Hawk	25,927.3	Construction	509.8	1,041.7	263.6	68.6	124.9	132.7	2,141.4
		Operation	0.0	496.9	236.7	0.0	0.0	0.0	733.6
Great Gray Owl	16,206.8	Construction	61.1	1,592.9	163.1	15.5	54.3	108.1	1,995.1
		Operation	0.0	247.8	148.9	0.0	0.0	0.0	396.7
Great Horned Owl	15,256.8	Construction	61.1	1,611.9	148.0	2.0	46.3	108.1	1,977.4
		Operation	0.0	250.2	134.4	N/A	N/A	N/A	384.6
Northern Goshawk	38,820.0	Construction	568.6	2,852.1	308.5	77.7	159.0	257.3	4,223.1
		Operation	0.0	839.1	277.9	0.0	0.0	0.0	1,117.0
Northern Harrier	13,105.0	Construction	183.5	878.0	91.7	192.8	32.7	166.6	1,545.3
		Operation	0.0	125	131.3	0.0	0.0	0.0	256.3
Northern Saw-whet Owl	12,917.4	Construction	55.5	1,935.4	141.7	4.3	39.9	65.3	2,242.1
		Operation	0.0	174.8	129.6	0.0	0.0	0.0	304.4
Short-eared Owl	14,155.9	Construction	167.7	1,031.8	103.7	196.7	38.1	167.1	1,705.0
		Operation	0.0	138.7	220.3	0.0	0.0	0.0	359.0

Of the 59 Bald Eagle nests observed in 2011, 32 will be lost with the construction of the Project. The only other known nests of targeted species that will be removed are Northern Goshawk nests. Of the eight known goshawk nests, two are within the proposed reservoir and will be lost.

Habitat fragmentation can further lead to a decrease in the availability of suitable habitat, especially for species that prefer to nest in the interior of older forest stands, away from forest edges. Remnant patches of older forest may not meet thermal requirements or provide stand structures that assist in predator avoidance or sub-canopy flight – notably for Broad-winged Hawk and Northern Goshawk. In addition, Hinam and St. Clair (2008) suggested that, although low levels of fragmentation and habitat loss may benefit Northern Saw-whet Owls through possible increases in prey abundance, a reduction in foraging efficiency and reproductive success coupled with increased stress appears to be correlated with high levels of fragmentation and habitat loss. The same thing can be said for species that prefer open sites. Fragmentation of grassland and field habitats suitable for Short-eared Owl can lead to increased nest predation and reproductive failure (Johnson and Temple 1986).

14.3.1.6 Mammals

14.3.1.6.1 Bats

Vegetation clearing, facilities construction, and reservoir filling will result in the loss of roost sites and foraging habitat. The loss and fragmentation of roosting and foraging habitat is considered a threat to bats (Russell et al. 2008). While some habitat disturbance or tree removal on a small scale may increase the area of foraging habitats and travel corridors for bats, forests are necessary for roosting and foraging habitat for forest-feeding species (Grindal and Brigham 1998). Clearing of forest cover will directly eliminate roost trees, and may cause additional losses of roost trees adjacent to the cleared area indirectly through "wind throw".

Project construction could directly affect 23% of the available suitable foraging habitat for bats within the LAA and 11% of the total reproducing habitat within the LAA (Table 14.12). It is important to note that not all of the foraging habitat within each Project component will become unusable to bats after Project construction. Foraging opportunities will still be available over the water of the reservoir and over the open habitat of the transmission line.

Operations are expected to affect less than 3% each of the currently suitable foraging and reproducing habitat within the LAA (Table 14.12). Again, the estimate of foraging habitat loss is considered an overestimate within the transmission line right-of-way.

Table 14.12 Potential Habitat Loss: Bats

Total Suitable Habitat in LAA (ha)	Project Phase	Loss of Suitable Habitat by Project Component (ha)						
		Dam Site	Reservoir	Transmission line	Highway Realignment	Roads	Quarries	TOTAL
Foraging Habitat (ha)								
31,450.7	Construction	246.3	6,356.5	297.5	2.1	115.2	110.6	7,128.2
	Operations	0.0	255.9	325.7	0.0	0.0	0.0	581.6
Reproducing Habitat (ha)								
33,758.8	Construction	647.8	2,454.4	303.1	71.1	136.2	215.2	3,827.8
	Operations	0.0	713.7	0.0	0.0	0.0	0.0	713.7

Effects of inundation on foraging habitats are less clear. Open water habitats do provide foraging opportunities for bats, especially during hatches of aquatic insects (Grindal et al. 1999). Rebelo and Rainho (2009) reported a clear decline in bat activity over foraging areas submerged during reservoir creation in Portugal, while islands that remained above water retained similar foraging activity levels. Bat foraging activity also increased in riparian habitats surrounding the reservoir.

Blasting and excavation through cliffs, rock outcrops, and cutbanks, and removal of bridges could potentially remove bat roosts and hibernacula. Bridge removal and reconstruction would occur at Halfway River, Farrell Creek, Lynx Creek, and Cache Creek. Field surveys of bats revealed that Halfway River, Farrell Creek, and Cache Creek bridges in particular are used by bats as night roosts. Results of the acoustic sampling in 2012 suggest that the rock crevice habitat at Portage Mountain is used for hibernation. Extraction of rock from that site could remove any hibernacula present.

Clearing may result in changes in the community structure of the insects on which bats forage. Dodd et al. (2012) reported that abundance of moths decreased after forest disturbance in the Appalachians, while that of flies increased, and the abundance of beetles remained unchanged. Bat activity, as measured by numbers of echolocation detections, was also positively correlated with disturbance. Changes in vegetation structure from clearing may result in changes in the bat species assemblages that use these areas.

Temporary artificial lighting will be used to illuminate construction areas and permanent lighting will be installed at facilities during operation. While some bat species are attracted to the insects that congregate at street lamps, other species avoid lights (Rydell 2006). The use of artificial lights that deter bat species from using the illuminated space results in habitat loss.

14.3.1.6.2 Beaver

With the filling of the reservoir, over 60 beaver lodges will be lost along the Peace River and tributaries. Fluctuating water levels during construction have the potential to remove some of these prior to filling when construction of the dam is complete. The removal of vegetation in riparian areas during reservoir clearing has the potential to decrease food availability prior to inundation. Additional work around upland wetlands may alter habitat through the introduction of deleterious substances and changes in hydrology.

Construction of the dam will impede movements of animals along the river between the reservoir and the river downstream of the dam. During operations, the changes in flows – most pronounced in the first 16 km immediately downstream of the dam – may remove lodges and food caches. Within the reservoir bank, erosion is expected to reduce habitat quality for beavers. This will continue until slopes become more stable. The formation of ice on the reservoir and fluctuations in the level of the reservoir, although limited, may inhibit use.

14.3.1.6.3 Fisher

The loss of riparian valley bottom forest that overlaps the proposed reservoir will have an effect on fisher. The Project will remove 1,973 ha of potential reproductive denning habitat in the LAA. This equates to 14% of the suitable habitat available within the LAA (Table 14.13). Cavity tree surveys estimate that 2,950 potential reproductive den trees will be lost during habitat removal, representing about 15% of the suitable den trees available in the LAA. The majority of the potential dens trees that would be lost are within the reservoir (2,232) and dam site (374) areas. Three den trees used by one female (F03) in this study were located within the LAA along the Halfway River. One of these den trees is within the proposed reservoir and would be removed.

Table 14.13 Potential Habitat Loss: Fisher

Total Suitable Habitat in LAA (ha)	Project Phase	Loss of Suitable Habitat by Project Component (ha)						
		Dam Site	Reservoir	TL	Hwy Realignment	Roads	Quarries	Total
14,142.6	Construction	45.0	1,690.1	110.2	4.3	34.3	89.5	1,973.4
	Operation	0.0	199.1	0.0	0.0	0.0	0.0	199.1

Based on the fisher density calculated for the Project, 4.28 fishers would be expected to occur in the LAA, and 0.72 fishers would be affected by the habitat loss. The fisher density calculated during the Peace River fisher study is much lower than the reported density in the Williston and Kiskatinaw study areas, and several factors indicate that the fisher population on the south is far below the carrying capacity for that area. The factors are listed below:

- The north provides 29,162 ha of suitable habitat in the trap area (Year 2) and had an estimated density of 7.7 fishers/1,000 km^2, while the south provides 31,404 ha of suitable habitat and had an estimated density of 2.6 fishers/1,000 km^2.
- The fisher trap efficiency on the north (0.0111 captures per trap night) was double the trap efficiency on the south (0.0050 captures per trap night).
- The trap efficiency for marten on the south (incidentally taken during fisher trapping) was double that observed on the north (captures per trap night = 0.1155 north and 0.2476 south). The abundance of marten indicates that the area is not being overharvested. It is not known how marten abundance, distribution, or behaviour influences fisher populations, but their relative size suggests the potential to compete for resources, particularly prey (Lofroth et al. 2010). It is unlikely that marten numbers are reducing fisher presence; other unknown factors are probably limiting the fisher population on the south of the Peace River.
- Trapping records indicate that few fishers have been trapped on the south, with 40 fishers captured in 25 years. Interestingly, two fishers were trapped on the south – including one study animal – during the Year 2 baseline fisher telemetry study.

Habitat fragmentation will affect the ability of fishers to move between patches of suitable habitat. In particular, riparian forests are often used as travel corridors, and loss of riparian habitat along the Peace River is expected to affect the movement of resident animals. Study animals were observed travelling along the Peace River during movements within their home range and during dispersal (e.g., F02 moving along lower floodplain near Moberly confluence, M05's telemetry and hair-snag locations along the river corridor, F12 dispersal). Connectivity of forest cover is important, as fishers avoid habitats that do not have overhead cover (Weir 1990; Powell et al. 1997; Weir and Harestad 1997). Lofroth (2010) reported that the amount of contiguous canopy cover was the most consistent predictor of fisher occurrence. Fragmentation will also affect prey species composition, abundance, and availability, which could have energetic costs to fishers, ultimately affecting survival, reproduction, and recruitment (Weir and Corbould 2008).

Linear features such as highway (> 90 km/hour), roads, the transmission line right-of-way, and reservoirs may act as filters or barriers to fisher movement, preventing population expansion and gene flow (Naney et al. 2012). Field observations and DNA analysis has confirmed that the Peace River is currently not a barrier to movement, and that fishers on the north and south sides of the river form one contiguous population. The filling of a reservoir has the potential to impede movement of individuals, but this is not anticipated to be a concern for the population.

14.3.1.6.4 Ungulates

The direct loss of habitat is the primary effect of the Project on ungulates. Loss of wintering habitat is considered to be most important, but the loss of other seasonal habitats (e.g., birthing) were also considered for each species. In northern populations, resources available to ungulates in winter are limited by snow accumulations, leaving access to generally poorer quality foods compared to what is available in other seasons. Habitat use and selection data demonstrated that radio-tagged moose, elk, and mule deer accessed a wider variety of habitats in spring, summer, and fall than they did in winter. Larger mortality events are consistently in winter, and government habitat management programs focus on maintaining ungulate winter ranges to reduce foraging stresses on ungulate populations. Changes to habitat in other seasons are unlikely to influence moose, elk, and mule deer survival, productivity, or population size.

Moose preferred valley bottom floodplains in winter, but were able to access most habitats within their range during all but the most severe winter periods. Elk favoured similar habitats, but were able to access a wider range of habitats than deer in most years. Mule deer were most numerous on steep south aspect slopes along the Peace River and its main tributaries in most winters. White-tailed deer rarely use wintering habitats that would be affected by the Project, so effects on that species are expected to be minimal.

Based on habitat mapping, hectares of suitable winter habitat and Ungulate Winter Range (UWR) were quantified within the LAA for moose, elk, mule deer, and white-tailed deer (Table 14.14). The amount potentially lost was quantified for each Project component during construction and operation. Loss associated with the transmission line is likely overestimated, as much of the younger, shrub-dominated habitat would remain during operations.

Table 14.14 Habitat Loss by Ungulate Species in the LAA

Species	Total Available (ha)	Project Phase	Loss of Suitable Habitat by Project Component (ha)						
			Dam Site	Reservoir	TL	Hwy Realign	Roads	Quarries	Total
Moose	75,603	Construction	1,505	8,770	761	298	338	430	**12,102**
		Operation	0	1,375	1,249	0	0	0	**2,624**
Elk	71,871	Construction	1,615	8,947	577	459	239	556	**12,395**
		Operation	0	1,409	983	0	0	0	**2,392**
Mule Deer	27,901	Construction	353	6,337	117	156	43	177	**7,182**
		Operation	0	714	139	0	0	0	**853**
White-tailed Deer	8,617	Construction	87	424	138	15	59	40	**763**
		Operation	0	219	289	0	0	0	**508**
UWR	2,578	Construction	0	365	0	0	0.1	0	**365**
		Operation	0	113	0	0	0	0	**113**

Less severe winters, which have been more common recently in the Peace Region, and access to agricultural crops have allowed elk and deer to reach high densities in parts of the LAA. Elk numbers have steadily increased, suggesting that they have not reached a habitat limited population. Deer numbers appear to have measurable fluctuations between years and will likely continue to do so, regardless of the Project. Portions of four UWRs are present within the LAA (SPE-001, 003, 014, and 025) but only SPE-001 has habitat removed during construction and operation. Though a third of the SE-001 is being removed, this represents approximately 20% of the available UWR within the LAA.

Others have documented cases of islands being used for parturition (Edwards 1983; Timmermann & McNicol 1988; Poole et al. 2007). Islands in the Peace River valley and in the reservoir area in general were rarely used for birthing by collared moose, elk, mule deer, or white-tailed deer. Potential effects of the Project on reproduction of ungulates are expected to be low, since only a small proportion of habitats used for birthing will be influenced by the Project.

The construction of roads and the resulting traffic could have three main effects on ungulate populations: 1) a reduction in available suitable habitat and resource variety, 2) a decrease in movement across roadways, potentially causing habitat fragmentation and genetic isolation, and 3) vehicular collisions resulting in mortality (Gagnon et al. 2007). Ungulates, particularly elk and moose, are known to avoid areas in proximity to roads (Gagnon et al. 2007). Several well-used roads and highways traverse the LAA; existing roads do not seem to form barriers to movement, since every collared animal incorporated existing roadways within their annual range. Some suitable habitat will be affected with the construction of both temporary and permanent roads, but a restriction of movement is not expected to be measurable.

Effects on ungulate movement across the reservoir to suitable wintering habitats were also considered. Ice formation will now occur on an annual basis where it has not occurred for some time (Volume 2 Appendix H Reservoir Water Temperature and Ice Regime Technical Data Report). Movement to winter ranges occurs in the fall, prior to freezing most years. Ungulates rarely crossed the flowing river in winter and it is expected that avoidance of the unfrozen reservoir in winter would continue. When the reservoir freezes, it is expected to facilitate more winter movements. The reservoir would be relatively narrow, and it is expected that most individuals would continue to swim across during the spring, summer, and fall seasons, although debris levels within the reservoir and bank stability may hamper movement.

14.3.1.6.5 Large Carnivores

Habitat loss and fragmentation are primary factors limiting grizzly bear populations in B.C. (B.C. Ministry of Water, Land and Air Protection 2004a) and have caused a decline in grey wolf populations through North America (Boitani 2003, cited in Leonard et al. 2005). Resident grizzly use within much of the Project activity zone is considered to be scarce or nonexistent. Thus, habitat loss to the species was not considered.

Road densities exceed published thresholds for road density for wolf persistence (Mech et al. 1988; Thiel 1985), but larger patches with few roads do occur. The greater restriction to wolf movement and occurrence in some parts of the LAA is considered to be caused by mortality. Hunting, trapping, and predator control are affecting local populations.

14.3.2 Effects Assessment – Disturbance and Displacement During Construction and Operations

Disturbance and displacement refers to activities that cause individuals to alter their behaviour or to avoid habitats that are otherwise suitable.

Wildlife resources would be displaced as a result of the timing of flow releases and construction headpond flooding resulting from seasonal and daily fluctuations in water level – upstream of the dam during construction and downstream of the dam during operation – most notably, downstream to the Pine River confluence. During Stage 1 and Stage 2 of dam construction, the confinement of the flow past the dam site would cause the Peace River to flood upstream of the dam site. The extent of flooding would be dependent on the amount of water within the system, and is dependent on flow releases from the Peace Canyon Dam and natural inputs from tributaries. The spring freshet is expected to increase flooding at a time when many species are breeding.

A summary of expected disturbance and displacement effects by key indicator group is provided below.

14.3.2.1 Butterflies and Dragonflies

The effect of disturbance on butterflies and dragonflies is difficult to quantify; a species' persistence in an area is considered to be more strongly related to habitat quality, rather than proximity to activities. Displacement is expected when temporary changes force individuals to flee or relocate from suitable habitat.

As stated above, headpond flooding (during construction) and temporary flooding immediately downstream (during operations) may lead to displacement, depending on the season. This would be expected only for adult life stages, as immediate effects on egg or larval stages are linked more with mortality.

14.3.2.2 Amphibians and Reptiles

Disturbance to amphibians and reptiles due to noise or human presence is difficult to quantify; similar to butterflies and dragonflies, a species' persistence in an area is considered to be more strongly related to habitat quality, rather than proximity to activities. Displacement is expected when changes or noise force individuals to flee or relocate. This could result in increased energy expenditures, utilization of suboptimal habitats, and increased predation risk.

Similar to butterflies and dragonflies, headpond flooding (during construction) and temporary flooding immediately downstream (during operations) may lead to displacement, depending on the season. The spring freshet may lead to an increase in flooding upstream of the dam during construction, and may lead to displacement at a time when amphibians may be breeding.

The dam site and other Project components would require artificial lighting. There are few actual data on the effects of artificial lighting on free-living amphibians. Inferences from laboratory studies suggest artificial lighting may have effects on amphibian migration and metamorphosis, and light pollution may pose a serious threat to reptiles and amphibians in urban environments (Perry et al. 2008). Artificial light may interfere with movements to breeding areas or inhibit frog breeding choruses (Longcore and Rich 2004; Baker and Richardson 2006). Some frog species may be attracted to artificially lit areas. It is unclear whether individuals are attracted to the light or if they are attracted to the prey that congregate under the lights (Perry et al. 2008). If amphibians are attracted to construction lighting, displacement within the Project activity zone is expected to increase.

14.3.2.3 Migratory birds

Loud construction-related activities, such as drilling, blasting, helicopter use, pile driving, and tree falling, would disturb migratory birds. The magnitude of disturbance to any species would depend on the type of activity, how close the activity is to the individual, the frequency of the activity, and the species' susceptibility to disturbance (Miller et al. 1998; James and Stuart-Smith 2000; Environment Canada 2011). Ongoing industrial noise and human use has the potential to reduce species diversity, change population age structure, and may alter avian predator-prey dynamics (Francis et al. 2009). This may be due to anthropogenic noises masking mate-attracting calls (Pohl et al. 2009; Rheindt 2003), communication with other flock members and offspring (Leonard and Horn 2005; Slabbekoorn and Ripmeester 2008), or defending territories and detecting predators (Francis et al. 2009; Habib et al. 2007).

Lighting at construction sites may also affect birds in migration as well as choice in nesting location (De Molenaar et al. 2006; also, van de Laar 2007, cited in Kociolek et al. 2011). Artificial lights can attract nocturnally migrating birds which can alter flight paths, resulting in depletions of energy stores (van de Laar 2007, cited in Kociolek et al. 2011) and may result in fatal collisions with neighbouring structures (Ogden 1996).

During operations, maintenance activities near the dam and along the transmission line could disturb birds that forage, roost, or nest around the Project infrastructure. The extent of disturbance or displacement is dependent on the timing and type of activities planned. Activities in the breeding season and during spring and fall migration would cause greater disturbance than activities occurring in the winter.

Clearing of vegetation during the breeding season could cause disturbance or destruction of active nests, resulting in increased stress, increased energy expenditure, changed behaviour, and potential abandonment of the nest.

14.3.2.4 Non-Migratory Game Birds

Noise and physical disturbance from construction machinery, equipment, and a large work force have the potential to disturb or displace grouse. Documented disturbance of grouse includes a variety of sources: human presence, all-terrain vehicles, mowing, livestock presence, and hunting dog training and trials (Leupin 2003). Male Sharp-tailed Grouse have previously been described as having a high tolerance for disturbance of their leks, returning once a disturbance has ceased; female Sharp-tailed Grouse consistently avoided leks located near disturbed areas, possibly leading to a reproductively inactive lek if only males are present (Baydack and Hein 1987). Individuals using two leks, one adjacent to the Highway 29 realignment and one adjacent to Area E, have the potential to be displaced due to Project activities.

Similar to migratory birds, clearing of vegetation during the breeding season could cause disturbance or destruction of active nests, resulting in increased stress, increased energy expenditure, changed behaviour, and potential abandonment of the nest.

14.3.2.5 Raptors

Loud construction-related activities such as drilling, blasting, helicopter use, pile driving, and tree falling could disturb raptors. The magnitude of disturbance would depend on the type of activity, proximity of activity, frequency of activity, and species' susceptibility to disturbance (Environment Canada 2011). Bald Eagles are particularly sensitive to disturbance during the early stages of nesting, including courtship, nest building, and egg-laying (U.S. Fish and Wildlife Service 2007), although eagles would often acclimatize to the disturbance if it is perceived to be non-threatening. Based on 2011 surveys for Bald Eagle nests, there is one nest downstream of the dam site within 500 m of the proposed dam site and one nest along Boucher Lake that is within 500 m of the existing 138 kV transmission line. All other known Bald Eagle nests not removed during construction are greater than 500 m from the Project activity zone, and not expected to be affected by project activities. Other species with nests within 500 m of the Project activity zone include Broad-winged Hawk (one nest) and Northern Goshawk (three nests). In the absence of mitigation, individuals using these nests could be affected by activities.

While forested habitat would be removed prior to filling the reservoir, raptors may still build or utilize existing nests in remaining forest patches within and adjacent to the proposed reservoir. These individuals would be displaced once the reservoir is filled.

Increased competition for foraging areas and nesting sites could occur as resident populations are displaced into neighbouring areas. This could be for either foraging areas or nesting sites. Some raptors may have increased predation risk from larger, more adaptable raptor species.

During operations, maintenance activities near the dam and along the transmission line could disturb raptors using the Project infrastructure, e.g., transmission towers, for roosting or nesting.

14.3.2.6 Mammals

14.3.2.6.1 Bats

Noise and physical disturbance from construction machinery or other sources has the potential to disturb bats. Construction noise, including blasting within 300 m of bat hibernacula during the winter, can cause premature arousal of hibernating bats. Disturbed bats burn through their energy reserves and can die of starvation before the end of winter. One arousal episode is estimated to cost the energetic equivalent of 68 days of hibernation (Thomas et al. 1990). Female bats that emerge from hibernation with insufficient fat reserves may be unable to reproduce that year (Holroyd 1993). Noise and vibration disturbance effects on day roosts used by small numbers of non-reproductive bats are likely negligible, as long as the structural integrity of the roost remains. Laboratory experiments suggest that some foraging bats avoid areas subject to noise such as road traffic (Schaub et al. 2008).

The potential use of white lights opposed to orange lights during construction and operation could lead to an increased concentration of aerial insects, which has been documented to result in an increased level of bat foraging activity (Blake et al. 1994). Other studies have shown drastic reductions in bat activity for certain species of bats in the presence of artificial lighting, affecting the onset of commuting behaviour (Stone et al. 2009).

14.3.2.6.2 Beaver

Beaver would be displaced during reservoir clearing, flooding during Stage 1 and Stage 2 construction, and reservoir filling. Displacement may be temporary or permanent, and individuals would either move over land, downstream or upstream, or recolonize the edge of the reservoir.

The timing of water releases downstream during operations has the potential to disrupt beaver activity immediately downstream of the dam. Effects would lessen as the fluctuations in water levels attenuate. Beavers are susceptible to this level of disturbance due to current water management regimes along the river. As such, a measurable effect during operations is not anticipated.

14.3.2.6.3 Fisher

Fishers are less tolerant of open areas that limit prey availability, movement, and security. The clearing of land within the reservoir and other Project components would displace animals out of their traditional home ranges. Fishers tend to maintain intrasexually exclusive home ranges in which home ranges of members of the same sex very rarely overlap (Weir 2003). Home range overlap was observed between the female fishers with 95% Fixed Kernel home range estimates, indicating that some females in the general area do not maintain intrasexually exclusive home ranges.

14.3.2.6.4 Ungulates

Construction and clearing activities are expected to have the greatest effect on ungulates during the winter season, when most ungulates are confined to smaller geographic areas within their annual ranges. Disturbance can cause animals to relocate to less suitable habitat or onto agricultural land (Canfield et al. 1999). Once the forested areas within the reservoir have been cleared, the shrub-dominated communities could provide a considerable amount of browse. Fluctuations in water levels during construction of the dam may displace individuals into adjacent habitats. The extent of displacement would be dependent on the extent of flooding and the season.

