Ecosystem Restoration Strategic Plan: Phase 1

Selkirk Resource District

Prepared for:

Selkirk Resource District Ecosystem Restoration Steering Committee
Ministry of Forests, Lands and Resource Operations
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Executive Summary

This project provides an ecologically-based framework for the Selkirk Resource District (SRD) Ecosystem Restoration Steering Committee to pursue its long term Ecosystem Restoration (ER) goals. The report: 1) defines ecosystems of concern through a threats assessment approach; 2) provides a detailed threat activity summary with affected ecosystems of concern; 3) identifies ecosystem restoration techniques that address impacts to ecosystems of concern; and 4) discusses climate change and restoration goals.

In order to identify ecosystems of concern in the Selkirk Resource District, a risk-based assessment of present and future threats and impacts was required. To achieve this, we adapted a methodology developed by Holt et al. (2003) in a report focusing on provincial and regional threats to biodiversity in BC for local use. The latter methodology was modified to reflect the specific area of interest and particular needs of this project. The approach involved the following:

(a) Separating the Selkirk Resource District (SRD) into *terrestrial* and *aquatic* realms, and then dealing with both realms separately. Wetlands and riparian areas overlap with both realms, but were nested within the terrestrial realm for this exercise;

(b) Stratifying the terrestrial and aquatic realms by *geographic sub-basins* based on watershed boundaries within the Selkirk Resource District:

- Kettle/Granby Sub-Basin
- Lower Columbia/Kootenay Sub-Basin
- Upper Columbia Sub-Basin

(c) Further stratifying the terrestrial and aquatic realms into *ecological units* based on the biogeoclimatic ecosystem classification (BEC) system:

- Interior Dry
- Interior Moist/Wet
- Montane/Subalpine/Alpine

(d) Then separating the ecological units into *ecological subunits* or '*ecosystems of concern*' for both the terrestrial and aquatic realms:

- Terrestrial
  - rock and talus, avalanche features, high elevation meadows, grasslands-shrub-steppe, dry forests, intermediate forests, wet forests, cottonwood forests, riparian areas, forested wetlands and non-forested wetlands.
- Aquatic
  - streams, rivers, lakes and reservoirs.

To assess past impacts plus present and future threats to potential ecosystems of concern in the SRD, a list of Threat Categories and associated Threat Activities from Holt et al. (2003) was filtered and modified for local use. The complete list used for this project included 12 threat categories further divided into 42 threat activities. Using the output derived from various sources, rankings for each ecological/ geographic unit combination were determined subjectively by our team and entered into a database. The output was a series of assessment tables with rankings for the top ten or more threat activities in each ecological unit/geographic sub-basin combinations.

The top threats were then included in the threat activity summary. General types of impacts, the key ecosystems of concern that are affected by the threat impacts, key ecosystem attributes affected by the impacts and potential ER techniques were described.

The following 29 main threats were identified:

AG -Cultivation
AG – Fertilization
AG – Water Demand
CC- Climate Change
CC – Hydrograph Changes
DA – Flow Regulation
DA – Habitat Conversion
DA- Physical Obstruction
DE Habitat Conversion
DE- Sewage Disposal
DE-Water Demand
FO- Fire Suppression
FO:- Landscape Level Modification
FO - Roads
FO- Riparian Disturbance Modification
FO- Silviculture
FO - Stand Structure Modification
GR –Riparian / Wetland Disturbance
GR - Vegetation Modification
HA – Recreational Harvest
ME - Discharge
ME – Mine Site
NS - Non-Native Species
RE – Resort Development and Operation
RE- Motorized Aquatic
RE- Motorized Terrestrial
RE-Non-motorized Terrestrial
TC - Highways
TC - Railways

The ecological impacts associated with different stressors vary widely, depending on their geographic and temporal extent, the severity of the activity, and the particular ecosystem being impacted. In the case of some threats, the ecosystem itself is expected to respond in a particular way to a specific threat. For example, some systems are predicted to be moving towards a regime shift under climate change because they are located close to moisture tolerance threshold for key tree species. Other threats are highlighted because they are located in a particular location that has been subject to a variety of cumulative effects over a longer time period (e.g., areas of early settlement and development). There is often interaction between various threats which has tended to result in higher levels of impact at lower elevations and in the southern areas of the SRD.