Vehicular noise is likely the largest contributor to ungulate avoidance of roads. Visual disturbance and deleterious substances also contribute to road avoidance by ungulates. A variety of large mammals have lower population densities within 100–200 m of roads (Forman and Alexander 1998). Roads also provide improved access for hunters and poachers (James and Stuart-Smith 2000; Nellemann et al. 2001; Vistnes and Nellemann 2001; Nalcor Energy 2009), and possibly carnivores.

14.3.2.6.5 Large Carnivores

Disturbance and displacement of large carnivores due to Project activities is not expected.

14.3.3 Effects Assessment – Mortality During Construction and Operations

14.3.3.1 Butterflies and Dragonflies

Mortality is anticipated for all life stages of butterflies and dragonflies: egg, larva, and adult. The greatest mortality risk is associated with the alteration of habitats due to construction activities, flooding, including temporary inundation, and the release of deleterious substances. In addition, the introduction of fish into wetlands that were previously without fish can decrease invertebrate populations, as fish can be predatory to larvae (Cannings et al. 2011).

Almost 500 ha of potentially suitable aquatic habitat, including wetlands, would be lost due to the filling of the reservoir. Headpond flooding during construction would include some of this same area. The timing of activities would influence the overall effect on various species, although flooding of aquatic environments can eliminate dragonfly larvae and eggs regardless of the time of year (R. Cannings., Royal B.C. Museum, 2012. pers. comm.).

14.3.3.2 Amphibians and Reptiles

Mortality is anticipated for all life stages of amphibians and snakes. The larger mortality risk is associated with the alteration of habitats during construction activities, flooding including temporary inundation, and the release of deleterious substances into aquatic habitats. Adults have a limited flight response and may not be able to escape these events.

In late summer, juvenile western toads (toadlets) congregate in large numbers along the sides of breeding pools before dispersing (COSEWIC 2002). Roadways that cut through core habitat areas or dispersal corridors and lack appropriately sighted exclusion fencing and amphibian or wildlife passage structures lead to increased levels of vehicle-induced mortality and population fragmentation (deMaynadier and Hunter, Jr. 1995; Waye 1999; Marsh et al. 2005; Eigenbrod et al. 2008). Road mortality is also a factor for snakes, as they are attracted to the sun-warmed road surface for thermal regulation in evenings (Shine et al. 2004).

Clearing of riparian vegetation and the movement of large construction machinery within or adjacent to riparian areas during construction may cause direct mortalities to amphibians and reptiles. Blasting through rock cliffs, rock outcrops, and talus slopes may result in direct mortality to snakes by potentially removing hibernacula and thermal habitats.

Deleterious substances, including herbicide, can be harmful to amphibians and snakes. Amphibians are considered more susceptible to environmental contamination than many other species (Geer and Krest 2000). Herbicides are known to cause mortality in amphibians if they are exposed at sufficient concentrations of the herbicide (Edginton et al. 2004; Chen et al. 2004; Relyea 2004, 2005a, 2005b, 2005c, 2006). Uncertainty and debate surround the potential direct effects of herbicides to amphibians, particularly what concentration of herbicide leads to measurable increases in mortality and whether this concentration can be found following industrial herbicide applications (Thompson et al. 2006; Relyea 2006). Toxicity of herbicides is often dependent on the herbicide's main ingredient, the surfactant used, and the amphibian species exposed (Howe et al. 2004).

14.3.3.3 Migratory birds

Direct and indirect mortality to individuals – including adults, chicks, and eggs – is expected to occur for most species. The greater mortality risk is associated with the alteration of habitats due to construction activities and flooding, including temporary inundation during dam construction. Other sources of mortality from the Project include deleterious substance releases and collision risk.

Mechanical vegetation removal and the timing of vegetation maintenance are of concern to migratory birds if activities are planned during the breeding season. The initial clearing for the reservoir can provide nesting habitat for ground- and shrub-nesting birds. These same areas have the potential for flooding during Stages 1 and 2 of dam construction, which would cause mortality to eggs and chicks. The extent of flooding would be dependent on the amount of water within the system, flow releases from the Peace Canyon Dam, and natural inputs from tributaries.

Road mortality associated with traffic is dependent on timing of activities and location of the road in relation to migratory bird use (Ascensao and Mira 2005). This can either be when birds cross the road or, in the case of Common Nighthawkroost, on the road (COSEWIC 2007).

Migratory bird mortality caused from bird/power line interactions is a result of either electrocution or collision, although electrocution is more common with distribution lines than transmission lines (Bradley 2003; Avian Power Line Interaction Committee 2006). This is because the spacing between two energized conductors and between a conductor and the support structure on transmission lines is too great to provide an opportunity for electrocution.

Factors influencing collision risk include the design layout of the power line, species-specific bird behaviour, and bird population densities. The chance of collision increases if the power lines bisect seasonal or daily migration paths, such as shorelines and wetlands (Dorin and Spiegel 2005).

Nocturnal or diurnal periods of activity (Bevanger 1994), in-flight manoeuvrability, and the altitude at which birds fly all affect collision potential (Dorin and Spiegel 2005). According to McNeil (1985) and Bevanger (1994), power lines located between feeding areas and roosting sites for wetland birds can have increased risk of bird collision, particularly when a short distance separates the two, as birds must make a short flight at a critical height. Inexperienced birds or birds exhibiting territorial or courtship behaviour can also be at higher risk of collision (Avian Power Line Interaction Committee and U.S. Fish and Wildlife Service 2005) as a result of decreased alertness.

Bird collisions are generally a result of poor visibility of suspended wires. Many collisions occur at the thinner, less visible overhead static lines (Savereno et al. 1996; Avian Power Line Interaction Committee and U.S. Fish and Wildlife Service 2005). Static wires act as safeguards to protect against power outages caused from lightning strikes. These lines are particularly difficult to see during fog, rain, snow, or other weather conditions that decrease overall visibility.

Many empirical studies find that, for most species involved in collisions, the death rate at the population level is low (e.g., Beaulaurier 1981; Brown 1993; Faanes 1987; Hugie et al. 1993). That said, small populations of rare or endangered species can be highly susceptible to anthropogenic mortality (Bevanger 1994; Drewien 1973; Janss and Ferrer 1998; Lockman 1988; Savereno et al. 1996).

14.3.3.4 Non-Migratory Game Birds

Direct and indirect mortality to non-migratory game birds – including adults, juveniles, and eggs – is expected to occur. The greatest mortality risks are associated with alteration of habitats due to construction activities and flooding, including temporary inundation. Eggs and pre-fledged juveniles would be unable to escape these mortality risks. Initial clearing of the inundation zone is planned to take place outside the breeding season. Grouse may move into this area the following spring, as suitable areas for ground nesting are anticipated. Nests located within areas flooded annually upstream of the dam would be lost.

Direct mortality would result from collisions with equipment, machinery, and vehicles. Road access would bisect areas grouse frequent, and road mortality would be anticipated. Hunting pressure on grouse may increase with increased human presence along temporary roads used during construction.

14.3.3.5 Raptors

Direct and indirect mortality to individuals – including adults, juveniles, and eggs – is expected to occur. The greatest mortality risks are associated with alteration of habitats due to construction activities and flooding, including temporary inundation. Eggs and pre-fledged chicks are immobile and unable to escape, although initial clearing of the inundation zone is planned to take place outside the breeding season for raptors, minimizing the risk. Any nests located within areas flooded annually upstream of the dam – notably ground nests, such as those of Northern Harrier and Short-eared Owl – would be lost.

Direct mortality to raptors would result from collisions with equipment, machinery, and vehicles. Supporting literature suggests that vehicular collisions are a noteworthy source of mortality (Loos and Kerlinger 1993; Massemin and Zorn 1998; Hager 2009). Some raptor species, such as hawks and falcons, may be attracted to roads because of the availability of perches and the productivity of road verges, rather than the availability of roadkills (Dean and Milton 2003).

Mortality caused from raptor and power line interactions occurs as a result of either electrocution or collision. Electrocution is more common with distribution lines than transmission lines (Bradley 2003; Avian Power Line Interaction Committee 2006), as the spacing between two energized conductors and between a conductor and the support structure on transmission lines is too great to provide an opportunity for electrocution. Transmission lines are thought to have a greater collision risk than distribution lines based on the principle that the higher the lines are above ground, the greater the risk (Dorin and Spiegel 2005; Heck 2007). The number of vertical levels on a power line and the line height in direct relation to the surrounding landscape – e.g., through grassland or above the treetops – may increase the risk of collision (Bevanger and Brøseth 2001; Bradley 2003; Avian Power Line Interaction Committee and U.S. Fish and Wildlife Service 2005).

14.3.3.6 Mammals

Direct and indirect mortality to both adults and young is expected. The highest mortality risk is associated with the alteration of habitats due to construction activities and flooding, including temporary and permanent inundation. Species or life stages with limited mobility may not be able to move fast enough or far enough to escape flooding and construction activities. The initial clearing within the reservoir may leave some habitat for dens or lodges. These would be flooded during Stage 1 and 2 of dam construction, potentially causing mortality.

Other sources of mortality include vehicular collisions and increased access for hunting or poaching.

14.3.3.6.1 Bats

Destruction or disturbance of hibernacula in the winter has a high mortality risk for bats. Bats may be using the exposed rock at the proposed quarry site at Portage Mountain for hibernation between late August and May. Physical alteration and removal of the exposed rocks during the winter could crush hibernating bats or cause them to rouse in mid-winter. Bats that emerge during unfavourable winter conditions are likely to perish.

Excavation of cutbanks or removal of rock cliffs could potentially trap bats in roosts or crush individuals (Hayes and Loeb 2007). Buildings in the flood zone may have bats occupying them, and building demolition may cause mortality to adults and pups, especially if buildings used as maternity roosts are demolished before the pups are able to fly.

Clearing treed habitat during the growing season may result in mortality to bats as roost trees are felled. Non-volant pups are particularly vulnerable to felling of maternity roost trees.

Chemical use could negatively affect bats if their insect prey has eaten vegetation sprayed with herbicides, but the chronic exposure to contaminants is unlikely, due to the size of bat foraging areas (Bautista 2005; Baron et al. 1999). Bats may be killed by collisions with vehicles, but there are minimal data available regarding the frequency of roadkills. Russell et al. (2008) described roadkills of little brown bats in Pennsylvania, but that study involved thousands of bats observed crossing a heavily trafficked highway. Potential effects of roadkills on bats in the Peace River valley are unknown.

14.3.3.6.2 Beaver

The majority of beaver habitat in the LAA is along larger river systems, wetlands, and lakes. Much of the available habitat along the Peace River would be flooded by the reservoir. Construction headpond flooding of the reservoir may result in direct mortality of young kits if flooding occurs during the breeding season (late spring to early summer). Flooding during the fall has the potential to decrease winter beaver survival rates, due to losses of food caches.

The release of deleterious substances into waterways has the potential to cause mortality.

14.3.3.6.3 Fisher

Direct mortality due to vegetation clearing has the potential to occur, especially when trees are used for denning and resting. Denning females with kits would be particularity susceptible if clearing is competed during rearing period when kits are present and immobile (March 20–June 30).

Additional mortality could occur with increased heavy traffic on current and proposed roads, particularly in high-speed areas. Forest access roads or trails may also be used as travel corridors for predators, increasing the fisher's vulnerability to predation (Nancy 2012).

14.3.3.6.4 Ungulates

Adult ungulates are highly mobile and are also adept at swimming, although debris, ice shelves, riprap, and other barriers may prevent ungulates from leaving the water after swimming and may result in drowning. Juveniles, within the first month of life, may be vulnerable to drowning if the areas they occupy are flooded in the spring (LeResche 1968; Ballard et al. 1981).

Equipment and materials movement by road or train are expected to result in collision mortalities, particularly if transport routes traverse areas with high numbers of ungulates. Numbers of collisions are influenced by the frequency and speed of traffic, and by the time of day (Klinkenberg 2012). Roadkills occur frequently on existing highways and they would increase with upgrading of highways and increased traffic. Hunting and illegal poaching are also considered a concern associated with increased access (Blood 2000).

14.3.3.6.5 Large Carnivores

The risk of bear mortality due to human defence of life and property would increase in construction areas in proximity to food sources, or to other attractants such as road-killed ungulates or garbage. Improper handling of waste disposal and treatment is known to create nuisance wildlife and negative human-bear interactions. This is more of a concern with black bears, but could also occur with grizzly bears, where they occur in the LAA.

Similar to ungulates, collisions with bears and wolves are expected to continue to occur. Increased hunting and illegal poaching associated with changes in road access is also a concern.

14.4 Mitigation Measures

This assessment proposes technically feasible mitigation measures to address potential Project effects on wildlife resources during construction and operations. Avoidance measures can include refining Project boundaries and selecting the most appropriate construction methods, equipment, material, and timing of activities. Additional mitigation measures to consider include environmental protection measures such as establishment of no- or restricted-activity buffer zones around wildlife features, Best Management Practices (BMPs) and protocols, and engineering standards. Where feasible, mitigation measures can be refined based on consultation with federal and provincial regulatory agencies and Aboriginal groups. Table 4.1 in Section 4.1 Project Evolution in Volume 1 Section 4 Project Description summarizes changes that have been incorporated into the project design to avoid or mitigate potential Project-related effects.

14.4.1 Mitigation for Habitat Alteration and Fragmentation

The potential adverse effects of permanent habitat loss to wildlife resources cannot be avoided within the reservoir and much of the dam, generating station, and spillways, although they can be measurably reduced for other Project components, e.g., transmission line and roads, during final design. This would include placing transmission towers and access roads away from wetlands unless it is proven that no other design option is feasible. The placement of the transmission lines over wetlands and other non-forested areas would not alter the habitats, as only minor clearing would be required during either construction or operations.

The areas within the Project activity zone have already experienced varying levels of habitat fragmentation associated with forestry, agriculture, oil and gas, and urban development. Efforts on this Project have been made to use existing corridors, deactivate temporary access roads, and minimize disturbance where possible, to help minimize fragmentation. Project components where this has occurred include:

- **Substation and Transmission Lines to Peace Canyon Dam:** building the transmission lines adjacent to the existing line, therefore using the existing corridor and maintenance access roads
- **Highway 29 Realignment:** use portions of existing roads and select borrow sites that already exist or would be covered by the reservoir
- **Quarried and Excavated Construction Materials:** further develop existing quarry sites such as Wuthrich, Del Rio, and West Pine, and use a site that has already seen development – the 85th Avenue Industrial Lands.
- **Road and Rail Access:** use existing infrastructure for moving material, upgrade existing access roads, and deactivate temporary roads used for reservoir clearing, and place the Project access road to the dam site area along the existing transmission line corridor

Mitigation measures to be implemented to reduce the effect of Habitat Alteration and Fragmentation are outlined in Table 14.15.

1 **Table 14.15 Mitigation Measures for Habitat Alteration and Fragmentation**

Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction and operations	Habitat alteration and fragmentation: ▪ Wetlands and wetland-associated key indicators: amphibians and reptiles, migratory birds, raptors, bats	All known wetland locations (e.g., breeding habitat for butterflies and dragonflies, amphibians, migratory birds), snake hibernacula, bat hibernacula, Sharp-tailed Grouse lek sites, beaver lodges, and large raptor stick-nest locations would be provided as inputs during the final design phase so further reductions and avoidances can be considered. If work is required immediately adjacent to any wetlands, then appropriate barriers and no- or restricted-activity buffer zones would be established to avoid direct disturbance to these sites. Habitat would be cleared in the approved areas only and construction would be monitored to prevent any unnecessary clearing. Construction and maintenance activities in and around watercourses and wetlands would conform to BC Hydro's regulator-accepted practices including Approved Work Practices for Managing Riparian Vegetation (BC Hydro et al. 2009). New wetland habitat areas would be created as partial compensation for wetland loss due to the reservoir. Consideration for creating areas that are fish-free would be included to minimize the effects of fish predation on invertebrate and amphibian eggs and larvae and young birds.	Recommended mitigation measures would reduce but not fully mitigate the potential effects of the Project	BC Hydro
Construction and operations	Habitat alteration and fragmentation: ▪ Wetlands and wetland-associated key indicators: amphibians and reptiles, migratory birds, raptors, bats	Maintaining surface flow patterns is important in the retention of functioning wetlands. Measures would be implemented to maintain existing hydraulic patterns as much as possible if roads cannot avoid wetlands. Ditches, culverts, and other structures would be placed to maintain the natural drainage patterns and allow the movement of flows.	Effective with proper consideration for flow maintenance; monitoring with adaptive management may be required	BC Hydro

Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction and operations	Habitat alteration and fragmentation: all key indicators: ▪ Introduction of deleterious substances ▪ Erosion and sedimentation ▪ Hydrocarbon and hazardous materials management ▪ Invasive species management	Construction and maintenance activities in and around watercourses and aquatic habitats would conform to BC Hydro's accepted work practices with additional input from Standards and Best Practices for Instream Works (B.C. Ministry of Water, Land and Air Protection 2004b) and the Land Development Guidelines for the Protection of Aquatic Habitat (Chilibeck et al. 1992), which are designed to reduce sedimentation and avoid introduction of deleterious substances to aquatic environments. BC Hydro would have an Erosion Prevention and Sediment Control Plan (Section 35.2.2.9 in Volume 5 Section 35 Summary of Proposed Environmental Management Plans) as part of their Construction Management Framework. Stripping vegetation and soils would be minimized as much as possible, taking into consideration proximity to sensitive habitats, e.g., wetlands, and slope stability. Within the reservoir, a hierarchal decision matrix has been developed for clearing to reduce erosion potential along steep, unstable slopes and along riparian zones for all defined watercourses. Specifically, the decision matrix includes: ▪ Retention of all trees in areas with steep, unstable slopes that would be highly susceptible to landslides if the vegetation was removed ▪ Retention of non-merchantable trees and vegetation within riparian areas around existing water bodies within a 15 m buffer from the high water mark. Merchantable trees may still be removed using clearing practices, in order to maintain a 15 m machine-free zone. These same standards would be employed in other work areas and would follow BC Hydro's approved work practices. Stormwater management would aim to control runoff and direct it away from work areas where excavation, spoil placement, and staging activities occur. Consideration for maintaining recharge levels to wetlands would be considered when diverting water around work sites, providing there is not expected to be a measurable increase in sediment transport to these sensitive areas. A Surface Water Quality Management Plan (Section 35.2.2.21 in Volume 5 Section 35 Summary	Effective – measures based on accepted work practices	BC Hydro

Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
		of Proposed Environmental Management Plans) would be developed as part of BC Hydro's Construction Environmental Management Framework. Cleared areas that will not have permanent features would be replanted with appropriate vegetation in order to promote soil stability. Regionally appropriate vegetation would be included in the reclamation activities. BC Hydro would develop a Soil Management, Site Restoration and Revegetation Plan (Section 35.2.2.19 in Volume 5 Section 35 Summary of Proposed Environmental Management Plans). All activities that involve potentially harmful or toxic substances, such as oil, fuel, antifreeze, and concrete, would follow approved work practices and consider the provincial BMP guidebook Develop with Care (B.C. Ministry of Environment 2012). BC Hydro would have a Fuel Handling and Storage Management Plan (Section 35.2.2.11 in Volume 5 Section 35 Summary of Proposed Environmental Management Plans). This plan would include the need for all construction machinery and vehicles to be properly maintained to ensure that harmful fluids do not leak into aquatic environments or other sensitive areas. Prior to initiating construction activities in proximity to any water body, the hydraulic, fuel, and lubrication systems of all equipment would be checked to ensure that systems are in good condition and free of leaks. All machines would have a spill kit and operators would be educated on how to use the kit. Minimum distances between maintenance and refuelling sites and water bodies would be specific in the plan. BC Hydro's Construction Environmental Management Framework would include an Emergency Response Plan (Section 35.2.1.1 in Volume 5 Section 35 Summary of Proposed Environmental Management Plans) as well as a Hazardous Waste Management Plan (Section 35.2.2.13 in Volume 5 Section 35 Summary of Proposed Environmental Management Plans). Herbicide application would be used to control invasive plants and for the maintenance of some vegetation along the transmission line and at project facilities. The use of herbicides is described in BC Hydro's Pest Management Plan for Management of Vegetation at BC Hydro Facilities (BC Hydro 2012) and Integrated Vegetation Management Plan for		

Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
		Transmission Rights-of-way (BC Hydro 2010). Disturbed sites would be replanted quickly with ground cover, shrubs, or trees that are regionally appropriate, once erosion concerns have been addressed per BC Hydro's Soil Management Site Restoration and Revegetation Plan. A Wildlife Management Plan (Section 35.2.2.24 in Volume 5 Section 35 Summary of Proposed Environmental Management Plans) and Vegetation and Invasive Plant Management plan (Section 35.2.2.22 in Volume 5 Section 35 Summary of Proposed Environmental Management Plans) would also be included, defining objectives for limiting invasive species by monitoring the presence and possible spread of invasive plants in temporarily disturbed areas, as well as the success of revegetation programs. Mitigation measures to reduce the spread of invasive species include: ▪ Prior to work commencing, surveys would be conducted to identify invasive species populations. Treatment would be initiated as required ▪ All vehicles entering and leaving work sites would be washed thoroughly, with special attention to wheel wells, tire treads, and tracks where mud and seeds of noxious weeds may be lodged ▪ Locating wash areas away from any water body and riparian areas ▪ Treating used wash water to prevent seed dispersal The Pest Management Plan for Management of Vegetation at BC Hydro Facilities (BC Hydro 2012) and the Integrated Vegetation Management Plan for Transmission Rights-of-Way (BC Hydro 2010) would be followed in order to reduce or avoid the spread of invasive species during the operations phase of the Project.		
Construction	Habitat alteration and fragmentation: ▪ Loss of snake hibernacula	As mitigation for the loss of snake hibernacula, artificial dens would be considered during habitat compensation. These artificial dens would be located on warm aspect slopes in open areas away from major roads.	Effective, on a limited scale	BC Hydro

Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Habitat alteration and fragmentation: ▪ Loss of nesting habitat: migratory birds	Nest boxes for cavity-nesting waterfowl would be incorporated into wetland mitigation plans. Additional boxes would be established within riparian vegetation zones established along the reservoir on BC Hydro-owned properties, where feasible. The feasibility of placing small floating islands along some areas within the reservoir would be examined. Based on present land ownership, it is estimated there would be over 300 ha of BC Hydro-owned Cultivated Field remaining after the reservoir is filled. A portion of these fields would be managed to provide some breeding habitat for Northern Harrier and Short-eared Owl. Wetland compensation would also address some habitat losses for these two species.	Limited in scale, but can be effective	BC Hydro
Construction	Habitat alteration and fragmentation: ▪ Bats	Bat roosting habitat features would be considered for incorporation into new bridge designs. This can be achieved following published guidelines (Keely and Tuttle 1999; Johnston et al. 2004; Gore and Studenroth 2005) without compromising bridge safety or structural integrity. Bridge night roosts are currently the only public sites within the Peace River valley where relatively large numbers of bats can be captured in a night. Bat boxes may be installed on free-standing poles or on facility walls where their presence would not interfere with facility operations and maintenance. The feasibility of incorporating bat boxes onto mounting poles being used for artificial eagle nest sites would be examined. Bat boxes should be situated where they will get at least 10 hours of sun to provide warm conditions for maternity roosts. Additional information on design, construction, and installation of bat boxes is available from Bat Conservation International (2012). Balsam poplar and aspen would be considered in plantings when reclaiming disturbed habitats and when enhancing habitat for wildlife compensation. Deciduous trees would provide future roosting habitat for bats. Once rock extraction is complete at Portage Mountain, opportunities for creating hibernating and roosting sites would be explored. This can include leaving deep drill holes at least 3 m deep in remaining rock	Installation of bat boxes around dams and generating stations has proven to be successful at providing bat habitat features at other BC Hydro facilities (Nagorsen 2009) Limited in scale	BC Hydro

Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
		faces, and creating roost microsites on warm aspects that are inaccessible to predators.		
Construction and operations	Habitat alteration and fragmentation: ▪ Fisher	The fisher population, particularly south of the Peace River, is lower than initial estimates, based on habitat availability and provincial density. Throughout its range, fur harvest, timber harvest, predator control, and urbanization have been the greatest contributors to fisher population declines (Lofroth et al. 2010). Mitigation measures that limit these factors may increase the population. Create natural or artificial piles of coarse woody debris dispersed throughout the disturbed landscape to maintain foraging areas and cold-weather rest sites. Focus on younger plateau forest where coarse woody debris is limited. Create arboreal resting sites. Spruce rust broom was found to be rare in the Peace River valley, primarily due to the lack of coniferous forests. Creating rust broom-like structure in deciduous stands may provide additional resting opportunities for fisher. Provide artificial den boxes within forested stands that have limited den trees.	Limited in scale, but may be effective	BC Hydro
Construction and Operations	Habitat alteration and fragmentation: ▪ Ungulates	BC Hydro would continue to manage lands it owns to the east of the Halfway River and west of Wilder Creek to maintain values of these areas as winter range and their accessibility. Other jurisdictions have implemented supplemental feeding programs to support ungulate populations during severe winter conditions. It is a method commonly used in the western United States for mule deer and elk (Baker and Hobbs 1985; Smith 2001; Peterson and Messmer 2007). Supplemental feeding has also been used for moose in Alaska and Scandinavia (Van Beesta et al. 2010). Such programs require careful planning and management by experienced biologists in order to be effective (Putman and Staines 2004). They can be costly, depending on the size of the area and numbers of animals. The use of feeding programs during severe winters would be considered.	Limited in scale, but may be effective	BC Hydro

14.4.2 Mitigation for Disturbance and Displacement

The avoidance and reduction of displacement due to construction headpond flooding is not possible, as the timing of flooding is dependent on natural events (e.g., rainfall and the spring freshet) and power generation. Effects may be alleviated with the creation of habitats within the reservoir and the creation of some additional habitats through compensation works.