Ecosystem restoration techniques identified in the threats summary table address the key threats and impacts to the SRD. The restoration techniques broadly describe ways to restore ecosystems of concern. Restoration techniques are important components of an overall ecosystem restoration approach, as they may serve to repair or re-introduce degraded or missing parts in a "broken" system. However, it is important to acknowledge that single stand alone techniques may not restore underlying ecosystem function, structure and processes. Simultaneous implementation of a mosaic of restoration techniques coupled with resumption of the underlying driving processes (e.g., fire in NDT4 ecosystems, seasonal flooding regimes in cottonwood bottomland forests) will be required to fully achieve restoration on an ecosystem scale.

An important component of restoration planning is incorporating the potential effects of climate change. Climate change is identified as a primary threat to all ecosystems, yet its potential effects are not well known or understood within the field of resource management or restoration (Utzig and Holt 2009). In this report a summary of climate change impacts by sub-basin and ecological unit is provided. The predicted climate change information can be applied and used to modify:

- Wetland systems – these will likely become increasingly stressed through SRD and highest emphasis for restoration should be placed on systems where long term maintenance is likely (e.g., wetlands with a relatively predicable water source);
- Streams / rivers – those already stressed by low flows either because they are already located in dry areas or experience high water demands should be prioritized;
- Riparian systems – especially in southern regions of the study area, these may become increasingly stressed due to moisture reduction, particularly during summer (restoration of vegetation that promotes maintenance of wetland processes should be a high priority where possible);
- Drier forested ecosystems – in southern zones and on dry sites in the mid and north of the region, consider potential future transition from forested to non-forested ecosystems (identify areas where the transition agent [e.g., fire] may cause significant resource losses [such as

important wildlife habitat]and look for opportunities to buffer or otherwise reduce fire probability in high priority areas);.

- All ecosystems – consider genetic diversity, and whether current provenance approaches are appropriate (also consider non-local species);
- Movement corridors – identify known potential movement corridors and manage to promote resilience;
- Identify crucial habitat for key species today – and assess whether appropriate for a 'resistance' strategy;
- Consider target sites where future species may move – restore or maintain habitat and habitat structures in target areas ;
- Build in resilience – consider a wider range of species than may have been applicable historically (e.g. consider promoting a move to more fire resistant tree species in areas where this has traditionally not been a goal).

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1. Introduction and Background

The recently formed Ecosystem Restoration Steering Committee for the Selkirk Resource District will be continuing the work of the previous Ministry of Forests Ecosystem Restoration (ER) Program by striving for an integrated and coordinated approach to reducing the risks associated with degraded or destroyed ecosystems. The Committee is interested in expanding the scope of the ER Program in order to support restoration of all degraded, damaged or destroyed terrestrial and aquatic ecosystems, regardless of land ownership or other rights and responsibilities. Furthermore, the Committee sees a need to support ER initiatives at multiple spatial scales using a full range of resource management tools which, taken together, will help to achieve integrated ER objectives over space and time.

Given this broad scope, the priorities of the ER Steering Committee will be defined through the development of a Five-Year Strategic Plan and subsequent Annual Work Plans. As the Selkirk Resource District is large and contains a diversity of ecosystem types and ER issues, it is necessary to define and spatially identify geographic sub-basins and ecological units for the purposes of (a) establishing objectives, strategies, priorities, targets and delivery mechanisms by ecosystem and for the program as a whole; and (b) annual reporting on strategic plan implementation, including ER efforts to reduce risks associated with each ecosystem of concern, as well as district wide.

2. Goals and Objectives

The goal of this project is to provide an ecologically-based framework for the Committee to pursue its long term ER goals within the Selkirk Resource District. This project has four main objectives:

1. To define ecosystems of concern based on a risk assessment of present and future threats;
2. To create baseline descriptions for ecosystems of concern;
3. To identify ecosystem restoration techniques that address impacts to ecosystems of concern; and
4. To identify key knowledge gaps with respect to ecosystems of concern.