Mitigation measures to reduce the effect of disturbance and displacement from the Project are outlined in Table 14.16.

1 **Table 14.16 Mitigation Measures for Disturbance and Displacement**

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction and Operations	Disturbance and displacement: ▪ Migratory birds, non-migratory birds, raptors ▪ Timing of works ▪ Lighting ▪ Roads	The clearing of vegetation for all work would consider both the *Migratory Bird Convention Act* and the B.C. *Wildlife Act,* where active nests are protected from disturbance and removal. The provincial government has developed least-risk windows for terrestrial wildlife that are of management concern within the Peace Region of the B.C. Ministry of Forests, Lands and Natural Resource Operations. Suggested critical time periods when construction should be avoided are: ▪ Songbirds: May 1 through July 31, when nesting could occur (B.C. Ministry of Forests, Lands and Natural Resource Operations 2011). ▪ Trumpeter Swan, raptors and owls: April 1 through July 31 Goddard (2010) observed lek attendance by Sharp-tailed Grouse between mid-April and mid-May in the Peace River region, and a nesting initiation to hatching date range from early May to mid-July. There is no specific mention for grouse within the least-risk windows, but nesting overlaps the critical time frame suggested for raptors. Clearing activities for much of the area are presently scheduled to occur during the winter months, thereby avoiding conflicts with nesting birds (see Volume 1 Appendix A Vegetation, Clearing, and Debris Management Plan). Scheduling constraints may require clearing activities to occur outside the winter months. If clearing work during the critical bird breeding season outlined above cannot be avoided, a nest and lek search protocol would be developed and implemented prior to clearing, to avoid disturbance to active nests. The protocol would be developed in consultation with Environment Canada, Canadian Wildlife Service, and the Ministry of Environment. The protocol would outline buffers required around active nest sites. As feasible, lighting would be focused on work sites, minimizing light pollution in surrounding areas. During construction, access would be restricted on roads used by work crews. Temporary roads would be closed and reclaimed when no longer needed.	Effect would be partially mitigated	BC Hydro

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction and Operations	Disturbance and displacement: ▪ Butterflies and dragonflies, amphibians and reptiles, migratory birds, non-migratory birds, raptors, bats, fur-bearers, ungulates, and large carnivores	BC Hydro uses a GIS-based mapping system for recording, storing, and analyzing information for managing resources along all of its rights-of-way. The information is reviewed when developing vegetation management prescriptions during operations. If occurrences for rare species (e.g., Yellow Rail) are known along the transmission line right-of-way or are adjacent to generation facilities, the location of these sites would be incorporated into the database for future planning and consideration, so as to minimize or avoid unnecessary disturbance.	Effects would be partially mitigated; is dependent on the extent of known occurrences	BC Hydro
Construction	Displacement and disturbance: ▪ Sharp-tailed Grouse	All known lek locations would be provided as inputs during the final design phase so further reductions and avoidances are considered. If new construction sites are added or the area where disturbance is to occur is poorly understood, the new areas would be checked to confirm if leks are present and possible ways to minimize disturbance. If work is required immediately adjacent to any leks, then appropriate barriers would be added so as to instruct construction personnel to avoid these sites. Habitat would be cleared in the approved Project activity zone only, and construction would be monitored to prevent any unnecessary clearing.	Effects partially mitigated; effectiveness depends on duration of construction activity and level of alteration around the lek	BC Hydro

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Disturbance and displacement: ▪ Bald Eagle nests	The baseline data on Bald Eagle nest sites from 2011 would be updated prior to commencement of construction to ensure an accurate understanding of the number of nests that would be affected by the Project. To mitigate the loss of Bald Eagle nests within the proposed reservoir, new nesting platforms would be erected along the expected reservoir shoreline. Platforms would be designed to be attractive to nesting Bald Eagles – i.e., platform suitable for supporting a large stick-nest, with structures extending above the platform to provide perch sites for adults and juveniles prior to fledging – and would be placed in areas removed from potential human disturbance. The Best Management Practices for Raptor Conservation during Urban and Rural Land Development in British Columbia (Demarchi et al. 2005) provides further guidance. For each active nest lost due to the Project, two nesting structures would be provided; the two-to-one ratio is proposed by BC Hydro. Bald Eagle nests are typically located adjacent to water. With construction lasting up to eight years, it is possible Bald Eagles would not use the newly erected platforms until the reservoir is filled. Bald Eagle nests confirmed active the year clearing is started within the reservoir, and outside the dam construction area would be retained through the entire construction phase until reservoir filling is initiated. Nests that could be lost during seasonal flooding associated with Stage 2 dam construction would be removed to limit displacement or possible mortality. Appropriate government approvals and permits would be obtained prior to removing any nest. For active nests retained through construction, a no-clearing buffer centred on each active nest would be employed.	Effects would be partially mitigated	BC Hydro

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction and Operations	Disturbance and displacement: ▪ Large carnivores	Preventative measures would be used to avoid creating human-bear conflicts. Before commencement of work, all crews should participate in a Bear Aware™ or similar training program. Feeding of wildlife (including birds) would be prohibited at work sites. Construction areas and worker housing sites would be fenced and kept clean and free of waste, with garbage securely stored in bear-proof containers or removed from site. Trucks and work vehicles are not secure storage areas for garbage, because bears have been known to break into vehicles for food (Davis et al. 2002). Work crews would be prohibited from hunting and cleaning game around construction sites. If precautions to remove bear attractants such as food and garbage are not effective in deterring aggressive bears from construction areas, the Environmental Monitor would notify a Conservation Service Officer that a potential “problem bear” is in the area. A bear would only be classified as a “problem bear” if: ▪ It shows repeated interest in people and their facilities ▪ It is heavily habituated to people and has repeatedly obtained unnatural foods ▪ It displays aggressive behaviour (unprovoked charges or predatory behaviour) and is an imminent threat to human safety The Conservation Service Officer would determine whether further actions, such as more aggressive aversive conditioning (e.g., use of rubber bullets, hard capture and release, etc.), translocation, or destruction of the bear are necessary, and would advise about how to ensure worker safety. A detailed Human-Bear Conflict Management Plan would be developed for the Project.	Effects would be partially mitigated	BC Hydro

14.4.3 Mitigation for Mortality

Mortality related to habitat loss cannot be fully avoided for the entire Project, but can be reduced with wetland avoidance along the transmission line when building access roads and by maintaining hydraulic patterns, should a road bisect a wetland. Mortality can also be reduced by clearing during times of the year that would pose the least risk to wildlife. Additional mitigation measures to reduce mortality on wildlife as a result of the Project are outlined in Table 14.17.

1 **Table 14.17 Mitigation Measures for Mortality**

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction and Operations	Mortality: ▪ Migratory birds, non-migratory birds, raptors ▪ Timing of works	The clearing of vegetation for all work would consider both the *Migratory Bird Convention Act* and the B.C. *Wildlife Act,* where active nests are protected. The provincial government has developed least-risk windows for terrestrial wildlife that are of management concern within the Peace Region of the B.C. Ministry of Forests, Lands and Natural Resource Operations (see above in Disturbance and Displacement mitigation). Clearing activities for much of the area are presently scheduled to occur during the winter months, thereby avoiding conflicts with nesting birds (see Volume 1 Appendix A Vegetation, Clearing, and Debris Management Plan). Scheduling constraints may require clearing activities to occur outside winter months. If clearing work during the critical bird breeding season outlined above cannot be avoided, a nest and lek search protocol would be developed and implemented prior to clearing to avoid disturbance and possible mortality to nesting birds. The protocol would be developed in consultation with Environment Canada, Canadian Wildlife Service, and the Ministry of Environment. The protocol would outline buffers required around active nest sites.	Effect would be partially mitigated	BC Hydro
Construction	Mortality: ▪ Butterflies and dragonflies, amphibians and reptiles, migratory birds, non-migratory birds, raptors, bats, fur-bearers, ungulates and large carnivores ▪ Introduction of deleterious substances ▪ Erosion and sedimentation	The project would avoid the release of deleterious hydrocarbons and other hazardous materials by conforming to BC Hydro's accepted work practices with additional input from Standards and Best Practices for Instream Works (B.C. Ministry of Water, Land and Air Protection 2004b) and the Land Development Guidelines for the Protection of Aquatic Habitat (Chilibeck et al. 1992), which are designed to reduce sedimentation and avoid introduction of deleterious substances to aquatic environments. Mortality due to sedimentation would be reduced or avoided following similar plans, e.g., BC Hydro would have an Erosion Prevention and Sediment Control Plan (Section 35.2.2.9 in Volume 5 Section 35 Summary of Proposed Environmental Management Plans) as part of their Construction Management Framework. Surface water quality would be monitored to ensure it does not exceed established guidelines for aquatic life (see Volume 2 Appendix E Water Quality Baseline Conditions in the Peace River). BC Hydro would follow their Pest Management Plan for Management of Vegetation at BC Hydro Facilities (BC Hydro 2012) and Integrated Vegetation Management Plan for Transmission Rights-of-Way (BC Hydro 2010) for the use of herbicides.	Effects would be mitigated – as measures based on accepted work practices	BC Hydro

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
	▪ Hydrocarbon and hazardous materials management ▪ Invasive species management	This includes consideration for use around wetlands and species at risk.		
Construction and Operations	Mortality: ▪ Butterfly and dragonfly, amphibians and reptiles ▪ Predation	A portion of the wetlands created to compensate for habitat loss would be designed to remain fish-free to eliminate predation to invertebrates (dragonfly larva) and amphibians and reptiles.	Effect would be partially mitigated	BC Hydro
Construction and Operations	Mortality: ▪ Amphibians and reptiles, mammals ▪ Roads	Road mortality for both amphibians and snakes was documented during baseline studies and is expected to occur during Project construction, as many roads have multiple users. During detailed road design, efforts would be made to minimize or avoid additional losses. Where roads are adjacent to wetlands or amphibian migrations across roads are anticipated, fencing would be placed along the length of the road to guide amphibians through structures designed for wildlife passage under the road. The size and number of the structures needed and the length of fencing would be determined in consultation with regulators. Road mortality of mammals is expected to occur during Project construction. Measures to minimize road mortality include: ▪ Reducing vehicle traffic by using buses and car-pooling for workers ▪ Requiring workers to adhere to strict speed limits ▪ Instructing workers that wildlife has right-of-way unless there are safety concerns ▪ Maintaining a logbook of wildlife sightings, including roadkills, and posting warning signs at locations with frequent wildlife crossings ▪ Promptly moving roadkill well off the road to avoid secondary mortality of scavengers ▪ Including wildlife-vehicle collisions as safety issues for discussion on worker tailboard meetings	Effects would be mitigated with proper consideration for movements; monitoring with adaptive management may be required	BC Hydro

Project Phase	Project Effect	Mitigation Measures	Mitigation Effectiveness	Responsibility
		Temporary workers involved in on-site Project construction would be encouraged not to hunt in the LAA.		
Construction and Operations	Mortality: ▪ Mammals ▪ Roads	Mammal mortality associated with filling the reservoir can be reduced by clearing forested habitat – potential roosting and cover sites for bats and fisher – before flooding begins. Clearing should take place during late fall and winter before the birthing season and when bats are not present or are in hibernacula. Scheduling of construction activities should follow guidance in Peace Region Selected Terrestrial and Aquatic Wildlife Least Risk Windows (B.C. Ministry of Forests, Lands and Natural Resource Operations 2011).	Effects would be partially mitigated	BC Hydro
Construction and Operations	Mortality ▪ Large carnivores	Preventative measures would be used to avoid creating human-bear conflicts. Before commencement of work, all crews should participate in a Bear Aware™ or similar training program. Feeding of wildlife (including birds) would be prohibited at work sites. Construction areas and worker housing sites would be fenced and kept clean and free of waste, with garbage securely stored in bear-proof containers or removed from site. Trucks and work vehicles are not secure storage areas for garbage, because bears have been known to break into vehicles for food (Davis et al. 2002). Work crews would be prohibited from hunting and cleaning game around construction sites. If precautions to remove bear attractants such as food and garbage are not effective in deterring aggressive bears from construction areas, the Environmental Monitor would notify a Conservation Service Officer that a potential “problem bear” is in the area. A bear would only be classified as a “problem bear” if: ▪ It shows repeated interest in people and their facilities ▪ It is heavily habituated to people and has repeatedly obtained unnatural foods ▪ It displays aggressive behaviour (unprovoked charges or predatory behaviour) and is an imminent threat to human safety The Conservation Service Officer would determine whether further actions, such as more aggressive aversive conditioning (e.g., use of rubber bullets, hard capture and release, etc.), translocation, or destruction of the bear are necessary, and would advise about how to ensure worker safety. A detailed Human-Bear Conflict Management Plan would be developed for the Project.	Effect would be partially mitigated	BC Hydro

14.4.4 Other Mitigation Options Considered

Avoidance and reduction measures have been employed to reduce wetland loss but removing Watson's Slough, and the associated marl fen, from the reservoir is not technically or economically feasible. Protection of Watson's Slough from inundation from the reservoir would have required a large berm several metres in height. The effectiveness of such a berm would be uncertain, and seepage from the reservoir and input from natural springs may have affected the slough.

14.5 Residual Effects

14.5.1 Characterization of Residual Effects

Although the mitigation measures summarized above would reduce the effects on wildlife resources, residual adverse effects remain for habitat alteration and fragmentation, disturbance and displacement, and mortality. The characterization of residual project effects assumes that the specific mitigation measures described above are all implemented.

Residual effects are not expected for large carnivores during construction or operations and are not discussed further.

The criteria used to characterize residual adverse effects are provided in Table 14.18.

Table 14.18 Characterization Criteria for Residual Effects on Wildlife Resources

Criterion	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The ultimate long-term trend of the effect relative to baseline case.	**Negative:** Condition of the VC is worsening in comparison to baseline conditions
		Positive: Condition of the VC is improving in comparison to baseline conditions
Magnitude	The amount of change in a key indicator or variable relative to baseline case.	**Low:** Less than 10% change
		Moderate: Between 10–20% change
		High: Greater than 20% change
Geographical Extent	The geographic area in which an environmental effect of a defined magnitude occurs.	**Site-Specific:** The extent of the effect will have sub-local implications to key indicators
		Local: The extent of the effect will have sub-population implications to key indicators within the LAA
		Regional: The extent of the effect will have broader population implications to key indicators
Duration	The period of time required until the VC returns to its baseline condition, or the effect can no longer be measured or otherwise perceived.	**Short-term:** Effect is limited to < 1 year
		Medium-term: Effect occurs > 1 year but only during construction
		Long-term: Effect lasts into Project operation but dissipates during the life of the Project
		Permanent: Effect lasts during the life of the Project and possibly beyond

Criterion	Description	Quantitative Measure or Definition of Qualitative Categories
Frequency	The number of times during a project or a specific project phase that an environmental effect may occur.	**Once:** Occurs once
		Continuous: Occurs on a regular basis and at regular intervals
		Weekly: Occurs on a regular basis within one month but is sporadic throughout a year
		Monthly: Occurs on a regular basis for more than a month, but is sporadic throughout a year
Reversibility	The degree or likelihood to which existing baseline conditions can be regained after factors causing the effect are removed.	**Reversible:** With reclamation and/or over time
		Irreversible: Over time, even with reclamation
Context	The extent to which the area effected has already been adversely affected by human activities, and is ecologically fragile with little resilience and resistance to imposed stresses.	**High resilience:** Area or key indicator persists when it is subjected to frequent natural or anthropogenic disturbances
		Low resilience: Area is relatively pristine with little or no recent disturbance, or the key indicator requires long-term ecosystem stability in order to thrive
Level of Confidence	An evaluation of the scientific certainty in the review of Project-specific data, relevant literature, and professional opinion.	**Low:** The effectiveness of mitigation or scale of the effect is poorly understood; follow-up monitoring is recommended
		Moderate: Greater certainty in understanding an effects outcome, but reflective of modelling confidence and an understanding of effect pathways
		High: Detailed modelling and an understanding of effect pathways are well understood
Probability	The likelihood that an adverse effect will occur	**Low:** An effect is unlikely to but may occur
		High: An effect is likely to occur

14.5.1.1 Habitat Alteration and Fragmentation

The Project would cause alteration and fragmentation of habitat used by key indicator species by the following mechanisms: i) changes to the structural stage of habitats, ii) loss or reduction in the area of individual habitats, iii) changes to connectivity between habitats, iv) changes in hydrology and flow patterns, v) release of deleterious substance, and vi) loss or reduction in specific habitat features such as nests, winter range areas, and hibernacula. Habitat alteration and fragmentation is considered the primary effect of the project on wildlife resources because the presence and use of the LAA by wildlife resources is driven by the presence and distribution of habitats.

Table 14.19 summarizes the characterization of the residual adverse effect of habitat alteration and fragmentation on all key species groups. An explanation of the characterization is provided by key indicator species group in the text that follows.

14.5.1.1.1 Butterflies and Dragonflies

Construction

The effects of habitat alteration and fragmentation would differ based on a species' habitat preferences.

Due to the range in losses, the magnitude during construction has been assessed as ranging from low to moderate. Geographic extent has been characterized up to regional, due to losses to habitat required by species considered at risk regionally. Most habitat alteration and fragmentation would occur once the clearing within the Project activity zone is completed. It is considered reversible in areas that would be revegetated or where habitats are compensated, and irreversible for suitable habitats that are affected and cannot be readily replaced. Some butterflies and dragonflies require long-term ecosystem stability to survive; portions of the Project activity zone are relatively pristine, while others are not; for this reason, context, the resilience of the key indicator, has been characterized as low. The level of species knowledge and certainty associated with species models leads to a confidence level ranging from moderate to high, depending on species. The probability of an adverse effect occurring is high.

Operation

A magnitude of low has been assessed for operations due to limited habitat alteration and fragmentation associated with erosion along the reservoir.

Table 14.19 Summary of Characterization of Residual Effects: Habitat Alteration and Fragmentation – Butterflies and Dragonflies

		Residual Effect: Habitat Alteration and Fragmentation								
Key Species Group	**Phase**	**Direction**	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Context**	**Level of Confidence**	**Probability**
Butterflies and Dragonflies	Construction and Operations	Negative	Low to Moderate	Local to Regional	Permanent to Long Term	Once to continuous	Irreversible and Reversible	Low to	High to Moderate	High
Amphibian and Reptiles	Construction and Operations	Negative	Low to High	Local	Permanent to Long Term	Once to continuous	Irreversible and Reversible	Low and High	Moderate	High
Migratory Birds	Construction and Operations	Negative	Moderate to High	Site-Specific to Regional	Moderate Term to Permanent	Once to continuous	Irreversible and Reversible	Low to High resilience	Low to High	High
Non-migratory Birds	Construction and Operations	Negative	Low to Moderate	Local	Moderate Term to Long Term	Monthly to Continuous	Reversible	High resilience	Moderate to High	High
Raptors	Construction and Operations	Negative	Low to Moderate	Site-Specific to Local	Short term to Long Term	Once to Continuous	Reversible	Low to High resilience	Low to High	Low to High
Bats	Construction and Operations	Negative	Low to Moderate	Local	Permanent	Once	Irreversible	Low to High resilience	Low	High
Fur-bearers	Construction and Operations	Negative	Low to Moderate	Site-Specific to Local	Moderate Term to Permanent	Once to Continuous	Reversible-Irr eversible	Low to High resilience	Low to High	Low to High
Ungulates	Construction and Operations	Negative	Low to High	Site-Specific to Local	Long Term to Permanent	Once to Continuous	Reversible	High resilience	Moderate to High	Moderate to High

14.5.1.1.2 Amphibians and Reptiles

Construction

Mitigation measures can reduce or avoid habitat loss – especially along the transmission line and access roads – but loss cannot be avoided within the dam and reservoir.

Characterization of magnitude ranges from moderate for garter snakes, due to a loss of 15% of the potentially suitable hibernation habitat within the LAA too high for western toad due to a loss of 38% of suitable habitat within the LAA. These losses include delineated wetlands, riverine back channels, and wet forests. These changes are characterized as permanent, as they are expected to last for the life of the project and irreversible, as conditions would not be returned to baseline over time or with reclamation. Geographic extent is categorized as local, as changes to amphibian and reptile populations would not extend beyond the LAA. Western toads require long-term ecosystem stability to survive, and portions of the Project activity zone are relatively pristine; for this reason, context has been characterized low for this species. Garter snakes use steep-sided slopes for hibernation, which are prone to periodic slumping. As such, the context for garter snakes is high. The level of species knowledge and certainty associated with habitat loss and species models leads to a confidence level of moderate. The probability ranking of an adverse effect occurring is high.

Operation

Very little potential western toad breeding habitat – 0.2% within the LAA – would be affected during operations of the reservoir; therefore, a residual adverse effect is not considered as likely for this species during this phase.

The magnitude of residual effects on garter snakes during operations is characterized as low, as a less than 10% change in habitat is anticipated during operational maintenance of the transmission line and reservoir operations. Frequency during operations is characterized as continuous, due to habitat alteration and fragmentation due to erosion along the reservoir. These effects are considered reversible, as slopes would stabilize to the extent of current baseline conditions through time. The level of species knowledge and certainty associated with habitat loss and species models leads to a confidence level of moderate. The probability ranking of an adverse effect occurring is high.

14.5.1.1.3 Migratory Birds

Construction

The characterization of the residual adverse effect resulting from habitat alteration and fragmentation during construction for migratory birds would differ between species, depending on habitat needs. Characterization of the residual effect of habitat alteration and fragmentation on songbirds is reflective of the effects on Canada Warbler and Black-throated Green Warbler, the two rare species that were observed the most. Of their available habitat in the LAA, 17% and 11% respectively would be lost due to construction, which corresponds to a magnitude characterization of moderate. The geographic extent for songbirds is characterized as regional, because the Canada Warbler is considered at risk federally, which implies that any effect could have population-level implications outside the LAA. This leads to a characterization of long-term or permanent, as the loss of older valley bottom forest could reduce populations to levels lower than present baseline conditions, and populations may not be fully recoverable. They are considered irreversible, due to the level of loss of habitats that are difficult to replace. Portions of the Project activity zone are relatively pristine; for this reason, context has been characterized as low. A confidence level of low reflects the uncertainty associated with the response of populations of specific songbird species at risk of habitat alteration and fragmentation.

The characterization of the residual adverse effect for swallows is reflective of the effects on Bank Swallow. Of the swallow species occurring in the LAA, this species is expected to be affected most by habitat alteration and fragmentation, as it nests on banks along the edge of the proposed reservoir. The total number of nests lost is difficult to quantify, but is expected to be more than 20% of what was observed along the banks of the Peace River and is therefore characterized as having a high magnitude. Effects are not expected to extend beyond the LAA and are characterized as local. Duration is characterized as medium term, as the species nests in areas that are prone to continued disturbance, and should re-colonize sites once banks re-stabilize after filling of the reservoir. For these reasons, the effects are characterized as reversible and the environment is considered to have high resilience. A moderate level of confidence reflects the uncertainty in the ability to quantify the number of Bank Swallow nests that would be lost and the ability for the population to find alternative colony sites.

The characterization of the residual adverse effect for waterfowl and shorebirds is high in magnitude, as the Project would remove over 20% of the available river and back channel habitat, based on the ecosystem mapping (see Volume 2 Section 13 Vegetation and Ecological Communities). Waterfowl and shorebirds are a diverse group that use a wide range of aquatic habitats. Within this group, riverine specialists and species that use the river back channels would be the most affected with the filling of the reservoir. Effects are not expected to extend beyond the LAA and are characterized as local. Duration is characterized as long term, as the effects on nesting habitat are expected to dissipate during the life of the project as vegetation is re-established along the edges of the reservoir and species begin to use placed nest boxes. This is reflected in the characterization of the effects as being reversible. Waterfowl and shorebirds are known to persist when subject to natural or anthropogenic disturbance, and are considered to have high resilience to the effects of habitat alteration and fragmentation, providing there is suitable forage and nesting available.

The characterization of the residual adverse effect for marsh birds is reflective of the effects on Le Conte's Sparrow, Nelson's Sparrow, and Yellow Rail. Effects on American Bittern are not considered based on scarcity of individuals within the LAA. Magnitude is considered high, as the amount of suitable habitat lost during construction would be over 20% for these three species. Effects are not expected to extend beyond the LAA and are characterized as local. Duration ranges from long term to permanent, as the effects of loss of habitat are expected to last for, and possibly beyond, the life of the project, due to the loss of particular wetlands habitats. Marsh birds have specific habitat requirements for breeding – wetlands – and thus, have low resilience to the effects of habitat alteration and fragmentation. A confidence level of moderate reflects the uncertainty associated with the response of marsh birds to habitat alteration and fragmentation.

The characterization of the residual adverse effect for woodpeckers is reflective of the effects on the three species for which habitat suitability mapping was completed: American Three-toed Woodpecker, Pileated Woodpecker, and Yellow-bellied Sapsucker. Magnitude is considered moderate, as the amount of suitable habitat lost during construction is approximately 12% for these three species. Effects are not expected to extend beyond the LAA and are characterized as local. The characterization of duration as medium term or long term reflects the species' ability to recover from the effect of habitat loss. This process is also reflected in the characterization of the effects as being reversible. Woodpeckers are known to persist when subject to natural disturbance, and are considered to have high resilience to the effects of habitat alteration and fragmentations, providing suitable nesting trees persist. The level of certainty associated with habitat loss and confidence in the species models leads to a confidence level of high. The probability of an adverse effect occurring is high.

Vegetation clearing within the reservoir and along the transmission line would create temporary suitable habitat for Common Nighthawk. Magnitude is considered moderate, as the amount of suitable habitat changed during construction is 16%. Effects are not expected to extend beyond the LAA and are characterized as local. The characterization of duration as moderate term is because suitable habitats are generally not limiting for the species, and the population should readily recover. This process is also reflected in the characterization of the effects as being reversible. Common Nighthawk breed in areas created through both anthropogenic and natural disturbance; they are therefore considered to have high resilience to the effects of habitat alteration and fragmentation. The level of certainty associated with habitat loss and confidence in the species models leads to a confidence level of high. The probability ranking of an adverse effect occurring is high.

Operation

No residual effects are anticipated for waterfowl or marsh birds during operation. Residual effects are expected for songbirds, swallows, woodpecker, and Common Nighthawk. The magnitude of residual effects on migratory birds during operation is characterized as low, as a less than 10% change in habitat is anticipated during operation and maintenance of the transmission line and reservoir. These changes are characterized as site specific, due to their limited extent. They are expected to dissipate during the lifetime of the project and have been characterized as long term. Frequency during operations is characterized as continuous, as habitat alteration and fragmentation during operations would occur on a regular basis and at regular intervals with bank erosion. These effects are considered reversible when slopes stabilize over time. The level of species knowledge and certainty associated with operational activities leads to a confidence level of high.

14.5.1.1.4 Non-Migratory Game Birds

Construction

The characterization of the residual adverse effect for non-migratory game birds reflects the effects on both Ruffed Grouse and Sharp-tailed Grouse. Magnitude is considered moderate as the amount of suitable habitat lost during construction for Ruffed Grouse and Sharp-tailed Grouse is 15% and 18% respectively. Effects are not expected to extend beyond the LAA and are characterized as local. The characterization of duration as moderate term is based on the expected time frame for local populations to recover. This process is also reflected in the characterization of the effects as being reversible. These species inhabit areas created through both anthropogenic and natural disturbance and, as such, are considered to have high resilience to the effects of habitat alteration and fragmentation**.** A confidence level of moderate reflects modelling certainty and anticipated effect duration. The probability of an adverse effect occurring is high.

Operations

During operations, the magnitude of the residual effect would decrease to low, as changes of less than 10% of the suitable habitat are anticipated due to transmission line maintenance and operation of the reservoir. Duration would be long term, as the effects would last for the duration of the Project, but would dissipate with time.

14.5.1.1.5 Raptors

Construction

The effects of habitat alteration and fragmentation would differ between raptor species and, with the exception of Bald Eagle habitat, the Project would result in the removal of between 8% (Broad-winged Hawk) and 17% (Northern Saw-whet Owl) of the suitable habitat within the LAA during construction. This change is considered low to moderate in magnitude, depending on the species. Effects of habitat alteration and fragmentation on Bald Eagle are characterized as low, since the provision of alternate nesting platforms would replace lost nests. Geographic extent is categorized as site specific, and duration short term for all but Bald Eagle, Northern Goshawk, and Northern Saw-whet Owl, due to the limited effect on individual tree nests or cultivated fields for ground-nesting species. The local geographic extent and moderate-term duration reflect the potential for habitat alteration and fragmentation to affect Bald Eagle through loss of existing nests, Northern Goshawk through loss of interior old growth forests, and Northern Saw-whet Owl due to requirements for nesting cavities. This is reflective of the length of the duration of construction activities, and the length of time it would take a specific species to recover. For these species, a low resilience to the effects of habitat alteration and fragmentation is assumed, as they require longer-term ecosystem stability to meet their nesting requirements.

A confidence level of low reflects the uncertainty associated with the response of Bald Eagle to habitat alteration and fragmentation. A moderate level of confidence reflects the uncertainty in the response of Northern Goshawk, Great Grey Owl, Great Horned Owl, Boreal Owl, and Northern Saw-whet Owl to loss of nesting habitat. Level of confidence for Northern Harrier, Short-eared Owl, and Broad-winged Hawk is considered high, due to knowledge of local occurrence within the LAA and modelling. Probability of the residual effect ranges from low to high for raptors.

Operation

During operation, the magnitude of the residual effect would decrease to low, as changes of less than 10% of the suitable habitat are anticipated due to transmission line maintenance and operation of the reservoir. Geographic extend is characterized as site specific, as it is dependent on nest locations. Duration is long term, as the effects would last for the life of the Project, but the magnitude would dissipate with time. Frequency is characterized as continuous to reflect the nature of bank erosion along the reservoir. Much of the habitats affected during operations, once stable, would be similar to current baseline conditions; therefore, resilience is considered high.

14.5.1.1.6 Mammals

Effects of habitat alteration and fragmentation on are discussed separately for the four indicator species – bats, beaver, fisher, and ungulates – due to the differences in their habitat requirements and potential for the effects of habitat alteration and fragmentation.

Bats

Construction

With the exception of Portage Mountain, known or expected hibernacula would not be affected by the Project. Characterization of the residual effect for bats is reflective of the loss of roost sites associated with the riparian balsam poplar forests. These losses do not exceed 20% and are categorized as moderate in magnitude. Loss of roosting habitat would have sub-population effects, but would be limited to the LAA and is therefore considered local. Loss of riparian habitat would be permanent and duration has been classified as such. These effects are considered irreversible, as recovery over time would not occur with removal of the Project. The context has been characterized as ranging from high to low, to capture the use of anthropogenic sites by some bat species – little brown/northern myotis – for roosting (high resilience) and requirement for pristine habitats for other species (low resilience).

Operation

Effects of habitat alteration and fragmentation on bats during operations are associated with maintenance operations on the transmission line and bank erosion around the reservoir, both of which are considered site specific. Additional changes in habitat would not exceed 10% and are classified as low in magnitude. They are considered reversible, as the habitat and bat use should recover over time.

Fur-bearers

Effects of habitat alteration and fragmentation are discussed separately for the two indicator species beaver and fisher, due to the differences in their habitat requirements – aquatic versus terrestrial, respectively.

Construction

The characterization of the residual effect for beavers is reflective of reservoir clearing. These effects are considered reversible and are classified as having moderate magnitude, due to the level of habitat alteration. Alteration is considered local because it is based on location of existing lodges in relation to clearing activities. Beavers are expected to re-colonize after disturbance, using portions of the reservoir and compensation areas. Duration has thus been characterized as medium term. Beaver are adapted to habitats subject to frequent natural disturbance, and context is characterized as high. The level of species knowledge and certainty associated with construction activities leads to a confidence level of high.

The characterization of the residual effect for fishers is reflective of effect on denning habitat. Disturbance and displacement of resident fishers is expected to occur within the LAA and is characterized as local. The Project would remove approximately 14% of potential reproductive denning habitat within the LAA, and is characterized as moderate in magnitude. The effect would be greater for females, which have smaller home ranges and have specific requirements for den trees, especially where they overlap the reservoir. Context is therefore classified as low. Confidence is low, due to the effectiveness of mitigation measures.

Operations

The effects of habitat alteration and fragmentation on fur-bearers during operations are associated with maintenance operations on the transmission line and bank erosion around the reservoir, both of which are considered site specific. Additional changes in habitat are not expected to exceed 10%, and are classified as low in magnitude. They are considered reversible once erosion stabilizes.

Ungulates

No population effects are expected for white-tailed deer.

Numbers of elk are expected to continue to increase in the region, since they are not believed to be limited by habitat. Government management programs are currently attempting to reduce elk numbers. In the absence of mitigation, numbers of moose would be reduced within the LAA, since evidence suggests that they are at a stable long-term population that is related to available habitat. Numbers of mule deer are known to fluctuate dramatically in the Peace Region, primarily in response to winter severity. Their populations are thought to be maintained at high levels due to their use of agricultural lands and winter feed intended for cattle. The loss of suitable habitat may reduce their numbers in some parts of the LAA, but winter severity and access to agricultural lands would continue to have the most influence on total numbers of deer in the LAA. Geographic extent has thus been characterized as local.

The characterizations of the residual effect for ungulates are reflective of the effect on the winter habitats, because losses to other seasonal habitats and birthing habitats are not expected to influence moose, elk, or mule-deer population sizes.

Loss of winter range has been characterized as moderate for moose and elk, and high for mule deer, reflecting the amount of loss. This loss of winter range is considered permanent, as recovery during the life of the Project is not expected. Level of confidence is moderate due to the detailed data collected and subsequent habitat use modelling completed.

Operation

The effects of habitat alteration and fragmentation on ungulates during operations are associated with maintenance operations on the transmission line and bank erosion around the reservoir, both of which are considered site specific. Additional changes in habitat would not exceed 10% and are classified as low in magnitude. They are considered reversible, as use would resume over time.

14.5.1.2 Disturbance and Displacement

The Project can potentially cause disturbance and displacement of wildlife resources by the following mechanisms: i) temporary flooding as a result of the construction headpond, ii) clearing, and iii) human activity. For many criteria, the characterization of residual effects for disturbance and displacement reflects the characterization described above for the aspects of habitat alteration. Further, for most indicators, the disturbance and displacement effects are secondary to effects of habitat alteration and fragmentation, which represents a longer-term change to habitats and may have population-level effects.

Table 14.20 summarizes the characterization of the residual adverse effect of habitat alteration and fragmentation on all key species groups. An explanation of the characterization is provided by key species group in the text that follows.

1 **Table 14.20 Summary of Characterization of Disturbance and Displacement**

		Residual Effect: Disturbance and Displacement								
Key Species Group	**Phase**	**Direction**	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Context**	**Level of Confidence**	**Probability**
Butterflies and Dragonflies	Construction and Operations	Negative	Low	Local	Moderate to Permanent	Continuous to Monthly	Reversible	High resilience	Moderate	Low
Amphibian and Reptiles	Construction and Operations	Negative	Low	Local	Moderate to Permanent	Continuous to Monthly	Reversible	High resilience	Low to Moderate	Low
Migratory Birds	Construction	Negative	Low	Local	Moderate term	Monthly	Reversible	Low and High resilience	Low	High
Non Migratory Birds	Construction and Operations	Negative	Low	Local	Short term to Moderate	Monthly	Reversible	High resilience	Moderate	Low to High
Raptors	Construction	Negative	Low	Site specific	Moderate term	Monthly	Reversible	Low and High resilience	Low to Moderate	Low
Bats	Construction	Negative	Low	Site specific	Moderate term	Monthly	Reversible	Low-resilience	High	Moderate
Fur-bearers	Construction	Negative	Low	Site specific – local	Moderate term	Continuous – monthly	Reversible	Low and High resilience	Low to High	Moderate
Ungulates	Construction	Negative	Low	Local	Moderate term	Monthly	Reversible	High resilience	High	Moderate

14.5.1.2.1 Butterflies and Dragonflies

Disturbance and displacement effects are not expected to differ between construction and operations, and are discussed together. Temporary flooding due to the construction headpond and bank erosion are the mechanisms that would result in disturbance and displacement. Avoidance and reduction is not possible with mitigation, as the timing of events is dependent on natural events and power generation. The Peace River experiences high flows during any year, notably during the spring freshet. Upstream releases from the Peace Canyon Dam also influence daily water levels. The creation of potentially suitable habitats within the reservoir and the creation of additional habitats through compensation may further reduce effects of disturbance and displacement. For these reasons, the magnitude has been characterized as low, as changes are not expected to exceed 10%. Geographic extent is characterized as local because, although temporary flooding due to the construction headpond would occur over large areas, the effects would be restricted to specific sites associated with butterfly and dragonfly activity. Probability is assessed as low, reflecting two uncertainties. The first is uncertainty in the level of use after disturbance. This is directly related to disturbance and displacement, because individuals can only be disturbed or displaced if they are using the area. The second is uncertainty in the extent to which downstream releases – notably between the dam and the Pine River confluence – may displace local populations.

14.5.1.2.2 Amphibians and Reptiles

Disturbance and displacement effects are not expected to differ between construction and operations, and are discussed together. The avoidance and reduction of displacement of amphibians and reptiles due to temporary flooding associated with the construction headpond is not fully possible with mitigation, as the timing of events is dependent on natural events and power generation and on upstream releases from the Peace Canyon Dam. The Peace River experiences high flows during any year, notably during the spring freshet, which results in baseline disturbance and displacement. The creation of potentially suitable habitats along the edge of the reservoir and the creation of additional habitats through compensation may offset any effect. For these reasons, the magnitude has been characterized as low, as changes are not expected to exceed 10%. Geographic extent is characterized as local because, although temporary flooding due to the construction headpond would occur over large areas, the effects would be restricted to specific sites associated with amphibian and reptile activity. Probability is assessed as low, reflecting two uncertainties. First, uncertainty in the level of use after disturbance. This is directly related to disturbance and displacement because individuals can only be disturbed or displaced if they are using the area. Second, the level to which local populations of western toad and garter snake would be displaced by inundation resulting from headpond fluctuation during construction is not known.

14.5.1.2.3 Migratory Birds

The residual effects of disturbance and displacement are not expected to occur during operations, and are not discussed. The avoidance and reduction of displacement of migratory birds due to temporary flooding associated with the construction headpond is not possible with mitigation, as the timing of events is dependent on natural events and power generation. The Peace River experiences high flows during any year, notably during the spring freshet, which overlaps the migratory bird breeding season. Upstream releases from the Peace Canyon Dam also influence daily water levels in potential reservoir. The frequency of inundation of terrestrial habitats in the construction headpond is anticipated to be greater than baseline. The extent to which this may displace local populations is unknown and is dependent on use once initial clearing occurs. This would differ by species, but ground and shrub nesting species are anticipated to be affected the most. For these reasons, the magnitude has been characterized as low, as changes are not expected to exceed 10%. Geographic extent is characterized as local because, although temporary flooding due to the construction headpond would occur over large areas, the effects would be restricted to specific sites associated with migratory bird nesting, and would be restricted to the breeding season.

Scheduling clearing activities during times of least risk would avoid displacement and disturbance of nesting individuals. If work occurs during critical times, mitigation would reduce effects, but they may not be completely avoidable. Probability is assessed as high because ground-nesting species would nest in disturbed areas that would be affected by temporary flooding due to the construction headpond and construction areas after clearing is complete, and may result in disturbance or displacement.

14.5.1.2.4 Non-Migratory Game Birds

Construction

The avoidance and reduction of displacement of grouse due to temporary flooding associated with the construction headpond is not possible with mitigation, as the timing of events is dependent on natural events and power generation. The Peace River experiences high flows during any year, notably during the spring freshet. Upstream releases from the Peace Canyon Dam also influence daily water levels. The frequency of inundation of terrestrial habitats in the construction headpond is anticipated to be greater than baseline. The extent to which this may displace local populations of Ruffed and Sharp-tailed Grouse is unknown. For these reasons, the magnitude has been characterized as low, as changes are not expected to exceed 10%. Geographic extent is characterized as local because, although temporary flooding due to the construction headpond would occur over large areas, the effects would be restricted to specific sites associated with grouse occurrence. Frequency is characterized as monthly, since grouse are year-round residents of the LAA.

Scheduling clearing activities during times of least risk would avoid displacement and disturbance of nesting individuals. If work occurs during critical times, mitigation would reduce effects, but they may not be completely avoidable. Probability is assessed as high because ground-nesting species would nest in disturbed areas that would be affected by temporary flooding associated with the construction headpond and construction areas after clearing is complete, and could be disturbed or displaced.

Operation

Disturbance and displacement during operations would be associated with maintenance along the transmission line and bank erosion and is characterized as short-term. The magnitude has been characterized as low as changes would be site specific and are not expected to exceed 10%. Geographic extent is characterized as local because disturbance and displacement would be restricted to specific sites associated with grouse locations.

14.5.1.2.5 Raptors

The residual effects of disturbance and displacement are not expected to occur during operations, and are not discussed. The avoidance and reduction of displacement of raptors due to temporary flooding associated with the construction headpond is not possible with mitigation, as the timing of events is dependent on natural events and power generation. The Peace River experiences high flows during any year, notably during the spring freshet, which overlaps the raptor breeding season. Upstream releases from the Peace Canyon Dam also influence daily water levels. The frequency of inundation of terrestrial habitats in the construction headpond is anticipated to be greater than baseline. The extent to which this may displace local populations would differ by species. Ground-nesting raptors – Short-eared Owl and Northern Harrier – are anticipated to be affected more than other species. Few observations of ground-nesting raptors were made during baseline studies within the Project activity zone, suggesting low nesting use. This could change during construction, as clearing large areas of forest within the reservoir would provide suitable breeding habitat for ground-nesting species. Magnitude of disturbance and displacement has been characterized as low, as changes are not expected to exceed 10%. Geographic extent is characterized as site specific because, although temporary flooding associated with the construction headpond would occur over large areas, the effects would be restricted to specific sites associated with raptor nesting in the breeding season, and raptor roosting or hunting in the non-breeding season.

Scheduling clearing activities during times of least risk would avoid displacement and disturbance of nesting individuals. If work occurs during critical times, mitigation would reduce effects, but they may not be completely avoidable. Probability is assessed as low, reflecting uncertainty in the level of raptor use after disturbance. This is directly related to disturbance and displacement, because individuals can only be disturbed or displaced if they are using the area.

14.5.1.2.6 Mammals

Effects on disturbance and displacement of mammals during operation are not anticipated, and are not discussed further.

The avoidance and reduction of displacement of bats due to temporary flooding associated with the construction headpond is not possible with mitigation, as the timing of events is dependent on natural events and power generation. The Peace River experiences high flows during any year, notably during the spring freshet, which overlaps the period when bats are active in the LAA. Upstream releases from the Peace Canyon Dam also influence daily water levels. The frequency of inundation of terrestrial habitats in the construction headpond is anticipated to be greater than baseline. The extent to which this may displace local populations from foraging, roosting, or breeding sites would differ by species. Clearing large areas of forest within the reservoir would result in disturbance and displacement though the change in the availability and suitability of foraging and roosting habitat. Flooding also has the potential to disturb or displace bats from traditional foraging areas. Magnitude of disturbance and displacement has been characterized as low, as changes are not expected to exceed 10%. Geographic extent is characterized as site specific because, although temporary flooding associated with the construction headpond would occur over large areas, the effects would be restricted to specific sites associated with bat roosting and foraging in cleared areas and along the reservoir.

Scheduling clearing activities during times of least risk would avoid displacement and disturbance of roosting and breeding individuals. If work occurs during critical times, mitigation would reduce effects, but they may not be completely avoidable. Probability is assessed as moderate, because bats are expected to use cleared areas and are known to use edges of the Peace River for foraging.

Fur-bearers

Effects on fur-bearers during operation are not anticipated, and not discussed further. Effects of disturbance and displacement are discussed separately for the two indicator species beaver and fisher, due to the differences in their use of habitat – aquatic versus terrestrial, respectively – and potential to be effected by disturbance and displacement.

The avoidance and reduction of displacement of beaver due to temporary flooding associated with the construction headpond is not possible with mitigation, as the timing of events is dependent on natural events and power generation, and habitats used by beaver would be affected. The Peace River experiences high flows during any year. The frequency of inundation of terrestrial habitats in the construction headpond is anticipated to be greater than baseline. The extent to which this may displace beaver from riverine habitats is not known. Clearing large areas of forest within the reservoir would result in disturbance and displacement though the change in the availability and suitability of beaver food. Magnitude of disturbance and displacement has been characterized as low, as changes, although widespread, are not expected to exceed 10%. Geographic extent is characterized as site specific because the effects of disturbance and displacement would be restricted to specific sites associated with beaver activity in the Project activity zone.

The characterization of the residual effect for fishers is reflective of the timing of clearing within the reservoir. Disturbance and displacement of resident fishers is expected to occur within the LAA. The effect would be greater for females, which have smaller home ranges and have specific requirements for den trees, especially where they overlap the reservoir. The size of the individual home ranges of study animals and the lack of intrasexual exclusion may reduce the risk of displacement due to habitat loss. Magnitude of disturbance and displacement has been characterized as low, as less than 10% of the population in the LAA is expected to be affected. Geographic extent is characterized as local, as the effects of disturbance and displacement on fisher would affect the local population. The low level of confidence reflects the uncertainty in how the fisher population would respond to the effects of disturbance and displacement.

Ungulates

Measurable effects on moose, elk, and mule deer during operation are not anticipated, and not discussed. Project facilities and transportation infrastructure are not expected to have long-term or lasting disturbance or displacement effects on moose, elk, and mule deer over and above the habitat losses previously discussed above. Highways and the reservoir would not form barriers to movement, and disturbances would be mainly confined to the construction period. The extent of disturbance is site specific and dependent on the season and severity of weather conditions. Ungulates may use the newly cleared areas within the reservoir for forage, and could be displaced with temporary flooding associated with the construction headpond. Magnitude of disturbance and displacement has been characterized as low, as less than 10% of the population is expected to be affected. Geographic extent is characterized as local, as the effects of disturbance and displacement on moose, elk, and mule deer would affect the local population.

14.5.1.3 Mortality

The Project can potentially cause direct and indirect mortality to wildlife resources by the following mechanisms: i) when habitats are altered due to flooding, including temporary flooding associated with the construction headpond, ii) from collisions with vehicles and equipment, as well as increased harvest due to increases in roads and human activity, iii) from the release of deleterious substance, iv) when habitat are affected repeatedly (i.e., daily changes in reservoir stage during operations), and v) when predator-prey conditions are altered (i.e., predation of invertebrates when fish are introduction into non-fish-bearing habitat).

For many criterion, the characterization of residual effects for mortality reflects the characterization described above for the aspects of habitat alteration and fragmentation, and disturbance and displacement. Further, for most indicators, the mortality effects are secondary to the effects of these other aspects, because mortality effects represent a one-time loss of individuals in the altered habitat during construction, whereas the other aspects represent a longer-term change to habitats, which may have population-level effects.

Residual effects are not expected for large carnivores during construction or operations. Residual effects of mortality during operations are not expected for migratory birds, non-migratory birds, raptors, bats, fur-bearers, or ungulates, and are not discussed.

Table 14.21 summarizes the characterization of the residual adverse effect of mortality on all key species groups. An explanation of the characterization is provided by key species group in the text that follows.

1 **Table 14.21 Summary of Characterization of Mortality**

		Residual Effect: Direct and Indirect Mortality								
Key Species Group	Phase	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context	Level of Confidence	Probability
Butterflies and Dragonflies	Construction and Operations	Negative	Low to Moderate	Local to Regional	Moderate Term to Permanent	Monthly-Continuous	Reversible	High	Moderate	Low to High
Amphibian and Reptiles	Construction and Operations	Negative	Low to Moderate	Local	Moderate Term to Permanent	Monthly-Continuous	Reversible	High	Moderate	Low to High
Migratory Birds	Construction	Negative	Low	Local	Moderate Term	Monthly	Reversible	High Resilience	Low	High
Non-migratory Birds	Construction	Negative	Low to Moderate	Local	Moderate Term	Monthly	Reversible	High Resilience	Moderate	High
Raptors	Construction	Negative	Low	Site specific	Moderate Term	Monthly	Reversible	High Resilience	Low	Low
Bats	Construction	Negative	Low	Site specific	Moderate Term	Monthly	Reversible	Low Resilience	High	Moderate
Fur-bearers	Construction	Negative	Low	Local	Moderate Term	Continuous	Reversible	Low to High Resilience	Low	Low
Ungulates	Construction	Negative	Low	Site specific	Moderate Term	Continuous	Reversible	High Resilience	High	Low

14.5.1.3.1 Butterflies and Dragonflies

Construction

The magnitude of effects of flooding during construction on butterflies and dragonflies would vary depending on the time of year, with breeding season events having the greatest effects, and are thus characterized as low to moderate. The geographic extent is characterized as regional, because effects on species at risk could have population implications outside the LAA. Frequency is characterized as monthly, due to the expected frequency of occurrence during the spring freshet during the construction period.