3. Methodology

3.1. Defining Ecosystems of Concern

In order to identify ecosystem of concern in the Selkirk Resource District, a risk-based assessment of present and future threats and impacts was required. To undertake this assessment, an initial step involved stratifying ecosystems into units that could be defined and discussed in the context of restoration needs. To achieve this, we adapted a methodology developed by Holt et al. (2003) in a report focusing on provincial and regional threats to biodiversity in BC for local use. The latter methodology was modified to reflect the specific area of interest and particular needs of this project. The approach involved the following:

(e) Separating the Selkirk Resource District (SRD) into *terrestrial* and *aquatic* realms, and then dealing with both realms (wetlands and riparian areas clearly overlap with both realms, but were nested within the terrestrial realm for this exercise);

(f) Stratifying the terrestrial and aquatic realms by *geographic sub-basins* based on watershed boundaries within the Selkirk Resource District (Figure 1; Map 1-3;Table 1):

- Kettle/Granby Sub-Basin
- Lower Columbia/Kootenay Sub-Basin
- Upper Columbia Sub-Basin

The geographic sub-basins are based on BC Watershed Groups (1:50,000; BC Watershed Atlas 2012) which include a Hierarchy of Watersheds. The Watershed Atlas represents the boundaries of watersheds from third order up to the highest order watersheds that are nested within the geographic sub-basins. Although watershed boundaries generally correspond with the SRD sub-basins, the external boundary of the SRD does not follow all watershed boundaries. Of the 10 Watershed Groups, the following are dissected by the SRD boundary: Kettle River, Columbia Reach, Kicking Horse River, Kootenay River, and Kootenay Lake.

(g) Further stratifying the terrestrial and aquatic realms into ecological units based on the biogeoclimatic ecosystem classification (BEC) system. Three ecological groupings for the terrestrial realm and two ecological groupings for the aquatic realm (Table 1 and Figure 2) were identified based on elevation and moisture regime:

Terrestrial:

- Interior Dry: all IDF and PP zones/variants; ICHxw, ICHdw and ICHdm;
- Interior Moist/Wet: ICHmk, ICHmw, ICHwk, ICHvk,
- Montane, Subalpine and Alpine: AT, MSdm, MSdk, ESSFdk, ESSFdc; ESSF dm, ESSFmm, ESSFvc, ESSFvv, ESSFwc, ESSFwm.

Aquatic:

- Interior Dry/Moist/Wet: all IDF and PP zones/variants; ICHxw, ICHdw and ICHdm;

  ICHmk, ICHmw, ICHwk, ICHvk,
- Montane, Subalpine and Alpine: AT, MSdm, MSdk, ESSFdk, ESSFdc; ESSF dm, ESSFmm, ESSFvc, ESSFvv, ESSFwc, ESSFwm.

For the purposes of the threat analysis and discussing ecosystems of concern, these geographic sub-basins stratified by ecological groupings constituted the basic assessment unit for terrestrial and aquatic ecosystems. The aquatic realm combined Interior Dry/Moist/Wet to represent lower elevation aquatic ecosystems of concern and used Montane, Subalpine and Alpine to represent higher elevation ecosystems of concern.

(h) The aquatic realm was stratified into four ecological sub-units or potential "ecosystems of concern" (Table 1) based on Holt et al. (2003) as follows:

- *Streams*: Creeks and streams of 1st, 2nd and 3rd order (on 1:50,000 NTS mapping), including smaller ephemeral and discontinuous streams not generally shown on NTS maps.
- *Rivers:* These include 4th order streams and larger on 1:50,000 National Topographic System (NTS) mapping.
- *Lakes*: Naturally-occurring inland bodies of standing water.
- *Reservoirs*: Bodies of stored water created by the construction of dams or storage facilities generally for the purposes of generating hydroelectricity, water storage, diversion and/or flood control.

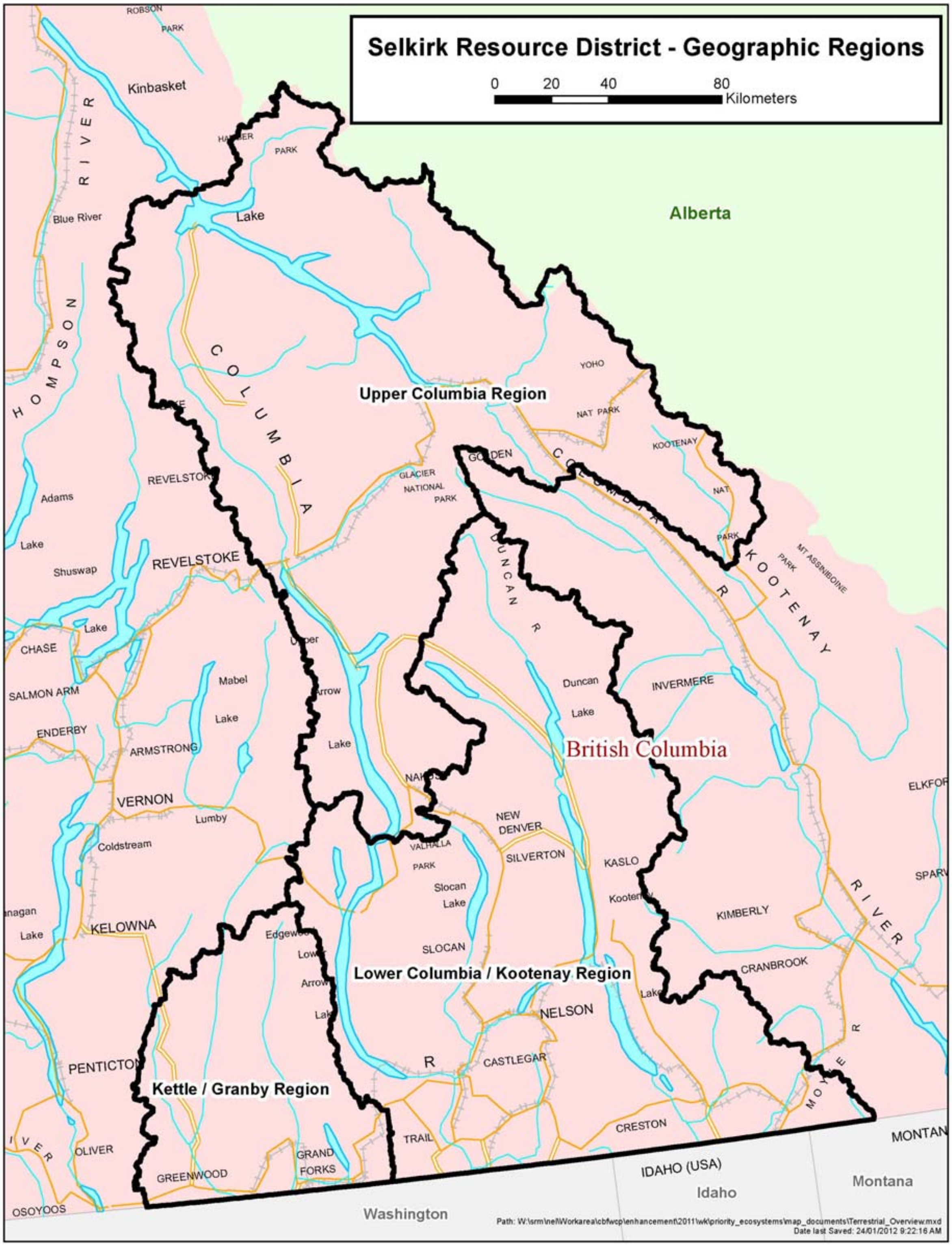

Figure 1. Selkirk Resource District Geographic Sub-Basins.

(i) The terrestrial realm was stratified into eleven ecological sub-units or potential “ecosystems of concern”, based on groupings previously identified in the Columbia Basin and described in detail by site series in MacKillop et al. (2008) (Table 1). Wetlands and riparian areas (as identified in MacKenzie and Moran 2004) are transitional to both aquatic and terrestrial realms, but were included here:

- Rock and Talus – rock outcrops, talus slopes, areas of exposed soils, and sparsely forested rocky site series
- Avalanche Features – chutes and run-out zones
- High Elevation Meadows - includes both subalpine and alpine meadows
- Grasslands – Shrub-Steppe
- Dry Forests – dry forest site series are broken down into dry, moist, and wet climatic region subgroups
- Intermediate Forests - intermediate forest site series are broken down into dry, moist, and wet climatic region subgroups
- Wet Forests – wet forest site series are broken down into dry, moist, and wet climatic region subgroups
- Cottonwood Forests – stands with ≥10% cover cottonwood
- Riparian Areas –The zone of interaction between aquatic and terrestrial ecosystems, readily distinguished by its distinctive plant communities and/or moisture regimes. Riparian areas border lakes, wetlands, streams and rivers.
- Forested Wetlands – forested wetland site series (e.g., Cedar–Spruce – Skunk cabbage swamps, Spruce – Horsetail swamps) are broken down into dry, moist and wet climatic region subgroups
- Non-Forested Wetlands – includes marshes, bogs, swamps, FENs, gravel bars, shallow open water and ponds

Table 1. Geographic Sub-Basins, Ecological Units and Ecological Subunits (Ecosystems of Concern) Delineated within Terrestrial and Aquatic Realms.