Operation

The magnitude of the effect during operation is characterized as low, given low levels of mortality expected due to operational activities. Geographic extent is characterized as local, because effects would be small and restricted to specific sites associated with operational activities or affected by changes in downstream flows.

14.5.1.3.2 Amphibians and Reptiles

Construction

Mortality related to habitat loss cannot be fully avoided for the entire Project, but would be reduced with wetland avoidance, provision of passage structures, and the establishment of no- or restricted-activity buffer zones at some Project components. The potential for mortality associated with flooding during the breeding season, as a result of road traffic and changes to the suitability of wetland habitat from siltation or deleterious substance releases, result in a characterization of moderate. As these effects are associated with construction, duration has been characterized as moderate term. While mitigation measures used to reduce the effects of mortality have proven track records or are industry standards, monitoring of amphibian crossing structures would be required. A confidence level of moderate has been assigned.

Operation

Residual effects on mortality during operation would be associated with maintenance activities along the transmission line, road mortality, and changes in downstream flows. The number of individuals affected is not expected to exceed 10% of the local population and mortality would be limited to the LAA. Magnitude is characterized as low and geographic extent local.

14.5.1.3.3 Migratory Birds

The effects of mortality associated with nest loss due to vegetation clearing and flooding during construction would depend on the time of year. Greater effects would occur when activities overlap the breeding season. Potential effects associated with clearing activities would be reduced because much of clearing is scheduled to occur during the winter months, thereby avoiding conflicts with nesting birds (see Volume 1 Appendix A Vegetation, Clearing, and Debris Management Plan). Scheduling constraints may require clearing activities to occur outside winter months. If clearing occurs during the critical bird breeding season (see Table 14.15), a nest search protocol would be developed and implemented prior to clearing, to avoid disturbance and possible mortality to nesting birds.

The extent of construction headpond flooding is considered to be a residual effect for ground- and shrub-nesting species. Effects are considered to be of low magnitude – less than 10% change in the population. Geographic extent is characterized as local, to reflect the limit of mortality effects in the LAA. Level of confidence is characterized as low because, similar to displacement and disturbance, the magnitude of the effect is dependent on the level of use of the altered habitat, which is poorly understood.

14.5.1.3.4 Non-Migratory Game Birds

The effects of mortality associated with nest loss due to vegetation clearing and flooding during construction would depend on the time of year. Greater effects would occur when activities overlap the breeding season. Potential effects associated with clearing activities would be reduced because much of clearing is scheduled to occur during the winter months, thereby avoiding conflicts with nesting birds (see Volume 1 Appendix A Vegetation, Clearing, and Debris Management Plan). Scheduling constraints may require clearing activities to occur outside winter months. If clearing occurs during the critical bird breeding season (see Table 14.15), a nest and lek search protocol would be developed and implemented prior to clearing, to avoid disturbance and possible mortality to nesting birds. Magnitude has therefore been characterized as low . The extent of construction headpond flooding is considered to be a residual effect for non-migratory birds, as they nest on the ground. Effects of flooding are characterized as moderate to reflect this increased vulnerability. Geographical extent is local, reflecting the restriction of mortality effects associated with construction to the LAA.

14.5.1.3.5 Raptors

Mortality related to vehicle collisions should not be greater than baseline, as many of the existing roads are used during construction. Potential effects associated with clearing activities would be reduced because much of clearing is scheduled to occur during the winter months, thereby avoiding conflicts with nesting birds (see Volume 1 Appendix A Vegetation, Clearing, and Debris Management Plan). Scheduling constraints may require clearing activities to occur outside winter months. If clearing work during the critical bird breeding season occurs (see Table 14.15), a nest search protocol would be developed and implemented prior to clearing, to avoid disturbance and possible mortality to nesting birds. Magnitude is therefore characterized as low and geographic extent site specific, as it is dependent on the location of nests. The extent of the construction headpond flooding is considered to be a residual effect for ground-nesting raptors, but similar to displacement and disturbance, the magnitude of the effect is dependent on use once vegetation clearing is complete. Effects of flooding are characterized as moderate to reflect this vulnerability. The low level of confidence reflects the poor understanding of the level of altered habitats that would be used by ground-nesting species during construction. Geographical extent is local, reflecting the restriction of mortality effects associated with construction to the LAA.

14.5.1.3.6 Mammals

<u>Bats</u>

Construction

The characterization of the residual effect for bats is reflective of the timing of clearing within the reservoir and quarrying activities at Portage Mountain. Most of the reservoir clearing is scheduled in the winter months, when roosting in trees does not occur. The timing of clearing activities and quarry operations on Portage Mountain would have the biggest risk of mortality for bats, due to the presence of a hibernaculum. Magnitude has been characterized as low, as mortality associated with quarry operations is not expected to result in a greater than 10% change. Geographical extent is local, reflecting the restriction of mortality effects associated with construction in the LAA. The low level of confidence reflects the poor understanding of the level of use of hibernacula at Portage Mountain by bats. Probability is assessed as low, reflecting the uncertainty in the level of mortality to bats that would result due to activities at Portage Mountain.

<u>Fur-bearers</u>

Construction

Consideration for removing beaver from the area prior to clearing and filling is being investigated. This opportunity has not been considered in the effects assessment, due to uncertainty in the ability to implement such a removal. Characterization of the residual effect of mortality is for fishers and is reflective of the timing of clearing within the reservoir.

The magnitude of effects of mortality due to fisher den or resting site loss and general vegetation clearing depends on the time of year, with greater magnitude expected if these activities occur during the spring and summer rearing period. Potential effects associated with clearing activities would be reduced because much of clearing is scheduled to occur during the winter months (see Volume 1 Appendix A Vegetation, Clearing, and Debris Management Plan), when young of the year are mobile; as such, magnitude is characterized as low. Vehicular mortality is expected to occur infrequently, as fishers avoid roads, and is also characterized as low. Geographical extent is local, reflecting the restriction of mortality effects associated with construction in the LAA. The low level of confidence reflects the poor understanding of how fisher would use altered habitats and thus be susceptible to mortality due to Project activities. Probability is assessed as low, reflecting these uncertainties.

<u>Ungulates</u>

Construction

Ungulate mortality from collisions with vehicles is a concern in the Peace Region. Upgraded transportation corridors combined with heavy day and night traffic during construction may lead to higher collision rates in some areas. The magnitude of collision mortality is characterized as low, as less than 10% of any ungulate species would be lost. Geographic extent is characterized as site specific, as collisions would occur at specific locations that are dependent on animal location – which would change with the seasons and associated habitat use by ungulates, and with road conditions, vehicle speed, and presence. Level of confidence is characterized as high, based on the detailed understanding of ungulate mortality patterns in the Peace Region. The low probability reflects the low number of individuals in the population that are expected to be killed in vehicle collisions during the construction period.

14.5.2 Thresholds for Determining Significance

The significance of each residual environmental effect is evaluated, taking into consideration the above criteria and existing knowledge about the VC key indicators. A residual environmental effect of habitat alteration and fragmentation, displacement and disturbance, or mortality would be significant if the effect could threaten extirpation of a key indicator, or result in considerable reductions to habitats or habitat use associated with a key indicator that may in turn further elevate provincial or federal listings and cause the key indicator to be a management concern. This means that a residual adverse effect would be significant:

1. For species that are currently provincially or federally designated as, or considered candidates for, threatened or endangered status (e.g., provincially Red-listed or SARA schedule 1), and the magnitude of the residual effect is characterized as high
2. For species that are currently within a lower listing category (e.g., provincially Blue-listed or SARA Schedule 1 special concern), the magnitude of the residual adverse effect is characterized as high, and the adverse effect may result in the key indicator being elevated to a threatened or endangered status listing

A number of species are listed provincially, but not federally. This could be solely based on the delineation of jurisdictional boundaries, or may be a result of provincial strategies for managing species and ecosystems at risk. So that both provincial and federal decision-makers appreciate the full context of any significance ranking, the determination of significance is provided taking into account both federal and provincial listings.

14.5.3 Determination of Significance of Residual Effects

Habitat alteration and fragmentation is considered the primary effect of the project on wildlife resources because the presence and use of the LAA by wildlife resources is driven by the presence and distribution of habitats. For most indicators, the disturbance and displacement and mortality effects are secondary to the effects of habitat alteration and fragmentation. The available measures to mitigate the potential effects on wildlife resources may not be fully effective. Therefore, the residual effect of the Project of habitat alteration and fragmentation on certain species would be significant because the sustainability of the regional populations of these species would be threatened (Table 14.22). This includes Yellow Rail (SARA-special concern, Red-listed), Canada Warbler (SARA-threatened, Blue-listed), Cape May Warbler (Red-listed), Bay-breasted Warbler (Red-listed), and Nelson’s Sparrow (Red-listed).

Table 14.22 Summary of Assessment of Potential Significant Residual Adverse Effects

Valued Component	Project Phase	Potential Effects	Key Mitigation Measures	Significance Analysis of Residual Effects (Summary Statement)
Wildlife resources	Construction and Operations	Habitat alteration and fragmentation	▪ Minimize project footprint ▪ Establish no- or restricted-activity buffer zones to protect habitat features (wetlands, raptor nests, dens, lodges, leks, mineral licks, etc.) adjacent to construction sites ▪ Maintain a spatial database of wildlife features (wetlands, raptor nests, dens, lodges, leks, mineral licks, etc.) within the LAA ▪ Wetland creation ▪ Maintain surface flow patterns ▪ Follow approved work practices as outlined in Project Environmental Management Plans (See Volume 5 Section 35 Summary of Proposed Environmental Management Plans) ▪ Establish a buffer around riparian areas and water bodies ▪ Manage invasive species within the Project activity zone ▪ Avoid clearing during the breeding season; implement survey protocol if avoidance is not feasible ▪ Revegetate disturbed areas as soon as feasible post-disturbance, using regionally appropriate species ▪ Create artificial snake dens ▪ Erect nesting boxes for cavity-nesting waterfowl in riparian areas and at wetland mitigation sites ▪ Erect alternate platforms for Bald Eagle nesting ▪ Manage select cultivated fields to provide habitat for	Significant

Valued Component	Project Phase	Potential Effects	Key Mitigation Measures	Significance Analysis of Residual Effects (Summary Statement)
			Northern Harrier and Short-eared Owl ▪ Create bat hibernating and roosting sites at Portage Mountain after extraction is complete ▪ Erect bat boxes ▪ Erect fisher den boxes ▪ Create piles of coarse woody debris in disturbed areas ▪ Provide arboreal resting sites for fisher ▪ Manage BC Hydro lands at the Halfway River and Wilder Creek to provide ungulate winter range on the north bank of the Peace River ▪ Explore supplemental feeding of elk and mule deer during severe winter conditions	
Wildlife resources	Construction and Operations	Disturbance and displacement	▪ Avoid clearing during the breeding season; implement survey protocol if avoidance is not feasible ▪ Maintain surface flow patterns during maintenance activities ▪ Manage invasive species along the transmission line and at Project facilities ▪ Revegetate areas disturbed by maintenance activities as soon as feasible post disturbance using regionally appropriate species ▪ Follow approved work practices as outlined in Project Environmental Management Plans (See Volume 5 Section 35 Summary of Proposed Environmental Management Plans) ▪ As feasible, focus lighting on work sites to minimize light pollution in surrounding areas ▪ Restrict access and close temporary roads when no longer needed ▪ Maintain a spatial database of wildlife features (wetlands,	Not significant

Valued Component	Project Phase	Potential Effects	Key Mitigation Measures	Significance Analysis of Residual Effects (Summary Statement)
			raptor nests, dens, lodges, leks, mineral licks, etc.) within the LAA ▪ Establish no- or restricted-activity buffer zones to protect habitat features (wetlands, raptor nests, dens, lodges, leks, mineral licks, etc.) adjacent to construction sites ▪ Retain Bald Eagle nests outside Project activity zones until immediately prior to reservoir filling ▪ Avoid creating bear-human conflicts thorough proper handling of attractants and training of workforce	
Wildlife Resources	Construction and Operations	Mortality	▪ Avoid clearing during the breeding season; implement survey protocol if avoidance is not feasible ▪ Restrict access and close temporary roads when no longer needed ▪ Establish no- or restricted-activity buffer zones to protect habitat features (wetlands, raptor nests, dens, lodges, leks, mineral licks, etc.) adjacent to construction sites ▪ Establish and enforce speed limits on Project roads ▪ Install and maintain amphibian exclusion fencing and crossing structures adjacent to wetlands used by western toad for breeding ▪ Clear reservoir prior to filling ▪ Follow approved work practices as outlined in Project Environmental Plans (See Volume 5 Section 35 Summary of Proposed Environmental Management Plans)	Not significant

14.6 Cumulative Effects Assessment

14.6.1 Screening of Cumulative Effects

With the Project likely to result in residual adverse effects on wildlife resources, the potential cumulative effects of the Project have been assessed. The cumulative effects assessment follows methods explained in Volume 2 Section 10 Effects Assessment Methodology and includes a review of projects and activities, the residual effects of which may interact cumulatively with potential residual effects on wildlife resources as a result of the Project.

14.6.2 Description of Potential Cumulative Effects on VCs

For each project or activity that could cumulatively contribute to habitat alteration and fragmentation, disturbance and displacement, and mortality, an overview of the project or activity, project status, spatial and temporal boundaries, and potential residual effects is provided below, based on the information that is available. To generate the Future Case without the Project, foreseeable future projects and activities are prioritized to assess how they may interact with the Baseline Case. Projects recently constructed or operational (in the last few years) are included in the summary, as their recent status would not be reflected in the habitat mapping that was prepared for the assessment or would yet to be fully incorporated in the provincial and federal governments' current understanding of the status of the key indicators associated with the VC. Many of the projects and activities listed below that occur within the defined RAA are well removed from the LAA for which residual effects of the Project are anticipated. The projects and activities have been included, as they may still remove suitable habitats or affect species that are the same as those affected by the Project.

Figure 14.2 shows the locations of all of the projects and activities occurring in the RAA for which spatial information is available.

14.6.2.1 Projects submitted through Approval Agencies

14.6.2.1.1 Alliance Pipeline Sunrise Meter Station Relocation

The project has been in operation since 2010, and involved the relocation of an existing meter station to a new 50 m by 50 m site closer to Huron Energy's Sunrise Compressor Station (TERA Environmental Consultants Ltd. 2010c), approximately 27 km northwest of Dawson Creek. The relocated meter station was constructed to accommodate the receipt of natural gas originating in the Sunrise producing area of northeastern B.C. The goal was to minimize natural gas liquids dropping out from the rich incoming natural gas stream before reaching the desired location.

Connecticut warbler was the only listed animal species found within 5 km of the site. No wildlife species with conservation status, or potential habitat for wildlife species at risk, or species of special status were identified at the Project site (SHARP Environmental Ltd. 2010).

As outlined in the Environmental Assessment report (TERA Environmental Consultants Ltd. 2010c), residual environmental effects include:

- Loss or alteration of potential wildlife habitat

- Displacement of wildlife away from Project area
- Potential increase in wildlife mortality due to vehicle/wildlife collisions

A cumulative effect is not expected.

14.6.2.1.2 Groundbirch East Receipt Meter Station

The project has been in operation since 2011 by NOVA Gas Transmission Ltd. It involves the construction and operation of a new meter station approximately 45 km west of Dawson Creek to provide an interconnect between Westcoast Energy Inc.'s pipeline system – downstream of the Sunset Creek compressor station – and Groundbirch Mainline (National Energy Board 2012).

Potential residual environmental effects from this project identified were (National Energy Board 2012):

- Loss or alteration of wildlife habitat for wildlife species at risk
- Increase in vehicular collisions on access roads and at the project site
- Sensory disturbance and potential displacement of wildlife away from the meter station site during construction and cleanup activities
- A spill, fire, or rupture that may potentially adversely affect wildlife habitat

Species at risk that may be affected include Common Nighthawk, Barn Swallow, and Short-eared Owl, all of which are species at risk that would be affected by the Project. Effects from the Groundbirch East Receipt Meter Station may combine with those of the Project and result in a cumulative effect.

14.6.2.1.3 Groundbirch Mainline

NOVA Gas Transmission Ltd. operates a 24 km pipeline, of which 5 km parallels existing rights-of-way and roads; the remaining 19 km was newly cut (TERA Environmental Consultants Ltd. 2010a). A construction right-of-way of 39 m was required for the project, with 20 m being a permanent right-of-way and 19 m being temporary workspace. The pipeline is located 40 km northwest of Dawson Creek and 33 km southwest of Fort St. John. Construction of the project was completed in 2012.

The potential residual environmental effects on wildlife and wildlife habitat associated with the construction and operation of the project were (TERA Environmental Consultants Ltd. 2010c):

- Alteration of habitat
- Displacement of wildlife from the project area and temporary changes to movement patterns
- Increase in mortality or injury rates due to collisions and spills
- Loss of potential habitat for species at risk

A cumulative effect is not expected.

14.6.2.1.4 Moberly River Pipeline Replacement

Westcoast Energy Inc. replaced a section of the Fort Nelson natural gas mainline, with work finished in 2011. A 14 m long section of pipe became exposed due to southward migration of the Moberly River along an outside bend at the pipeline crossing location. The exposed section of pipe was replaced, and a new 50 m x 600 m right-of-way was created adjacent to the northwest edge of the existing right-of-way, as well as additional workspace to accommodate all of the equipment and machines used on the project.

No Environmental Assessment for this project could be located, but effects are expected to be similar to other pipeline projects. Rare species and suitable habitats may be affected, and potential residual effects may combine with those of the Project and result in a cumulative effect.

14.6.2.1.5 Provident Beatton River Replacement Project

This project involved the replacement of portions of the approximately 53 km long Taylor to Boundary Lake Pipeline, which carries sweet high vapour pressure hydrocarbon products from the city of Taylor to Boundary Lake, Alberta. A 36 km long section of the pipeline required replacement to ensure safe and reliable operation. The majority of the replacement work occurred within the existing right-of-way under operations and maintenance activities; however, a new right-of-way (approximately 16 km long) was required for the construction of a more suitable crossing of the Beatton River (National Energy Board 2011).

No residual effects could be located within available reports. Possible effects on wildlife identified include alteration of habitat, disturbance of migratory bird nests and nestlings, displacement of wildlife, habituation of wildlife to construction waste, and wildlife conflicts/mortality (National Energy Board 2011).

From the National Energy Board report (2011), six Sharp-tailed grouse leks were found in close proximity to the project. The nearest lek was 210 m from the proposed right-of-way and all other leks were located 500 m away or greater. The project fell within ungulate winter range and important migratory waterfowl habitat. Common Nighthawk, Canada Warbler, Olive-sided Flycatcher and western toad are all Schedule 1 wildlife that occurs in the project area; however, no species or sign was observed along the proposed route during the 2010 survey. Short-eared Owls (Schedule 2-listed species) have potential habitat within the proposed pipeline vicinity. Effects on species at risk listed above, all of which would be affected by the Project, may combine with those of the Project and result in a cumulative effect.

14.6.2.1.6 Septimus Pipeline Project

This project has been in operation since 2010 and involved the construction of 21 km of rich gas pipeline between the Septimus Gas Plant and Alliance Pipeline. The route was within B.C.'s Agricultural Land Reserve and primarily traverses private cultivated agricultural land and some forested land. The start of the pipeline is located approximately 16 km directly south of Fort St. John.

No Environmental Assessment for this project could be located, but effects are expected to be similar to other projects (for example, altered habitat, changes to wildlife movement, potential increase in wildlife mortality and disturbance of undiscovered habitat). A cumulative effect is not expected.

14.6.2.1.7 Dawson Creek Processing Plant

The project involves the construction and operation of a raw natural gas processing facility 16 km west of Dawson Creek, and consists of a natural gas processing plant and the associated access road, approximately 1 km of gas pipeline, a liquid handing loop, and the acquisition of a segment of the Spectra Energy Midstream Bissette Pipeline. The processing capacity of the Dawson Plant is to be installed in two phases. The initial phase is complete and has been in operations since 2011. The second phase of this project, which includes the installation of additional processing equipment, has a planned in-service date of February 1, 2013.

Possible effects on wildlife include (TERA Environmental Consultants Ltd. 2010b):

- Alteration or loss of habitat
- Displacement of wildlife away from project area
- Potential for vehicular collision-related mortality
- Combined effects on the western toad, which include an incremental increase in mortality as a result of habitat loss during construction/maintenance activities that require vegetation/ground disturbance

Effects to western toad may combine with those of the Project and result in a cumulative effect.

14.6.2.1.8 Transmission North 2011 Expansion Project

The project provides incremental firm service from the outlet of the Fort Nelson Processing Plant to a new point of interconnection between the Transmission North system and NOVA Gas Transmission Ltd.'s Groundbirch Pipeline. The project was made up of two primary components in different locations. The first component involved the installation of a new compressor unit, upgrades at existing stations, and the construction of approximately 24 km of pipeline (Fort Nelson Mainline). The second component involved the construction of a new pipeline and associated facilities, construction of approximately 20 km of pipeline (Stewart Lake Pipeline), and construction of a new compressor station. The project was operational in 2011.

Residual effects on wildlife identified (Stantec Consulting Ltd. 2010) include:

- Loss of preferred habitat, including breeding and foraging
- Risk of mortality to wildlife
- Noise disturbance that can cause alterations in wildlife movement: sensory disturbance, habitat avoidance
- Displacement of wildlife, changes in species composition, and modification of predator/prey interactions

A cumulative effect is not expected.

14.6.2.1.9 Dokie Wind Project

Preliminary modelled layout comprises 200 turbines of 1.5 MW each. Phase 1 of the project (144 MW) has been operational since 2011. Phase 2 would include the construction of the remaining towers to produce 156 MW.

The residual effects identified for wildlife include altered habitat availability, disruption of movement patterns, and mortality risks (Hélimax et al. 2006).

Effects to species at risk, particularly bats, may combine with those of the Project and result in a cumulative effect.

14.6.2.1.10 Farrell Creek 88-I South Gas Plant Project

Talisman Energy Inc. is proposing to construct and operate a natural gas processing plant 25 km north of Hudson's Hope (Stantec Consulting Ltd. 2012). The proposed plant, which will be adjacent to its existing Farrell Creek Central Production Facility (88-I Plant), will remove water and natural gas liquids from the raw gas to meet the pipeline requirements. The project is to be developed in two or more stages, and will eventually build to a processing capacity of approximately 14 million m^3/day.

No detailed analysis of effects is available as this project, as it is still in the application phase. Possible effects on wildlife from this project include loss of habitat areas, disturbance of migratory bird nests, sensory (auditory or visual) disturbance, and direct or indirect mortality (Stantec Consulting Ltd 2012).

Effects to species at risk may combine with those of the Project and result in a cumulative effect.

14.6.2.1.11 Wolverine Secure Landfill Project

Tervita Corporation, formerly CCS Landfills Services, is proposing to develop a secure landfill approximately 48 km northwest of Dawson Creek (CCS Corporation 2011). The proposed location is on Crown land, and will accommodate industrial activities in northeastern British Columbia. The project is currently in the Environmental Assessment stage, with the goal of an Environmental Assessment Certificate to be issued in March 2013.

Residual effects have not yet been identified in available reports. Possible effects on wildlife include habitat loss, fragmentation and effectiveness, sensory disturbance, potential contaminant exposure, and vehicle encounters (CCS Corporation 2011).

Effects may combine with those of the Project and result in a cumulative effect.

14.6.2.1.12 Dawson Creek/Chetwynd Area Transmission Project

BC Hydro is planning to build a new substation (19 km east of Chetwynd), approximately 60 km of overhead transmission line from Sundance Substation to Bear Mountain Terminal, expansion of existing substations, 12 km of transmission line from Bear Mountain Terminal to Dawson Creek substation, and a passive reflector near Chetwynd substation for communication purposes (BC Hydro 2011).

Key residual effects on wildlife include direct and indirect changes to wildlife habitat – such as loss, alteration and fragmentation – and habitat avoidance due to sensory disturbance (BC Hydro 2011). In addition, increased access to wildlife habitat will increase the potential to have higher rates of wildlife mortality through hunting and defence of persons and/or property (BC Hydro 2011). Effects to species at risk may combine with those of the Project and result in a cumulative effect.

14.6.2.1.13 Transmission North 2012 Expansion Project

This proposed pipeline is designed to provide incremental firm service from receipt points along Westcoast's Fort Nelson Mainline and the NOVA Gas Transmission Ltd. Groundbirch Pipeline (TERA Environmental Consultants Ltd. 2011). The proposed 24 km route parallels the existing Fort Nelson Mainline pipeline right-of-way for most of its length, with the exception of small localized diversions at Mackie and Lynx creeks, to optimize the watercourse crossings. In addition to the construction right-of-way, temporary workspace will also be required at crossings, sidebends, and log decks, and where grading is necessary.

Possible residual effects on wildlife and wildlife habitat include (TERA Environmental Consultants Ltd. 2011):

- Habitat alteration – including forested areas, watercourses, and drainages
- Habitat loss or alteration due to spills or fire from gas release
- Displacement due to sensory disturbance – displacement of wildlife away from right-of-way during construction – and site-specific maintenance activities may result in use of potentially suboptimal habitat
- Changes to movement patterns – barriers associated with construction, windrows, trenches
- Mortality – vehicular collisions, increased predation, spills or fires

The project may have residual effects on alteration of potential habitat for wildlife species at risk (TERA Environmental Consultants Ltd. 2011). Effects to species at risk may combine with those of the Project and result in a cumulative effect.

14.6.2.1.14 Gething Coal Mine Project

The project involves Canadian Dehua International Mines Group Inc. constructing a new underground coal mine and on-site coal preparation plant approximately 25 km west of Hudson's Hope (Rescan Environmental Services Ltd. 2006).

This project is currently in the Environmental Assessment stage, with the estimated construction startup in 2013. Current status of proposal is unknown, and no specific residual effects are available for review. Effects to species at risk may combine with those of the Project and result in a cumulative effect.

14.6.2.1.15 Carbon Creek Coal Mine

This project involves the development of an open-pit surface and underground metallurgical coal mine. The mine will be designed to achieve a production rate of 2.9 million tonnes of clean coal per year, with an estimated mine life of 30 years (Rescan Environmental Services Ltd. 2012). Currently the project is in the Environmental Assessment stage, with construction of project tentatively planned to begin in 2014 and surface mine coal production beginning in same year.

The Project Description is available but no residual effects on wildlife resources have yet been identified. Potential direct and indirect effects of the project on wildlife include habitat loss and alteration, road mortality, disturbance, increased hunter access, and possible attractants (garbage, lights, etc.). Effects to species at risk may combine with those of the Project and result in a cumulative effect.

14.6.2.1.16 Hackney Hills Wind Project

The proposed wind power project is located west of Fort St. John and directly northwest of Hudson's Hope near the top of the W.A.C. Bennett Dam (Aeolis Wind Power Corporation 2008). The wind farm will have an estimated generation capacity of up to 1,000 MW, with the intent to sell electricity to BC Hydro. The wind farm falls on Crown land and is surrounded by all-season petroleum developments and forestry service roads. This project is currently in the Environmental Assessment stage.

Residual effects have not yet been identified. Possible effects on wildlife include habitat loss and alteration, disturbance to wildlife, and possible effects on wildlife habitat features (Aeolis Wind Power Corporation 2008).

Effects specific to bird populations include direct mortality associated with the operation of the turbines, operation of vehicles, site clearing, and the physical presence of overhead transmission lines, as well as sensory disturbance primarily associated with construction activities and noise generated from the turbines (Aeolis Wind Power Corporation 2008).

Effects specific to bats include exposure to, and potential disturbance by, project-related stimuli such as noise and light, and increased mortality risk from collisions with turbine blades, and to a lesser extent, collisions with other project features (power lines) (Aeolis Wind Power Corporation 2008). These, and effects on other species at risk may combine with those of the Project and result in a cumulative effect.

14.6.2.1.17 Wartenbe Wind Energy Project

The project site is located in the south of the Peace River region of B.C. on Mount Wartenbe, southeast of Chetwynd. The project originally received its environmental Assessment Certificate in 2006, but subsequently changed ownership. An application to extend the deadline of the certificate was submitted in 2011, as construction had not commenced and the certificate was set to expire. In 2012, the name of the holder of the Environmental Assessment Certificate was again changed. The preliminary modelled layout includes 47 turbines of 1.5 MW each (AXYS Environmental Consulting Ltd 2006).

Residual effects identified include effects on movement patterns, mortality risk, and habitat availability. Effects on species at risk may combine with those of the Project and result in a cumulative effect.

14.6.2.1.18 Wildmare Wind Energy Project

This project involves Finavera's construction of a 74 MW wind park, connector roads and electrical connections, access roads, substation and operations centre, and an overhead transmission line (Finavera Wind Energy Inc. 2011). It will be located 5 km west of Chetwynd. The project is currently under review.

Residual effects on wildlife include (Finavera Wind Energy Inc. 2011):

- Habitat loss and fragmentation
- Disruption of movement corridors

- Water quality degradation
- Auditory and sensory disturbance – noise
- Attractants
- Predation and hunting risk
- Mortality – roads, collisions

Finavera noted (2011) that there is likely to be cumulative adverse effects on bats, migrating raptors, nocturnal migrating birds, and breeding birds in the area – within 100 km – over the next 25 years from collisions with turbine blades. Effects to bat, raptor, breeding, and migratory bird species at risk may combine with those of the Project and result in a cumulative effect.

14.6.2.1.19 General Oil and Gas Activities

There are many oil and gas related activities found throughout the northeast portion of the province; collectively, there are a number of environmental effects that result from the exploratory stage, as well as from the drilling and development stage. As new extraction technologies become available, additional sites will be more attractive for exploration and development. The timing and level of development will likely be set by market prices, but recent plans for liquefied natural gas should continue interests in the region's gas sector.

During exploration, activities that take place that may have adverse effects on wildlife resources include drilling exploration, construction of access roads, and seismic exploration.

In the drilling/development phase, larger areas are required that involve the construction of well pads, access roads, pipelines, and other ancillary facilities, as well as the drilling of wells. Habitat loss would be the largest effect, although effects associated with fragmentation, disturbance and displacement, and mortality of wildlife species would also occur.

According to information available, a total of 32 oil and gas facilities are approved or under review within the RAA. Facilities are point features that indicate any grouping of equipment where water, hydrocarbon liquids, or natural gas are processed, measured, upgraded, or stored (Ministry of Labour – Citizens' Services and Open Government 2012).

A total of 344 pipeline projects (from 2004 to present) are approved within the RAA, with another 23 under review. Linear length of pipeline was estimated from available spatial information and totals 377 km within the RAA.

Petroleum Access Roads are applications for roads over any Crown land. A total of 1,422 approved or proposed access road applications are within the RAA, with a total length of 823 km. In addition, there are 37 approved or proposed Petroleum Development Road applications, totalling 163 km within the RAA. Petroleum Development Roads applications are for construction or to existing non-status tenured roads over any Crown land and/or use of non-status, unencumbered existing access roads on Crown land.

Effects may combine with those of the Project and result in a cumulative effect.

14.6.2.1.20 General Forestry Activities

A more detailed review of the forestry activities is provided in Volume 3 Section 21 Forestry. Information provided in that section has been summarized below.

The RAA for wildlife resources overlaps portions of the Fort St. John and Dawson Creek Timber Supply Areas, as well as Tree Farm Licence 48. The current Timber Harvesting Land Base for all three areas combined is 2,152,127 ha. Of this total area, the Annual Allowable Cut is presently set at 4,875,000 m^3 of both coniferous and deciduous forest. The government will be reviewing the amount cut and possibly setting new limits for both Timber Supply Areas in the near future, and in 2017 for Tree Farm Licence 48.

Timber harvesting replaces mature forest with early seral stage plant communities. Roads are considered a leading cause of habitat fragmentation, affecting wildlife and wildlife habitat. Roads can also contribute to erosion and sedimentation of aquatic and terrestrial habitats, and act as vectors for the persistence and spread of invasive plants. Loss of older successful forests or larger, intact tracks of forested lands can reduce the habitat availability for a variety of species, particularly Red- and Blue-listed species that rely on characteristics found primarily in older stands (for example, species that use cavities) or within interior forest conditions. Effects may combine with those of the Project and result in a cumulative effect.

14.6.2.2 Land Tenures

Over 11,000 ha have been identified within recent land tenure applications within the RAA (Table 14.23). Commercial recreation tenure applications account for the largest percentage of land use. Activities associated with commercial recreation include camps – for hunting and fishing – trail riding, cat skiing, heli-hiking, and guided nature viewing. These activities typically have considerably less disturbance compared to other industrial activities, but habitat loss and alteration for wildlife resources as well as disturbance and displacement of individuals and possible increases in hunting and poaching of select species will occur. Effects may combine with those of the Project and result in a cumulative effect.

Table 14.23 Total Number of Land Tenure Applications Within the RAA

Tenure Purpose	Number of Applications	Total Area (ha)
Agriculture	22	1,631
Commercial	1	<1
Commercial recreation	17	9,411
Communication	3	1
Community	2	5
Energy production	8	9
Industrial	35	98
Institutional	1	<1
Quarrying	18	293
Residential	3	1
Utility	24	43
Total	**134**	**11,492**

14.6.2.3 Parks and Protected Areas

The Peace River Boudreau Lake proposed protected area comprises a portion of the south bank of the Peace River valley, Boudreau Lake, the lower Moberly River valley, and the islands near the confluences of the Moberly River and Maurice Creek with the Peace River. The proposed protected area is 6,750 ha in size and partially overlaps BC Hydro's flood reserve for the Project (Dawson Creek LRMP Inter-Agency Planning Team 1999). The protected area has not been officially established.

The protected area would be a positive effect and represents habitats for a number of rare wildlife species.

14.6.3 Cumulative Effects Mitigation Measures

The projects summarized above will result in the alteration and fragmentation of habitats, displacement and disturbance of wildlife, and possible wildlife mortality.

It should be noted that BC Hydro is not the lone organization contributing to the decline in wildlife resources, as many of the other projects or industries mentioned above also contribute to the overall decline. Recovery efforts could be undertaken at the regional level collaboratively with other projects. BC Hydro has limited authority to guide regional initiatives to support the diversity and persistence of wildlife resources. This would be better guided by the provincial government.

14.6.4 Characterization of Residual Cumulative Effects

Past land use has shaped much of the region's current wildlife habitat abundance and distribution. Habitats for a variety of species at risk are currently under threat of loss and extirpation due to land development (Baseline Case). Some of the species listings are simply a result of the geographic distribution and provincial boundaries, which restrict occurrences to a small portion of the province. In other instances, populations or habitats are simply unique and rare on the landscape.

In the future, many of the same activities associated with the baseline case will continue (e.g., forestry, oil, and gas development) and residual effects are expected, regardless of the Project proceeding (Future Case without the Project). Most of these activities are removed from the Peace River valley, affecting areas of adjacent plateau and mountainous sites within the RAA. Some are within the LAA – notably, forestry, oil, and gas, and some land tenure applications.

The majority of the Project disturbance is within the Peace River valley, affecting riparian habitats that are generally removed from most other developments (Project Case). Other Project components situated in upland areas removed from the Peace River (e.g., transmission line and some quarry sites) may overlap with future projects and activities – especially with forestry, and oil and gas development. As such, the Project is likely to result in a residual cumulative effect of habitat alteration and fragmentation, disturbance and displacement, and mortality for songbird species at risk, non-migratory birds, raptors, bats, and fisher. The characterization of the effect is listed below (Table 14.24).

Table 14.24 Characterization of Residual Cumulative Effect – Habitat Alteration and Fragmentation

Effects Criteria	Project Case
Direction	Negative
Magnitude	High
Geographic Extent	Regional
Duration	Permanent
Frequency	Continuous
Reversibility	Irreversible
Context	Low and High resilience
Level of Confidence	High
Probability	High

14.6.5 Determination of Significance of Residual Cumulative Effects

The Project is likely to result in a significant adverse effect in the alteration and fragmentation of habitat for some key indicators (see Section 14.5). Consequently, the cumulative effect of the Project on habitat for those species is also significant. The anticipated residual effects of habitat alteration and fragmentation to wildlife resources from all other future projects and activities combined are also considered significant, even if the Project is not constructed. This occurs because effects associated with other projects and activities that involve road construction, forestry, land clearing, etc. are not fully mitigable, and the future loss of suitable habitats for species at risk is expected to further elevate provincial or federal listings.

14.7 Monitoring and Follow-Up

In accordance with the EIS Guidelines, follow-up programs would be required to verify the accuracy of the effects assessment, and to determine the effectiveness of the measures implemented to mitigate the adverse effects of the Project on wildlife resources.

A Wildlife Resources Follow-Up Plan would be implemented to address key uncertainties about the accuracy of the effects assessment and effectiveness of mitigation. The plan would include provisions to address the following residual effects characterizations identified in the effects assessment as having low confidence:

- Habitat alteration and fragmentation during construction for songbirds, waterfowl, shorebirds, Bald Eagles, bats, and fishers
- Disturbance and displacement during construction for migratory birds and ground-nesting raptors
- Disturbance and displacement during operations for western toad and garter snakes
- Mortality during construction for migratory birds, Northern Harrier, Short-eared Owl, and fishers

Habitat alteration and fragmentation during construction is expected to have a moderate magnitude effect on songbirds, reducing populations to levels lower than baseline conditions. This effect is characterized with a low confidence because of the variation in response by different songbird species, including how individual species' populations would respond to the loss of habitats.

The effect of habitat alteration and fragmentation during construction to waterfowl and shorebirds is characterized as a high magnitude, due to the amount of river and back channel habitat lost. The duration and geographic extent of the effect is dependent on expected use of the reservoir and wetlands created through habitat compensation. There is low confidence in the characterization of this expected use, because it largely depends on the success of vegetation establishment along the boundaries of the reservoir, the use of nest boxes, and the extent of ice formation.

A large number of Bald Eagle nests would be removed during construction. Mitigation would replace the number of available nest platforms at a 2-to-1 ratio for active nests lost. The magnitude of this effect is characterized as low, but is dependent on the success of the mitigation, and thus is characterized with a low confidence.

The effect of habitat alteration and fragmentation to bats during construction is characterized as a moderate magnitude, because over 11% of the total habitat available would be lost. The prediction of higher suitability habitat is subject to limitations, and the distribution and abundance data are incomplete for bat species in B.C. These uncertainties have led to a characterization of the effect prediction as having a low confidence.

Habitat alteration and fragmentation during construction would have a moderate magnitude effect on fishers, including a permanent loss of den sites. Mitigation measures can replace some den trees in areas adjacent to the reservoir, but the success of artificially created den trees or structures is not known. To account for this uncertainty, the effects characterization has been identified with a low confidence.

The effect of disturbance and displacement to migratory birds and ground-nesting raptors during construction is characterized as a low magnitude, with ground-nesting birds anticipated to be affected the most, although the majority of the clearing and filling of the reservoir is currently planned for the winter months, outside the nesting season. There is a low confidence in these characterizations, however, because magnitude is dependent on the scale of the activity and time of year that it occurs. In addition, some birds may be displaced more readily by activities that disturb them, while others would be more tolerant. It is also difficult to determine the extent to which ground-nesting birds would use the newly cleared areas in the reservoir.

The surface water regime downstream of the reservoir would be affected by dam operations. The effects of these changes to hydrology are expected to disturb and displace western toads and garter snakes in this area, particularly between the dam and the Pine River confluence (the first major influx of water downstream of the dam). The magnitude of this effect is characterized as low, but there is low confidence in the characterization because the reaction of these species to the anticipated changes in hydrology is difficult to determine.

Mortality of migratory birds, Northern Harrier and Short-eared Owl during construction was characterized as a low magnitude, but with a low confidence. The effects of nest loss due to vegetation clearing and flooding during construction could have greater effects, depending on the time of year and extent of use in areas seasonally inundated. Hydrology modelling provides an understanding of the extent of the flooding, but the extent of use of the newly cleared areas in the reservoir by ground- and shrub-nesting species immediately prior to flooding is difficult to determine.

The effect of fisher den or resting site loss due to vegetation clearing during construction was characterized as having a low magnitude. But this could have greater effects depending on the time of year (i.e., rearing period). In addition, the effectiveness of mitigation is unknown, so the residual effect characterization has a low confidence.

To address these uncertainties, the follow-up plan should include the following:

- Targeted mitigation monitoring
- Directed studies to address specific uncertainties

Targeted mitigation monitoring should include:

- Monitoring Bald Eagle nesting populations adjacent to the reservoir, including use of artificial nest structures
- Monitoring of waterfowl and shorebird use in natural wetlands, created wetlands, and artificial wetland features
- Monitoring the effectiveness of artificial den creation for fishers
- Monitoring the effectiveness of toad migration crossing structures installed along project roads

Directed studies should include:

- Surveys of songbird populations and ground-nesting raptors during construction and operations
- Surveys of western toad and garter snake distribution downstream of the dam

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15 GREENHOUSE GASES

15.1 Approach

Greenhouse gas (GHG) emissions (e.g., carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and others) accumulate in the atmosphere and are believed to be a major factor in producing the greenhouse effect that may affect climate. The global GHG emissions resulting from human activities have been rising over the last century. Since about 1850, the atmospheric CO_2 concentration has risen approximately 35% (Houghton 2007). Global GHG emissions are estimated to be 44,000 Mt CO_2e (Netherlands Environmental Assessment Agency 2011; U.S. EPA 2011).

In 2010, the total GHG emissions in Canada were estimated to be 692 Mt CO_2e, of which 562 Mt CO_2e (81%) were attributed to the energy sector. Fossil fuel combustion accounted for 90% of energy sector emissions, contributing 503 Mt CO_2e. For these reasons, recent federal and provincial government policies and regulations are focused on the reduction of GHG emissions to the atmosphere.

The release of GHGs from the Project has been identified as a concern by regulatory agencies and Aboriginal groups. The GHGs from the Project must be considered in the environmental assessment (CEA Agency 2003) and greenhouse gases have been selected as a VC for the assessment. The VC greenhouse gases will be assessed as outlined in the Environmental Impact Statement Guidelines (EIS Guidelines) for the Project, and following the methods set forth in Volume 2 Section 10 Effects Assessment Methodology. Specific aspects of the methodology are highlighted here.

In this assessment, releases of CO_2, CH_4, and N_2O are estimated according to best practice methods suggested by the IPCC (2003). Three approaches are described by IPCC (referred to as "Tier 1", "Tier 2", and "Tier 3"). The details for Tier 1 and 2 are presented in the GHG report (Volume 2 Appendix S Greenhouse Gases Technical Report). In this assessment, the predictions/estimates from the more detailed modelling approach ("Tier 3") are used and include a site-specific evaluation of ecosystem carbon cycling in the Local Assessment Area. Only the Tier 3 results are presented here, as these are based on the best model (and methods) for making the predictions. This specific carbon model was developed for the Project to simulate and estimate carbon flows over the lifecycle of the Project (Jacques Whitford Axys 2009), and has been updated for this assessment to reflect the current Project Description (Volume 1 Section 4).

15.1.1 Regulatory and Policy Setting

This assessment has been prepared in accordance with Section 8 and Section 14 of the Environmental Impact Statement Guidelines (EIS Guidelines) for the Project (BC Hydro 2012).

There are currently no provincial or federal standards or guidelines for GHG concentrations in ambient air, nor are there any emission limits with respect to GHG releases from individual sources or sectors in place for British Columbia at this time. As such, the scope of this Project does not contain any aspects that are currently regulated for GHG emissions provincially or federally.

The latest guidance from the CEA Agency (2003), Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners was followed for this environmental assessment. As summarized in the introduction of that document, GHGs as precursors to climate change constitute a global phenomenon rather than a local issue, and the science of this phenomenon is not yet developed to the stage where global environmental effects from a single project of this nature can be measured. Following CEA Agency guidance, “the environmental assessment process could not consider the bulk of GHG emitted from existing developments. Furthermore, unlike most project-related environmental effects, the contribution of an individual project to climate change cannot be measured” (CEA Agency 2003). This presents a technical boundary in that the specific contribution of the Project to global climate change ultimately cannot be established at this time under current guidance.

In light of this, CEA Agency (2003) recommends evaluation of the net changes in GHG emissions as a result of a project and consideration of detailed mitigation if GHG emissions are found to be medium or high (note that these terms are used but not clearly defined in the document). Based on descriptions of project activities in the CEA Agency document, it is logical to consider an industrial source, such as a fossil-fuelled electrical generating station or a petroleum refinery as a high GHG emitter, and a pipeline project or a hydroelectric facility as a low GHG emitter. The considerations of low, medium and high are related to the magnitudes of the releases of GHGs from the Project in comparison to those from the industrial profile, and the provincial and global totals. An additional consideration includes a comparison of emissions intensity with those for other modes of electrical generation.

Project-related GHG emissions “will be assessed and considered in the context of local, provincial, national and industry sector normals” (CEA Agency 2003) and significance of environmental effects will be based on the quantities of GHG emissions in those contexts. The assessment also considers mitigation and adaptive management strategies aimed at minimizing Project-related GHG emissions, and that the Project will be designed with adaptive management opportunities being taken into consideration to allow compliance with future regulations. This approach is consistent with the CEA Agency guidance (CEA Agency 2003), and is presented in additional detail throughout the remainder of Chapter 15.

15.1.2 Key Issues and Identification of Potential Effects

The consultation process identified key issues and concerns with the Project. For example, there are concerns amongst Aboriginal groups with respect to GHG emissions as they relate to climate change and associated Aboriginal interests, asserted or established Aboriginal rights, and existing Treaty 8 Rights. Generally speaking, there is concern that increased GHG emissions will bring about climate change and seasonal deviations in weather patterns. There is also public concern with the loss of the Project area as a potential carbon sink or displacing activities that are perceived to have a lower carbon footprint than a hydroelectric reservoir (e.g., agriculture). A summary of key issues is shown in Table 15.1.

Table 15.1 Key Issues: Greenhouse Gas Emissions

Key Issue	Approach to Addressing Key Issues
Aboriginal concerns that Project GHG emissions will change climate or seasonal weather.	The rationale for inclusion of GHG as a valued component is because of the link between GHG emissions and global climate change.
Concern that the current river valley and forest is a carbon sink that will be lost if the Project proceeds.	The GHG estimate approach includes an estimate of current GHG processes (both captures and releases) from the area proposed for the reservoir, and compares these to GHG emissions with the Project, and reports the difference as net emissions.
Interest in Project GHG emissions in context of B.C. GHG goals.	The assessment of Project GHG emissions is discussed in the context of provincial and national emission inventories.
Interest in assessing the valued component climate change and microclimate instead of greenhouse gas emissions.	Predicted Project-related changes to microclimate are included in Section 11.10 Microclimate, in Volume 2 Section 11 Environmental Background. The predictions for future climate change in northeastern B.C. are taken into account in the Project design, as well as in Agriculture. The Project GHG emissions are estimated and presented in this section of the EIS.
Interest in the estimated multi-year GHG emission profile associated with the reservoir.	This section of the EIS summarizes the estimated multi-year GHG emission profile, and Volume 2 Appendix S Greenhouse Gases Technical Report provides further information.
Interest in the comparison of the GHG profile of the Project with other electricity and demand-management supply options.	This assessment provides comparisons with other electricity supply options. BC Hydro's integrated resource planning process, including the resource options analysis, provides further technical, financial and environmental comparisons with electricity supply options and demand-side management (conservation) programs for BC Hydro customers.

The Project-environment interactions on each environmental effect were ranked for their potential to result in a change in GHG emissions, based on anticipated quantities of emissions, and using the methodology described in Volume 2 Section 10 Effects Assessment Methodology.

Potential Project interactions with the Greenhouse Gases VC are summarized in Volume 2 Appendix A Project Interactions Matrix, Table 2. Within the table, interactions for all identifiable Project activities are ranked as a “0”, “1”, or “2”, based on their ability to affect the greenhouse gases VC. A ranking of “0” indicates that there is no potential interaction between the Project activity and the VC. Project activities with a “1” ranking. These activities are discussed in Section 15.3.1. A “2” ranking in Table 2 indicates that the effects of an interaction may not be fully avoided or mitigated through the application of standard mitigation measures, or are not well understood. Therefore, they require analysis and evaluation in the environmental assessment.

The potential interactions between the Project and greenhouse gases that were ranked as “2” (using the methodology described in Volume 2 Section 10 Effects Assessment Methodology) are discussed in more detail in the effects assessment below and are presented in Table 15.2.

Table 15.2 Interactions of the Project with Greenhouse Gases

Project Activities and Physical Works	Key Aspects
	Change in GHG emissions
Construction	
Dam, Generating Station, and Spillways, and Quarried and Excavated Materials	✓
Reservoir Clearing	✓
Transmission Line to Peace Canyon	✓
Construction Access	✓
Highway 29 Realignment	✓
Worker Accommodation	✓
Operations	
Spillways	✓
Reservoir	✓

NOTE:

Only Project interactions ranked as "2" in Volume 2 Appendix A Project Interaction Matrix, Table 2 are carried forward to this table. A ✓ indicates that a project component or activity is likely to interact with Greenhouse Gas Emissions.

15.1.3 Standard Mitigation Measures and Effects Addressed

A "1" ranking was given where an adverse effect may result from an interaction, but standard mitigation measures to avoid or minimize the potential effects are available and well understood to be effective, and any residual effect is negligible. These interactions were not carried forward through the effects assessment.

During operation, dam, and generating station activities (e.g., water management and monitoring and maintenance), the transmission line to Peace Canyon and the Highway 29 realignment are also likely to generate some emissions of GHG from fuel combustion of equipment operation. However based on past experience, and in light of the standard mitigation regarding fuel conservation, fleet management, and trip reduction planned for the Project, these emissions are expected to be nominal and are very unlikely to cause GHG emissions that are considered important on the regional or provincial scale. These interactions with a change in GHG emissions are therefore also ranked as 1.