	Terrestrial Realm	Aquatic Realm
Geographic Sub-Basins	Three Sub-Basins (based on watershed boundaries): 1- Kettle/Granby 2-Lower Columbia/Kootenay 3-Upper Columbia	Three Sub-Basins (based on watershed boundaries): 1-Kettle/Granby 2-Lower Columbia/Kootenay 3-Upper Columbia
Ecological Units	Three Ecological Units (related to BEC zones): 1-Interior Dry 2- Interior Wet/Moist 3- Montane, Subalpine and Alpine	Two Ecological Units (related to BEC zones): 1-Interior Dry/Moist/Wet (lower elevation) 2-Montane, Subalpine and Alpine (higher elevation)
Ecological Subunits	Potential Ecosystems of Concern 1-Rock and Talus 2-Avalanche Features 3-High Elevation Meadows 4- Grasslands – Shrub-Steppe 5-Dry Forests 6-Intermediate Forests 7-Wet Forests 8-Cottonwood Forests 9-Riparian 10-Forested Wetlands 11-Non-Forested Wetlands	Potential Ecosystems of Concern 1-Streams 2-Rivers 3-Lakes 4-Reservoirs

3.2. Threats Assessment

To assess past impacts plus present and future threats to potential ecosystems of concern in the SRD, a list of Threat Categories and associated Threat Activities from Holt et al. (2003) was filtered and modified for local use. The complete list used for this project included 12 threat categories further divided into 42 threat activities (Table 2). In the threats assessment; activities were ranked in terms of their perceived impacts to each ecological/ geographic unit combination, both for the terrestrial and aquatic realms.

Background information used for ranking the type, significance and magnitude of threats were based on a combination of literature review, available data and expert opinion gathered from previous regional threat, impact and risk assessment reports, workshops and related initiatives (Abell et al. 2000; Holt et al. 2001, 2003, 2004; Utzig 2003; Utzig et al. 2003; Holt 2004; Nature Conservancy of Canada. 2004; Holt and Machmer 2005; Golder Associates Ltd. 2007, Machmer et al. 2007, Intrinsik Environmental Services Inc. et al. 2008; Utzig and Holt 2008, 2009; Kootenai Tribe of Idaho. 2009; Holt and Utzig 2010; BC Hydro 2011; CRIEMP 2011; Utzig et al. 2011).

Using the output derived from above sources, rankings for each ecological/ geographic unit combination were determined subjectively by our team and entered into a database. The output was a series of Assessment Tables (3-8) with rankings for the top ten or more threat activities in each ecological unit/geographic sub-basin combinations. Although the threat categories were