The activities described above that are ranked as 1 are not expected to result in substantive emissions. Therefore, the potential environmental effects of the Project-related activities that were ranked as 1 for a change in GHG emissions during all phases of the Project are not considered further in the environmental assessment.

15.1.4 Selection of Key Indicators

The assessment of a change in GHG emissions in the atmosphere requires knowledge of the constituents comprising and present in the atmosphere, both in magnitude and as trends. The emission of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) were selected as key indicators of the greenhouse gases VC (Table 15.3), due to the potential for Project activities to result in the release of these types of GHG emissions. These key indicators receive considerable local, national, and international attention in terms of existing and proposed legislation, development of action plans, and international agreements. The rationales for the key indicators used in the assessment of environmental effects are listed in Table 15.3.

Table 15.3 Key Indicators for Greenhouse Gases

Key Aspects	Key Indicators	Rationale for Selection of the Key Indicators [a]
Change in GHG Emissions	GHG emissions – CO_2, CH_4, and N_2O (in units of CO_2 equivalents or CO_2e)	• GHG emissions are identified as an important influence on climate change. • GHG emissions associated with the Project are an aspect of climate that must be considered in the environmental assessment (CEA Agency 2003; BC Hydro 2012). • Recent federal government policies and regulations are focused on GHG reduction [a, b] • The inventory and analysis of GHG emissions are widely recognized when assessing related environmental effects on climate (CEA Agency 2003)
	GHG emissions intensity in units of tonnes of CO_2e per year per (t CO_2e/year)	• To put the GHG emissions from the Project into context with respect to the industry profile, as recommended in CEA Agency (2003) guidance

NOTES:

[a] The Government of Canada has committed to reducing GHGs and improving the air quality nationally by taking action sector by sector. On September 1, 2010, Canada enacted the Renewable Fuels Regulations, which require gasoline and diesel fuels to contain an average renewable content of at least 5% and 2%, respectively. In October 2010, regulations to limit the GHGs from passenger vehicles and light duty trucks in model years 2011 to 2016 were released. Proposed regulations for GHG emission limits on for heavy-duty vehicles were released in April 2012. Regulations to reduce emissions from coal-fired electricity generators were released in September 2012. (Government of Canada 2012).

[b] The British Columbia Ministry of Environment (BCMOE) has prepared a Climate Action Plan (BCMOE 2008) in response to increasing concern for and awareness of these issues. The 2007 Greenhouse Gas Reduction Targets Act legislates three commitments, including a reduction of GHG emissions by 33% from 2007 emissions by 2020.

15.1.5 Spatial and Temporal Boundaries

The spatial and temporal boundaries for the assessment of potential environmental effects of the Project on greenhouse gases were determined by considering the activities with the potential to cause effects and by the potential zone of influence associated with Project activities, as well as the length of time expected for each of the Project phases.

15.1.5.1 Spatial Boundaries

The spatial boundaries for the assessment of potential environmental effects of the Project on Greenhouse Gases (Figure 15.1) are based on a combination of experience with similar projects and professional judgment. These are described in Table 15.4

The Local Assessment Area is the Project activity zone as the area within which GHG emissions from construction activities will occur, and as the area within which the reservoir will be formed, which enabled estimates of GHG emissions associated with land conversion.

In recognition of the global nature of the potential environmental effects of a change in GHG emissions on global climate, the assessment will compare Project-related GHG emissions to global, national, and provincial GHG emissions.

Table 15.4 Spatial Assessment Areas for Greenhouse Gases

Local Assessment Area (LAA)	Regional Assessment Area (RAA)
The LAA is defined as a 30 m buffer zone around the maximum reservoir elevation (to describe GHGs from land conversion) and the project activity zone to characterize emissions associated with construction activities	The RAA is defined as National

15.1.5.2 Temporal Boundaries

The temporal boundaries for greenhouse gases are the Project phases of construction (including reservoir filling, and reclamation) and operations.

The time period for construction is expected to be eight years, concluding with reservoir filling.

The time period for operation is at least 100 years; therefore, the carbon model has been established to cover 100 years of operation.

15.2 Baseline Conditions

15.2.1 Emission of GHGs from Existing Facilities

Greenhouse gases (GHG) of concern generally include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), among others. Provincial GHG emissions in 2010 were 56,100 kt of carbon dioxide equivalent (CO_2e), reported as part of the National Inventory Report (Environment Canada 2012).

Under the federal GHG reporting program, 68 facilities in British Columbia reported GHG emissions to Environment Canada for 2010 (Environment Canada 2010). The reporters with the four highest percentages of the total B.C.-reported GHG emissions included the Fort Nelson Gas Plant (9.5%), the Pine River Gas Plant (8.4%), the Kitimat Works facility (6.8%), and the Delta Cement Plant (5.3%) (Environment Canada 2010).

Canada's GHG emissions in 2010 were 692,000 kt CO_2e (Environment Canada 2012). British Columbia's contribution to the national total GHG emissions was 8.1%.

Canada's contribution to global GHG emissions is 1.6%, and British Columbia's contribution to global GHG emissions is approximately 0.13%, based on 2010 data.

15.2.2 Greenhouse Gas Emissions from Reservoirs

Land use changes, such as land clearing for agriculture, forestry, urbanization, or the development of large projects including dams, may change the balance of local or regional GHG storage or emissions. Critics of hydroelectric development (e.g., International Rivers Network) (IRN 2006) have argued that dams and their associated reservoirs are globally important sources of GHG emissions, including CO_2 and CH_4. Operational carbon emissions from hydroelectric developments are fundamentally different than carbon emissions from an electrical generating station that burns fossil fuels (i.e., coal, natural gas, oil, or peat). Whereas a fossil fuel burning generator emits CO_2 that was previously in some form of geological storage, the carbon emissions from a hydroelectric development represent carbon that is already engaged in the cycle between the atmosphere and green plants. A new hydroelectric reservoir is a living system that integrates with the surrounding environment – the effects to carbon cycling and whether the system as a whole is a source or sink for carbon is dependent on a number of factors, which are evaluated and modelled in this assessment.

There is a consensus that N_2O emissions from reservoirs are typically very low, relative to CO_2 and CH_4 (IPCC 2006). For instance, measured diffusive emissions of CO_2 and CH_4 were 20,000 and 5,300 times greater than N_2O emissions from a tropical reservoir (Galy-Lacaux 1996). Similarly, diffusive CO_2 emissions were 60,000 times greater and CH_4 emissions 2,000 times greater than diffusive N_2O emissions from a boreal reservoir (Hellsten et al. 1996). Since N_2O emissions measured from freshwater reservoirs have been considered negligible, it has been suggested that N_2O emissions need not be included in reservoir-induced GHG research (UNESCO 2006). Although there are few published data on N_2O emissions from flooded lands, it is generally accepted that these emissions are typically low unless the area is under intense agricultural production (IPCC 2006). Since farming occurs along the Peace River valley, with potential for elevated nitrogen concentrations from the application of agricultural fertilizers, the estimation of N_2O was added to the Project GHG emission estimate to account for anthropogenic inputs from agriculture.

Land flooding results in many changes, ranging from the obvious (e.g., conversion of terrestrial habitat to aquatic habitat) to the subtle (e.g., the balance between the creation of new or larger sediment traps where carbon may be stored, and the formation in reservoir sediments of CH_4, which has a stronger potential as a GHG than an equivalent amount of CO_2). UNESCO (2006) considers CH_4 to be the most important GHG produced by a reservoir, due in part to the high CH_4 emissions measured from tropical reservoirs, and also to the relative potency of CH_4 in comparison with CO_2 as a GHG.

Many factors may influence the emissions of CO_2, CH_4, and N_2O from flooded land. Examples include the age of the reservoir, land use prior to inundation, climate, and management practices as well as pH, salinity, depth, altitude, available carbon, and the carbon:nitrogen ratio (IPCC 2006). It is widely understood, for example, that temperature is an important control on the overall magnitude of CH_4 and CO_2 emissions. This is demonstrated by higher GHG emissions from reservoirs situated in tropical climates than those in boreal and temperate climates (Duchemin et al. 2002; St. Louis et al. 2000). Tropical reservoirs are 40% of the total global reservoir surface area, but account for 70% and 94% of CO_2 and CH_4 emissions from reservoirs, respectively. Temperate and boreal reservoirs account for the remaining 60% of the surface area, but only 30% and 16% of CO_2 and CH_4 emissions from reservoirs respectively (Lima et al. 2007). Average fluxes of CO_2 and CH_4 from five tropical reservoirs were estimated to be 3,500 $mg/m^2/d$ and 300 $mg/m^2/d$, respectively, whereas average fluxes from 17 temperate reservoirs were estimated to be 1,400 $mg/m^2/d$ and 20 $mg/m^2/d$ for CO_2 and CH_4, respectively (St. Louis et al. 2000). In a similar study, diffusive fluxes from tropical reservoirs averaged 3,625 $mg/m^2/d$ and 31 mg $mg/m^2/d$ for CO_2 and CH_4, respectively; with a mean bubble flux of 190 $mg/m^2/d$ for CH_4 (Duchemin et al. 2002). In comparison, diffusive fluxes from boreal and temperate hydroelectric reservoirs averaged 1,430 $mg/m^2/d$ and 16 mg $mg/m^2/d$ for CO_2 and CH_4, respectively; with a mean bubble flux of 0.1 $mg/m^2/d$ for CH_4 (Duchemin et al. 2002).

The CO_2 measured at reservoir surfaces largely represents a product of the natural carbon cycle. For a relatively short period of time following inundation, the decomposition of vegetation or near-surface soil carbon that was left in the flooded areas can result in high initial fluxes of CO_2 and CH_4. In the case of a newly formed reservoir, there tends to be a peak in emissions during the first two to three years following inundation as flooded vegetation decomposes (UNESCO 2006). However, after a period of time, a reservoir can reach a steady state that is similar in bacterial abundance and biomass to that of surrounding natural water bodies (Soumis et al., 2005). According to Tremblay et al. (2004a), in boreal and semi-arid reservoirs greater than 10 years of age, GHG emissions are similar to those measured from natural lakes in the same area.

In British Columbia, mean values from one literature source for measured CO_2 emissions were approximately 250 (+/- 800) mg CO_2/m^2/day and 500 (+/- 650) mg CO_2/m^2/day, for old reservoirs and natural lakes, respectively (Tremblay et al. 2004a). Measured CO_2 emissions from another literature source ranged from -1,786 mg CO_2/m^2/day to 3,666 mg CO_2/m^2/day (mean of 198 mg CO_2/m^2/day) and -419 mg CO_2/m^2/day to 2,780 mg CO_2/m^2/day (mean of 706 mg CO_2/m^2/day) for reservoirs and natural lakes, respectively (Tremblay et al. 2005). Overall, the measured data for British Columbia reservoirs indicate less CO_2 emissions and slightly higher CH_4 emissions when compared to other boreal reservoirs in Canada of similar age (Tremblay et al. 2005).

15.2.3 Modelling of Baseline Conditions

One of the main objectives in the assessment is to determine the net GHG emissions (CO_2, CH_4, and N_2O) in the area of Site C, where “net” refers to the emissions from the area with the Project in place and operating minus the emissions from area prior to the Project being constructed (existing or baseline). Therefore, it is essential to determine the baseline emissions of the study area prior to inundation.

A carbon mass-balance model was constructed to represent the primary carbon stocks (e.g., atmosphere, soil, vegetation, water, etc.) as well as the flows of carbon between stocks (e.g., water-atmosphere, vegetation-soil, etc.), and to estimate emissions of CO_2 and CH_4 (the full model description is provided in EIS Volume 2 Appendix S Greenhouse Gases Technical Report).

Mass-balance models provide a detailed accounting system for the movement of an element in a system, such as carbon, that cannot be eliminated, only transferred. This method also allows for carbon to be converted from one form (e.g., organic C) to another form (e.g., CO_2) through various processes. The modelled study area included an area extending 30 m beyond the reservoir contour at maximum capacity. The mass of carbon in stocks under current conditions and the flux rates between stocks were estimates using land cover inventories as well as site-relevant published literature values on carbon mass in stocks and observed flux rates. The values most representative of Site C conditions were selected for the model stocks and fluxes, and assumed to be representative of this system. As values were drawn from various literature sources of representative systems, but were not measured in the same location and time, it was also necessary to calibrate the model to integrate the various fluxes into one system. As some stocks (lakes and rivers, terrestrial vegetation) are expected to maintain constant average carbon masses over large areas and in the short term (i.e., on an annual basis), key fluxes (water to atmosphere CO_2 and terrestrial vegetation to water) were adjusted to balance fluxes and produce constant stock values. A smaller separate N_2O model was also built to model the fluxes of this GHG from agricultural sources (livestock and agricultural inputs) within the landscape.

Once the carbon model was calibrated and the N_2O model constructed, it was possible to estimate the annual net GHG emissions of the system. Under current conditions, the Site C study area is a weak source of GHGs, at approximately 5,700 t/year CO_2e. The landscape on its own is a carbon sink. However, the agricultural activities in the area release GHGs that are greater in magnitude than those from the sequestration processes of the landscape. These agricultural releases arise from the methylation of biomass carbon into CH_4, largely through ruminants, and the anthropogenic emissions of N_2O (Volume 2 Appendix S Greenhouse Gases Technical Report).

15.2.4 Aboriginal Traditional and Community Knowledge

Aboriginal people and First Nation communities did not provide any information specific to the GHG assessment. Aboriginal interests in GHG emissions and climate change, as expressed to BC Hydro, are summarized in Section 15.1.2 Key Issues and Identification of Potential Effects.

15.3 Effects Assessment

There is a potential for Project-related GHG emissions to contribute to the global concentration of GHGs in the atmosphere. In the assessment, consideration was given to GHG emissions from vehicles and heavy equipment during construction and biological processes during operations, as well as any reduction or increase in carbon sequestration.

The release of GHG emissions as a result of the Project's land clearing and construction activities are important considerations in estimating the life cycle emissions of the Project.

The expected GHG emissions associated with construction activities of the Project will consist of CO_2, CH_4, and N_2O, mainly from fuel combustion associated with equipment operation. The construction emissions are assessed for the following Project activities:

- Dam and generating station, spillways, and quarried and excavated materials
- Reservoir clearing
- Transmission line to Peace Canyon Dam
- Access road and rail
- Highway 29 realignment
- Worker accommodation

In the calculation of construction emissions, the values of CO_2, N_2O, and CH_4 emissions were converted to carbon dioxide equivalent (CO_2e) using an emission factor specific to the GHG source activity. These emission factors are calculated using the individual Global Warming Potentials as prescribed by the IPCC. Further, the emission factors specific to Canadian fuel and electricity generation were used in the estimates.

Consumption estimates for fuel combustion and electricity use for each activity were provided by the BC Hydro Design Team and through experience with similar projects. The data are organized by overall construction activity (as indicated above) and converted to GHG emissions using the applicable emission factors. Two sources for emission factors were used for the construction emissions inventory. These include publications from Western Climate Initiative (WCI) and Environment Canada. The references for the emission factors are provided in Table 15.5.

Table 15.5 Summary of Emission Factor Sources

GHG Emission Source	Emission Factor Reference
Fuel Combustion	Western Climate Initiative (WCI). Final Essential Requirements of Mandatory Reporting, 2011 Amendments for Harmonization of Reporting in Canadian Jurisdictions, December 2011, published in February 2012, Table 20.2.
Electricity Consumption	Environment Canada. National Inventory Report: (1990-2010) Greenhouse Gas Sources and Sinks in Canada, published in April 2012, Part 3: Annex 13.

The emission factors for fuel combustion from WCI are used to quantify GHG emissions associated with construction activities. It is noted that this referenced WCI publication is required to be used by industries reporting GHG emissions under the B.C. *Greenhouse Gas Reduction (Cap and Trade) Act*. The WCI publication does not provide separate emission factors for Stationary Diesel Combustion and Mobile Diesel Combustion. The emission factors in the units of grams CO_2e per litre are calculated from CO_2, CH_4, and N_2O emission factors and their respective Global Warming Potentials.

The Electricity Consumption Intensity (for B.C.) published by Environment Canada is used to quantify indirect GHG emissions from electricity consumption. It is noted that the WCI publication does not reference the Electricity Consumption Intensity, as emissions from electricity consumption are not regulated under the *Greenhouse Gas Reduction (Cap and Trade) Act*.

The most recent published emission factors are used in this study. A detailed spreadsheet including all calculations and emission factors is presented in the GHG Report (Volume 2 Appendix S Greenhouse Gases Technical Report).

For the operations phase of the Project, three separate methods of analysis were used to model and evaluate GHG emissions for the Project, following methods described by the Intergovernmental Panel on Climate Change (IPCC 2003). The first two IPCC methods are generic and use simple calculations to estimate emission rates from land flooding only (Tier 1) or from land flooding and degassing at turbines and spillways (Tier 2). The third method (Tier 3) involves developing a more detailed carbon model to account for the substantive carbon stocks, processes, and fluxes relevant to the Project (Volume 2 Appendix S Greenhouse Gases Technical Report).

The Tier 3 approach (IPCC 2006) provides guidelines for developing project-specific models that account for all major stocks, processes, and pathways (fluxes) of carbon within the watershed (Volume 2 Appendix S Greenhouse Gases Technical Report, Section 8.0). This approach provides the most precise estimate of the net emissions produced as a result of reservoir inundation and is therefore a more realistic and thus more applicable model.

For post-inundation, using Tier 3 methods, (after the dam is constructed and operating), the emissions of GHGs were estimated for two different scenarios: Firstly, a conservative (i.e., worst case) scenario with conservative default settings; and secondly, a likely scenario, which treated merchantable timber and buried biomass as stored carbon instead of emissions. While the likely scenario is the more probable of the two, both are modelled to ensure that a conservative approach is taken in the assessment.

On the use of cleared vegetation, the IPCC (2003) guidelines recommend including all cleared or flooded vegetation as a project carbon emission during calculations, though the guidelines recognize that carbon in the merchantable fraction of cleared vegetation may be permanently stored in various timber products.

Under the conservative emissions scenario, all cleared vegetation was included as an emission and treated as flooded biomass that undergoes decomposition, while in the likely emission scenario, it is assumed that the carbon in merchantable timber would be permanently stored and 30% of cleared non-merchantable timber would be buried in deep portions of the reservoir and permanently stored.

15.3.1 Effects Assessment – Construction

In the following sections, GHG emissions associated with various construction categories are described. Data sources and assumptions are provided in each section.

15.3.1.1 Dam and Generating Station, Spillways, and Quarried and Excavated Materials GHG Emissions

The GHG emissions associated with these project components arise from vehicle and equipment use (i.e., fuel combustion) during the following activities:

- Clearing of the areas associated with the dam, generating station, access roads, and transmission line
- Channelization (bridges, excavation, and cofferdam construction)
- Diversion (cofferdam construction, dam foundations, earthfill dam, spillway)
- Commissioning
- Site restoration (removal of temporary facilities and reclamation)

Greenhouse gas emissions from fuel combustion and electricity consumption are quantified using the emission factors published in Western Climate Initiative's Final Essential Requirements of Mandatory Reporting, December 2011 (WCI 2011) and Environment Canada's National Inventory Report (Environment Canada 2012) publications, respectively.

The total direct and indirect emissions of GHGs from the dam and generating station, spillway, and quarried and excavated material activity over the eight-year construction period are estimated to be 304,163 t CO_2e and 2,597 t CO_2e, respectively.

15.3.1.2 Reservoir Clearing GHG Emissions

The GHG emissions associated with the reservoir clearing activity are released from the fuel combusted during the harvesting of merchantable timber, and waste collection and disposal.

Greenhouse gas emissions from fuel combustion were calculated using the emission factors in Final Essential Requirements of Mandatory Reporting (WCI 2011).

The total direct GHG emissions from fuel combustion associated with Reservoir Clearing are 18,730 t CO_2e over the eight-year construction period.

15.3.1.3 Transmission Line to Peace Canyon GHG Emissions

The GHG emissions associated with the Transmission Line construction arise from vehicle and equipment use (i.e., fuel combustion) during the following activities:

- Distribution of components along the right-of-way
- Installation of foundations and guy anchors
- Assembly of towers and associated equipment
- Erection of towers
- Conductor pulling and tensioning equipment
- Installation of counterpoise
- Removal and reclamation of temporary access and cleanup and restoration of the right-of-way

Greenhouse gas emissions from fuel combustion associated with transmission line construction were calculated using the emission factors provided in Final Essential Requirements of Mandatory Reporting (WCI 2011).

The total direct GHG emissions from fuel combustion associated with the transmission line construction are 6,511 t CO_2e over the eight-year construction period.

15.3.1.4 Project Access Road and Rail GHG Emissions

The GHG emissions associated with the construction of the Project access road and rail (e.g., the building of a rail siding) are attributed to fuel combustion associated with construction equipment use. Greenhouse gas emissions from fuel combustion were calculated using the emission factors provided by in Final Essential Requirements of Mandatory Reporting (WCI 2011). Greenhouse gas emissions from electricity usage were calculated using the emission factors provided by the National Inventory Report, (Environment Canada 2012).

The total direct and indirect emissions of GHGs from fuel combustion and electricity use associated with Project access road and rail are 6,315 t CO_2e and 19.20 t CO_2e, respectively, over the eight-year construction period.

15.3.1.5 Highway 29 Realignment GHG Emissions

BC Hydro has estimated the fuel consumption associated with the Highway 29 realignment. The GHG emissions from combustion of fuel and consumption of electricity were quantified using the emission factors provided in the Final Essential Requirements of Mandatory Reporting (WCI 2011) and the National Inventory Report (Environment Canada 2012), respectively.

The total direct and indirect emissions of GHGs from fuel combustion and electricity use associated with the Highway 29 realignment are 26,910 t CO_2e and 34.14 t CO_2e, respectively, over the eight-year construction period.

15.3.1.6 Worker Accommodation GHG Emissions

There will be two worker accommodation camps available for workers. In addition to the construction of the accommodations, there will be electricity use associated with heating, utilities, and domestic use. The estimated GHG emissions were calculated using consumption data provided by BC Hydro and emission factors from the National Inventory Report (Environment Canada 2012).

The total indirect GHG emissions from electricity consumption at the worker accommodations are 3,490 t CO_2e over the eight-year construction period.

15.3.1.7 Summary of Construction GHG Emissions

A summary of the estimated GHG emissions (direct and indirect) released from each construction activity described above is presented in Table 15.6. The percentages of GHG emissions that contribute to the total Direct and Indirect Construction Emissions are also provided for each type.

Table 15.6 Summary of Construction GHG Emissions

Activity	GHG Emissions (Tonnes of CO_2e)		Contribution to Total Emissions from Construction (%)	
	Direct	Indirect	Direct	Indirect
Dam and Generating Station, Spillways, and Quarried and Excavated Materials	304,163	2,597	84	42
Reservoir Clearing	18,730	0	5	0
Transmission Line to Peace Canyon	6,511	0	2	0
Access Road and Rail	6,315	19.20	2	0
Highway 29 Realignment	26,910	34.14	7	1
Worker Accommodation	0	3,490	0	57
Total	**362,629**	**6,141**	**100**	**100**

Based on these estimates (Table 15.6), it is clear that dam and generating station construction activities represent the major GHG sources during construction activities. This is primarily due to the fuel combustion associated with construction equipment for dam and generating station construction.

Over the eight-year construction period, the total direct GHG emissions from construction are 362,629 t CO_2e. Assuming a 15% contingency is applied to address some uncertainty in the estimates, the direct emissions would be 417,023 t CO_2e. The total indirect GHG emissions from construction are 6,141 t CO_2e. The indirect emissions would be 7,062 t CO_2e with a 15% contingency.

The emissions may also be presented over the time for construction on an annual basis. These data are based on the expected activity levels for each year. The releases of GHGs by year (with contingency) are provided in Table 15.7.

Table 15.7 Construction GHG Emissions – by Year (Tonnes CO2e/Year)

Parameter (tonnes CO_2e per year)	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Total
Direct Emissions – Low	8,449	34,797	49,017	52,432	41,696	76,090	64,752	31,049	4,347	362,629
Direct Emissions – High	9,716	40,016	56,369	60,296	47,951	87,504	74,465	35,706	4,999	417,023
Indirect Emissions – Low	126.66	403.17	444.19	477.06	591.07	1,544.61	1,495.17	937.09	122.27	6,141
Indirect Emissions – High	145.65	463.64	510.82	548.61	679.73	1,776.30	1,719.44	1,077.65	140.61	7,062

15.3.1.8 GHG Emissions from Construction Materials based on Life Cycle Assessment (LCA)

An analysis of the GHG emissions associated with the materials used in the construction of the Project was also undertaken. These emissions were quantified based on emission factors associated with the production of concrete, fly ash, steel, stainless steel, aluminum, and copper. The emission factors and the related references, used for this LCA, are presented in the GHG report (Volume 2 Appendix S Greenhouse Gases Technical Report).