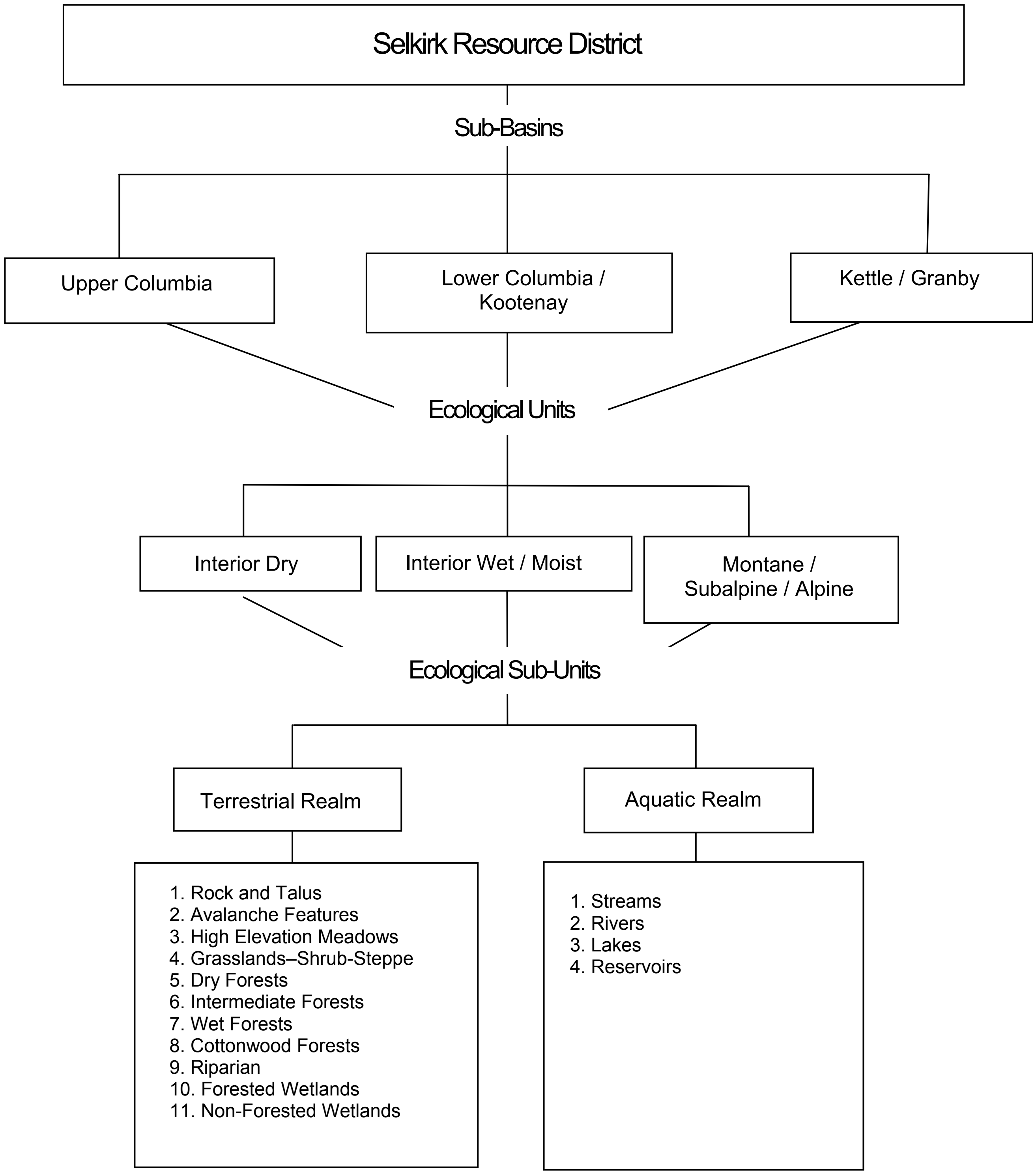

Figure 2. Framework for Sub-Basins, Ecological Units and Ecological Sub-Units within the Selkirk Resource District.

determined in a generalized hierarchy (largest threat first), we do not have sufficient confidence in the ranking of threats to specifically state a numbered ordered list of threats. Threat activities ranking higher than approximately 10, but nevertheless considered significant and worthy of mention were included where applicable. Ranking criteria used to determine the significance, extent and magnitude of threat activities relied on those developed by Holt et al. (2003). Ranking criteria (Appendix 1 and 2) provided the basis for ranking threats against one another. For additional information on the ranking criteria, indices and compilation of threat rankings, refer directly to Holt et al. (2003).

Table 2. Codes for Threat Categories and Threat Activities (adapted from Holt et. al 2003).

Agriculture	Climate change	Dams	Rural and Urban development	Forestry	Grazing	Harvest	Industry	Mining and exploration	Non-native species	Recreation	Transportation/ corridors
AG	CC	DA	DE	FO	GR	HA	IN	ME	NS	RE	TC

Code	Activity
AG	Cultivation
AG	Fertilisation
AG	Manure disposal
AG	Pesticide application
AG	Water demand
CC	Climate change
CC	Hydrograph changes
DA	Flow regulation
DA	Habitat conversion
DA	Physical obstructions
DE	Habitat conversion
DE	Sewage disposal
DE	Water demand
FO	Fire suppression
FO	Landscape level modification
FO	Riparian disturbance/modification
FO	Roads
FO	Silviculture
FO	Stand structure modification
GR	Riparian/wetland disturbance
GR	Soil modification
GR	Vegetation modification