The low range quantity of materials (tonnes) to be used in the construction (over the eight-year period) was estimated based on best available information and professional experience with similar projects. The high range quantity of materials to be used was calculated based on the percentage contingency (15% contingency for steel, aluminum, cement, and flyash; 25% contingency for stainless steel; and 50% contingency for copper). In order to estimate the GHG emissions (tonnes of CO_2e) from the construction materials, the low range and high range quantity of materials (tonnes) were subsequently applied to the low and high emission factors (tonnes CO_2 per tonne of material), respectively. Additional detail is provided in Volume 2 Appendix S Greenhouse Gases Technical Report.

The total life cycle GHG emissions for materials to be used in the construction are estimated to range from 628,455 to 1,059,622 t CO_2e.

15.3.2 Effects Assessment – Operations

In order to estimate the net environmental effect of the Project on carbon storage and fluxes, three different scenarios were evaluated, one representing the carbon exchanges of the assessment area under current conditions (pre-flooding) and two scenarios under the post-inundation conditions. The Site C carbon model was developed to consider all major carbon stocks, processes, and fluxes, including land conversion to the reservoir and the removal of trees and vegetation for Project construction. Models representing each of the following scenarios, were programmed to run for a model period of 100 years to compare GHG emission estimates:

- Current conditions (summary of results provided in Section 15.2.3)

- Post-inundation with conservative model parameters (conservative scenario)
- Post-inundation with likely model parameters (likely scenario)

The specific description on how vegetation, land areas, and carbon and nitrogen inventories were estimated for the Project is provided in Volume 2 Appendix S Greenhouse Gases Technical Report. In this report, the terms used in the Project carbon cycle and nitrogen cycle models with regards to the current and post-inundation conditions for the Project are described and quantified.

The Site C carbon model for the Peace River post-inundation scenarios suggest that, initially, the net emissions for the assessment area would be increased due to flooded organic matter decomposition. Emissions from the Site C reservoir are initially much higher than current levels, and decline back to current conditions by approximately Year 20 (Figure s 15.2 and 15.3). While this duration is longer than the typical extent before emissions return to near pre-inundation level (~10 years) (Tremblay et al. 2004b), it is not unreasonable given that several conservative assumptions were made, such as little biomass burial, conservatively low sedimentation estimates, and emissions include all releases from flooded biomass regardless of when and where gases are released. Furthermore, this difference may also be due to a slower modelled decomposition rate than typically occurs in reservoirs, which would partially explain why the modelled time to return to current conditions emissions estimates are higher than typically observed elsewhere, and would not be accounted for in emission estimates of reservoirs based solely on field measurements (Tremblay et al. 2004b; Teodoru et al. 2012).

The average annual net project emissions for the Project (using the Tier 3 model) are approximately 58,200 t CO_2e/year, and 43,400 t CO_2e/year, for the conservative and likely scenarios, not considering emissions from construction. The Tier 3 year values are initially high due to the initial pulse of GHG emissions, but by Year 20, these emissions are substantively reduced. These results are consistent with the observations of Bastien et al. (2007) that the GHG fluxes in Smallwood reservoir 30 years post-inundation are similar to those of natural lakes in the region.

This model indicated that initially, inundation removes 950,000 t of carbon from the soil, vegetation, and wetland stocks within Site C due to flooding, and an additional 323,000 t of carbon are removed from land cleared for new roads and transmission lines. This value does not change with respect to timber harvesting, as it represents the loss of terrestrial carbon stocks in the conservative scenario. Under the assumption that all harvested timber would be stored in long-term forest products and that 30% of non-merchantable vegetation would be permanently buried in the reservoir, there would be a 27% reduction in net emissions over the 100-year lifespan.

The estimated emission intensities for Site C under the conservative and likely scenarios decreased substantially over time (Figure 15.4). The estimated values during the time period immediately after inundation are expected to be relatively high due to the large flux of GHGs from biomass decomposition. The range in emission intensity between the maximum conservative and minimum likely scenario estimates, based on sensitivity analyses conducted for three key model parameters (i.e., livestock estimates, biomass burial rates, and sedimentation rates) was initially less than two-fold; this decreased over time, indicating that the model was relatively insensitive to these model parameters. Beyond Year 20, the emission intensity estimates stabilized at values between one and two orders of magnitude lower than in Year 1, were very similar among scenarios, and were well below emission intensities of any fossil fuel generating facility of similar capacity. Additional information on the sensitivity analysis is provided in the GHG report (Volume 2 Appendix S Greenhouse Gases Technical Report).

These model estimates were also comparable to observed emission intensity trends observed for Eastmain-1, a boreal hydroelectric reservoir in Québec (Teodoru et al. 2012).

15.3.3 Summary of Project GHG Emissions

A summary of estimated GHG emissions from Construction and Operation using Tier 3 and the associated GHG emission intensities are provided in Table 15.8.

Table 15.8 GHG Emissions Estimates - Site C Clean Energy Project

Activity/Method	GHG Emission Estimates [a]	
Emissions – Construction (tonnes CO_2e)	Scenario Conservative;	 Likely
Annual average over 8 years (fuel use)	52,128	45,329
Fuel total (8-year construction period)	417,024	362,629
Electricity and construction materials total (8-year construction period)	1,066,685	634,596
Construction sub-total (8 years) - fuel, electricity, and construction materials	**1,483,708**	**997,225**
Emissions – Operation (tonnes CO_2e)	Scenario Conservative;	 Likely
Annual average over 100 years [a]	58,200	43,400
Operations sub-total (100 years)	**5,824,820**	**4,343,633**
Emissions – Total Construction and Operations (tonnes CO_2e)	Scenario Conservative;	 Likely
Annual average over 108 years [b]	**57,795**	**43,576**
Total over 108-year period – excluding electricity and construction materials	**6,241,844**	**4,706,262**
Total over 108-year period – including Construction, and construction materials	**7,308,528**	**5,340,858**
Emissions Intensity		
Generating Capacity (MW)	1,100	
Electricity Generation (GWh/year)	5,100	
	Scenario Conservative;	 Likely
Emissions Intensity [c] (g CO_2e/kWh) - not including Construction	11.4	8.5
Emissions Intensity [d,] (g CO_2e/kWh) - including Construction	13.3	9.7

NOTES:

[a] Averaged annual emission estimates are rounded to the nearest 100 tonnes CO_2e/year (Volume 2 Appendix S Greenhouse Gases Technical Report)

[b] CO_2 equivalents (CO_2e) calculated on a 100-year global warming potential of 21 for CH_4 and 310 for N_2O

[c] Values represent 100-year average

[d] Includes emissions from construction fuel combustion and electricity use, and life cycle GHGs from construction materials, averaged over 108 years

15.3.4 Mitigation Measures

Initiatives to mitigate the GHG emissions have been incorporated into the design of the Project.

15.3.4.1 Mitigation of Construction GHG Emissions

The majority of GHG emissions during construction result from the burning of fossil fuels, namely the burning of diesel and gasoline in vehicles and heavy equipment. As a result, reduced GHG emissions are linked directly to reductions in fossil fuel consumption and implementation of fuel conservation strategies.

For this reason, greenhouse gas emission mitigation measures will be developed within the Project’s detailed Environmental Management Plans, targeted at fleet management to:

- Reduce fuel usage to reduce greenhouse gas emissions
- Increase fuel efficiency to reduce greenhouse gas emissions

Further mitigation, in the form of carbon stored in merchantable timber that is harvested during site preparation, is considered and quantified in the carbon modelling described above.

15.3.4.2 Mitigation of Operations GHG Emissions

There is limited ability or capacity to apply mitigation measures to reduce GHG emissions during operation of a hydroelectric facility. As outlined in IPCC (2006), emissions resulting from land use change are relative to the land area converted from forest to non-forested land. For this reason, greenhouse gas mitigation during operations was taken into consideration in the design of the project, where long-term conversion of land from current conditions was minimized to the fullest extent. As noted above, there is carbon stored in the merchantable timber, and this has potential to be stored over the long term, i.e., sequestered. This is quantified in the carbon modelling results described above.

15.3.5 Summary of Effects Assessment and Mitigation Measures

A summary of potential effects and mitigation measures is shown for greenhouse gases in Table 15.9.

Table 15.9 Project Effects and Mitigation Measures on Greenhouse Gases

Project Phase	Potential Effects	Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Emission of GHGs from construction activities	Fleet management to reduce fuel consumption and increase fuel efficiency	The application of mitigation must be a part of standard best practice by construction crew to be most effective	BC Hydro in cooperation with delivery agency or partner
Operation	Release of GHGs during operation	Long-term conversion of land will be minimized while achieving the purpose of the Project	The application of mitigation for operations must be considered at the design phase to be effective	BC Hydro in cooperation with delivery agency or partner

15.3.6 Other Mitigation Options Considered

Other mitigation measures have been considered by BC Hydro, including evaluating design options that would result in little reduction in generating potential, yet reductions in GHG emissions, as well as options for transmission lines and roads that would minimize the amount of land conversion, thus reducing GHG emissions. For detail on additional mitigation considerations, please refer to the Greenhouse Gases Technical Report (in Volume 2 Appendix S).

15.4 Residual Effects

15.4.1 Characterization of Residual Effects

The residual effects of the Project on GHG emissions were characterized using the criteria presented in Table 15.10.

Table 15.10 Characterization Criteria for Residual Greenhouse Gas Effects

Criterion	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	This refers to the ultimate long-term trend of the environmental, social, economic, heritage, or health effect (e.g., increase, decrease, or neutral).	**Increase**: GHG emissions are increasing in comparison to baseline conditions and trends.
		Decrease: GHG emissions are decreasing in comparison to baseline conditions and trends.
		Neutral: GHG emissions are unchanged in comparison to baseline conditions and trends.
Magnitude	This refers to the amount of change in a key indicator or variable relative to baseline case (low, moderate, high); consideration is given to factors such as the uniqueness of the effect, and the comparison to natural or background variation.	**Low:** GHG emissions are measurable but within normal variability of baseline conditions; GHG Emissions < 105 t/year CO_2e.
		Moderate: GHG emissions increase with regard to baseline but are within regular variability; GHG Emissions > 105 and < 106 t/year CO_2e.
		High: GHG emissions from the Project are substantive and above regular variability; GHG Emissions > 106 t/year CO_2e.

Criterion	Description	Quantitative Measure or Definition of Qualitative Categories
Geographical Extent	This refers to the geographic area in which an environmental, social, economic, heritage, or health effect of a defined magnitude occurs (site-specific, local, regional, provincial, national, international).	**Local:** the expected change in GHG emissions are within the LAA.
		Regional: the expected change in GHG emissions are within the RAA.
		Global: the expected change in GHG emissions are of global extent.
Frequency	The number of times during a project or a specific project phase that an environmental, economic, social, heritage, or health effect may occur (e.g., once, daily, weekly, monthly, continuous).	**Once:** occurs once.
		Continuous: occurs on a regular basis and at regular intervals.
		Sporadic: occurs rarely and at irregular intervals.
Duration	The period of time required until the valued component returns to its baseline condition, or the effect can no longer be measured or otherwise perceived (short term, medium term, long term, permanent).	**Short term:** effect is limited to < 1 year.
		Medium term: effect occurs > 1 year but not beyond 50 years.
		Long term: effect occurs > 50 years but not beyond 100 years.
		Far future: effect extends > 100 years.
Reversibility	This refers to the degree or likelihood to which existing baseline conditions can be regained after the factors causing the effect are removed. Effects can be reversible or irreversible.	Effect **reversible** with reclamation, reduction in GHG emissions, or over time.
		Effect **irreversible** and cannot be reversed with reclamation, reduction in GHG emissions, or over time.
Context	This refers to the extent to which the area within which an effect may occur; has already been adversely affected by human activities; and is ecologically fragile and has little resilience and resistance to imposed stresses.	**Developed:** area has been substantially previously disturbed by human development or human development is still present.
		Undeveloped: area relatively pristine or not adversely affected by human activity.
Level of Confidence	This is an evaluation of the scientific certainty one has in the review of project specific data, relevant literature, and professional opinion; the EIS will include a statement on the level of confidence in the assessment of direction, magnitude, extent, duration, frequency and reversibility.	**Low:** low level of confidence.
		Moderate: moderate level of confidence.
		High: high level of confidence.
Probability	The likelihood that an adverse effect will occur (e.g., low, high or unknown).	**Low:** low probability of occurrence.
		High: high probability of occurrence.
		Unknown: probability of occurrence is unknown.

The net emissions of the Site C reservoir operation, over the 100-year operating lifespan of the project, would be approximately 58,200 t CO_2e/year under the conservative scenario, and 43,400 t CO_2e/year under the likely scenario, with an additional emission of approximately 45,329 t CO_2e/year for the fuel use during construction. This represents 0.2% and 0.01% of provincial and national emission, respectively (conservative operation plus construction). In the global context, these net emission rates represent a tiny fraction (0.002%) of the net anthropogenic emissions (5.5 to 6.3 billion t CO_2e/year).

In the context of increasing global energy demand and global climate change, evaluating generating facilities by their emissions (g CO_2e) per unit of energy generated (kWh) is an important relative measure when evaluating the potential climate warming impact of a project.

Using the IPCC Tier 3 calculations for reservoir emissions, not including construction and clearing emissions, the net emissions per unit energy generated averaged over the 100-year operating lifespan are 11.4 g CO_2e/kWh for the conservative scenario (Table 15.8). Initially (in the first years of after inundation), the emissions per unit energy are much higher, due to the initial flux of GHG from the reservoir and are estimated to be 212 g CO_2e/kWh, but by Year 20 this value is reduced to 4 g CO_2e/kWh and reaches 2 g CO_2e/kWh by Year 35 (Figure 15.4).

Under the likely emissions scenario, the average emission intensity, not including construction emissions, is 8.5 g CO_2e/kWh, and ranges from 146 to 2 g CO_2e/kWh.

These values are consistent with the average range of 8 to 60 g CO_2e/kWh presented by the IRN (2006) for boreal reservoirs, though at the lower extreme. This is not surprising, given that Site C would have a constant water supply from the upstream Williston Reservoir for electricity generation while inundating a relatively small area of land. This type of reservoir can be characterized as a run-of-river type project rather than a traditional reservoir hydro project. The IEA (2000) reported that run-of-river hydro projects are among the lowest emitting of all generating types, which is consistent with this study's results. In contrast to these data, IRN (2006) estimated that, among other sources of electricity, modern coal-fired generating stations emit approximately 1,000 g CO_2e/kWh, and existing natural gas combined cycle generators emit approximately 545 g CO_2e/kWh (Table 15.11). In fact over the life cycle of the Project, relative emission estimates more closely resemble those of wind turbine facilities than other types of generating facilities, but the Project also has the advantage of constant water supply, compared to sporadic wind supplies.

While the construction and operation of the Site C reservoir and generating station would result in a net increase in GHG emissions, they are "low" as described by the CEA Agency guidance (2003). The emissions are considered to be much lower than GHG emissions from the combustion of fossil fuels to generate equivalent amounts of electricity over the long term, given the biogenic origin of the Peace River emissions. In other words, as the emissions from the Project originate primarily from decomposition of organic matter currently stored in soils and plants, this carbon could be recaptured rapidly when compared to fossil fuel emissions, which are not returned to their original carbon stocks (i.e., oil, coal, natural gas). As approximately 95% of emissions from the Project would originate from biomass removal and only 5% from emissions related to construction and fuel use, an analysis of measures to mitigate carbon emissions from biomass decomposition may be useful.

Table 15.11 Emissions Intensity – Project Compared with Other Generation

Generating Facility Type	Range (g CO_2e/kWh)	Average (g CO_2e/kWh)
Tropical Hydroelectric	1,750 – 2,700	2,150
Modern Coal	959 – 1,042	1,000
IGCC (coal)	763 – 833	798
Diesel	555 – 880	717
NGCC (Natural Gas)	469 – 622	545
Photovoltaic	13 – 104	58
Canada Boreal Hydroelectric	8 – 60	36
Wind Turbines	7 – 22	14
BC Hydro Site C (Tier 3 – conservative, with embedded carbon, fuel, and electricity use)	—	13.3
BC Hydro Site C (IPCC Tier 3 - conservative)	2 – 212 (annual range)	11.4 [a]
BC Hydro Site C (Tier 3 – likely, with embedded carbon, fuel, and electricity use)	—	9.7
BC Hydro Site C (IPCC Tier 3 - likely)	2 – 146 (annual range)	8.5*

NOTES:

[a] The average value is the 100-year average estimate

Intensities for Modern Coal, IGCC (coal), Diesel, NGCC (Natural Gas), Photovoltaic, and Wind Turbines include life cycle emissions. For more information, see IRN 2006. Intensities for Boreal and Tropical Hydroelectric facilities include only reservoir emissions.

— not collected

Source: IRN 2006

Overall, the GHG emissions from the Project are considered to be low in relation to other forms of non-renewable electricity generation and in relation to the provincial, regional or national GHG emission totals (CEA Agency 2003). The Project will result in a net benefit from a GHG perspective, producing electricity with substantively lower GHG emissions compared to other forms of electricity generation.

The residual environmental effects associated with a change in greenhouse gas emissions during construction and operation, in light of mitigation described above, are characterized in terms of direction magnitude, geographic extent, duration and frequency, and rating of significance is provided with a level of confidence in Table 15.12.

1 **Table 15.12 Characterization of Residual Greenhouse Gases Effects**

Activity	Residual Environmental Effect							
	Direction	**Magnitude**	**Geographic Extent**	**Duration and Frequency**	**Reversibility**	**Ecological or Social Context**	**Probability**	**Level of Confidence**
Construction								
Dam, Generating Station, and Spillways, and Quarried and Excavated Materials	Increase	Low	Global	Short term/ Continuous	Reversible	Developed	High	High
Reservoir Clearing	Increase	Low	Global	Short term/ Continuous	Reversible	Developed	High	High
Transmission Line to Peace Canyon	Increase	Low	Global	Short term/ Continuous	Reversible	Developed	High	High
Construction Access	Increase	Low	Global	Short term/ Continuous	Reversible	Developed	High	High
Highway 29 Realignment	Increase	Low	Global	Short term/ Continuous	Reversible	Developed	High	High
Worker Accommodation	Increase	Low	Global	Short term/ Continuous	Reversible	Developed	High	High
Operations								
Spillway	Increase	Low	Global	Far future/ Sporadic	Reversible	Developed	High	High
Reservoir	Increase	Low	Global	Medium term/ Continuous	Reversible	Developed	High	High

BC hydro
FOR GENERATIONS

15.4.2 Thresholds for Determining Significance

In the determination of significance for GHGs, the criteria described above (e.g., direction, magnitude, geographical extent, frequency, duration, reversibility, context, level of confidence, probability) are assessed and considered to establish the rating for the Project-related effects. Specifically, a significant adverse residual environmental effect of the Project on greenhouse gases is one where the release of GHGs (as a total) is of a quantity that is either medium or high, where those terms are used in the guidance provided by CEA Agency (2003). Since there is no clear quantitative threshold defined in the provincial or federal regulations, this qualitative definition is used to make the determination of significance.

15.4.3 Determination of Significance of Residual Effects

The net changes in GHG emissions as a result of changes in vegetation removal, growth, and management, and from the combustion of fossil fuels over the eight-year construction period were quantified and assessed. The overall net GHG emissions change associated with and during construction are expected to be low as inferred by CEA Agency (2003).

The net annual average GHG emissions from the operation of the reservoir and hydroelectric generating station have been assessed in detail using a detailed carbon model based on Tier 3 methodology. The plan is for these facilities to continue operating in perpetuity. It is thus of interest to consider the long-term average GHG emissions and place them in context with provincial and national emissions and GHG emissions from other sources of electricity. The average GHG emissions over the first 50 years of operation, taking into account the high rates in the early years, will fall into the range of 76,100 to 105,800 t CO_2e per year (likely to conservative). The average over the first 100 years will be between 43,400 and 58,200 t CO_2e per year.

The GHG emissions from operation activities associated with the Project are expected to be low in comparison to total emissions for the jurisdictions (Province of British Columbia; Canada) and to other sources of electricity generation. Canada's total anthropogenic GHG emissions were estimated to be approximately 692,000 kt CO_2e in 2010 (Environment Canada 2012). British Columbia's GHG emissions have decreased since 2007; the 2010 reported GHG emissions of 56,100 kt CO_2e put British Columbia on track to meet its 2012 reduction target of 6% of 2007 levels. The majority of the provincial GHG emissions are from road transportation (Environment Canada 2012).

The 1,100 MW hydroelectric generating facility has the potential to produce an average of 5,100 GWh of energy annually. Averaged over a 100-year operational lifespan, the net emissions intensity from Site C would be approximately 11.4 g CO_2e/kWh under the conservative scenario or 8.5 g CO_2e/kWh under the likely scenario. This intensity is much lower when compared to emission intensities of other generation types such as: 545 g CO_2e/kWh (natural gas), 1,000 g CO_2e/kWh (coal), and 717 g CO_2e/kWh (diesel) for other competing types of electricity generation (Table 15.10 and Figure 15.5) (IRN 2006).

The GHG emissions attributable to the Project during construction average approximately 45,329 t of CO_2e per year during construction and average approximately 43,400 t/year (likely) or 58,200 t/year per year (conservative) over its operating life.

These emission rates place the Project at the low end of the scale when compared with emissions from other sources of electricity generation, over the long term. Overall, the GHG emissions from the Project are considered to be low in relation to industry norms and in relation to the provincial, regional, or national GHG emission totals (CEA Agency 2003). The Project will result in a net benefit from a GHG perspective, producing electricity with substantively lower GHG emissions compared to other forms of electricity generation.

The CEA Agency (2003) recommends that net changes in GHG emissions as a result of a project be evaluated and detailed mitigation be considered if they are found to be medium or high. As the Project is considered to be a low emitter of GHG in the CEA Agency (2003) context, detailed mitigation beyond that of applicable regulations is not required.

The residual Project-related quantities of GHGs released to the atmosphere are a small fraction of the provincial, national, and global emissions, and are considered low (in terms of total and emission intensity), and not medium or high, in the context of the CEA Agency guidance (2003). Therefore, the environmental effects of the Project on Greenhouse Gases are rated not significant.

A summary of the assessment is provided in Table 15.13.

Table 15.13 Summary of Assessment of Potential Significant Residual Adverse Effects

Valued Component	Project Phase	Potential Adverse Effects	Key Mitigation Measures	Significance Analysis of Residual Effects
Greenhouse Gases	Construction	Emission of GHGs from construction activities	Fleet management to reduce fuel consumption and increase fuel efficiency	Not Significant
Greenhouse Gases	Operation	Release of GHGs during operation	Long-term conversion of land will be minimized while achieving the purpose of the Project	Not Significant

15.5 Cumulative Effects Assessment

15.5.1 Characterization of Cumulative Effects

Cumulative environmental effects associated with releases of GHGs to the atmosphere are not limited to the provincial or national borders; in other words, it is a global issue The sources of GHG emissions around the world are contributing to the environmental effect and these would act cumulatively with the Project.

While emissions from the Project will add to existing GHG emissions and potentially contribute to increasing GHG concentrations in the atmosphere, the status of the climate science to date cannot provide a clear statement on a direct cause-and-effect relationship between Project emissions and change in climate.

Releases of GHG emissions from past and current projects (and sources) are considered through the past and current emissions inventories of GHG emissions in British Columbia and Canada.

As noted above, the net emissions of the Site C reservoir operation, over the 100-year operating lifespan of the project, would be approximately 58,200 t CO_2e/year under the conservative scenario, and 43,400 t CO_2e/year under the likely scenario, with an additional emission of approximately 45,329 t CO_2e/year for the fuel use during construction. This represents 0.2% and 0.01% of provincial and national emissions, respectively (conservative operation plus construction). In the global context, these net emission rates represent a tiny fraction (0.002%) of the net anthropogenic emissions (5.5 to 6.3 billion t CO_2e/year).

15.5.2 Determination of Significance of Residual Cumulative Effects

Since the Project's contribution to a net change in global GHG emissions is small, relatively, and because the environmental effect of the Project-related GHG emissions (on its own) on global climate is not measurable, the change in GHG emissions as a result of the Project on its own (i.e., the Project contribution to the cumulative environmental effects) is not substantive.

However, increasing GHG emissions from the many sources globally and the resulting increase in GHG concentrations in the atmosphere, and the consequent changes to the global climate, are currently believed to be a significant cumulative environmental effect. Therefore, the cumulative environmental effects of a change in GHG emissions from the Project combined with existing and planned future projects, are rated significant. This rating is a result of the fact that the existing environmental effects of GHG emissions on global climate are significant, even in the absence of the Project.

15.6 Monitoring and Follow-Up

Recent monitoring of GHG emissions from reservoirs in northern latitudes has greatly improved the understanding of the GHG emissions from hydroelectric facilities in those regions (e.g., Bastien et al. 2007). The GHG emission generating activities will be tracked throughout construction and operation through monitoring. The main area of interest is the GHG emissions from the Project during operations. Therefore, the following activities will be implemented on an annual basis, during the first 10 years of operations:

- Monitor changes in GHG emissions from Site C reservoir to verify the GHG estimates and predictions presented in this EIS
- Monitor GHG emissions during operations and maintenance activities in accordance with BC Hydro corporate requirements, and report results to the province or other organizations per corporate reporting requirements

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