Code	Activity
HA	Commercial harvest
HA	Recreational harvest
IN	Air emissions
IN	Water discharge
ME	Discharges
ME	Gravel extraction
ME	Mine site
ME	Roads/trails
ME	Water demand
NS	Non-native species
RE	Motorised terrestrial
RE	Motorised aquatic
RE	Non-motorised aquatic
RE	Non-motorised terrestrial
RE	Resort development
TC	Highways
TC	Pipelines
TC	Powerlines
TC	Railways
TC	Wind generators

4. Results I: Threats to Ecosystems of Concern in the Selkirk Resource District

4.1. Terrestrial Realm

Table 3. Key Threat Summaries for Terrestrial Ecological Units in the Kettle/Granby Sub-Basin

Dry

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
FO	Fire suppression
NS	Non-native species
GR	Riparian/wetland disturbance
FO	Landscape level modification
AG	Cultivation
FC	Stand structure modification
GR	Vegetation modification
FO	Roads
DE	Habitat conversion
Additional Significant Threats	
Threat Code	**Threat Activity**
FO	Riparian disturbance/modification
TC	Highways
FO	Silviculture
RE	Motorised terrestrial
TC	Powerlines
AG	Fertilization
TC	Pipelines

Moist/Wet

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
FO	Landscape level modification
FO	Stand structure modification
FO	Fire suppression
FO	Riparian disturbance/modification
FO	Roads
GR	Riparian/wetland disturbance
NS	Non-native species
FO	Silviculture
RE	Motorized terrestrial
GR	Vegetation modification

Montane/Subalpine/Alpine

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
FO	Landscape level modification
FO	Stand structure modification
FO	Roads
FO	Riparian disturbance/modification
FO	Silviculture
FO	Fire suppression
GR	Riparian/wetland disturbance
RE	Motorized terrestrial
NS	Non-native species

Table 4. Key Threat Activity Summaries for Terrestrial Ecological Units in Lower Columbia / Kootenay Sub-Basin

Dry

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
FO	Fire suppression
NS	Non-native species
FO	Landscape level modification
FO	Stand structure modification
DA	Flow regulation
DA	Habitat conversion
DA	Physical obstructions
DE	Habitat conversion
FO	Riparian disturbance/modification
Additional Significant Threats	
Threat Code	**Threat Activity**
FO	Roads
IN	Air emissions
FO	Silviculture
RE	Motorized terrestrial
TC	Powerlines
ME	Mine site

Moist/Wet

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
FO	Landscape level modification
FO	Stand structure modification
FO	Riparian disturbance/modification
DA	Flow regulation
DA	Habitat conversion
DA	Physical obstructions
FO	Silviculture
FO	Roads
RE	Motorized terrestrial
Additional Significant Threats	
Threat Code	**Threat Activity**
ME	Mine site
FO	Fire suppression
NS	Non-native species
DE	Habitat conversion

Montane/Subalpine/Alpine

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
FO	Landscape level modification
FO	Stand structure modification
FO	Roads
FO	Riparian disturbance/modification
FO	Silviculture
RE	Motorized terrestrial
ME	Mine site
FO	Fire suppression
RE	Non-motorized terrestrial

Table 5. Key Threat Summaries for Terrestrial Ecological Unit in the Upper Columbia Sub-Basin.

Dry

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
FO	Stand structure modification
FO	Fire suppression
NS	Non-native species
FO	Landscape level modification
FO	Riparian disturbance/modification
FO	Roads
DE	Habitat conversion
RE	Motorized terrestrial
FO	Silviculture
Additional Significant Threats	
Threat Code	**Threat Activity**
RE	Resort development
TC	Railways

Moist/Wet

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
FO	Landscape level modification
FO	Stand structure modification
DA	Habitat conversion
DA	Physical obstructions
DA	Flow regulation
RE	Motorized terrestrial
FO	Riparian disturbance/modification
FO	Roads
FO	Silviculture
Additional Significant Threats	
Threat Code	**Threat Activity**
RE	Resort development
ME	Mine site
TC	Highways
TC	Railways
NS	Non-native species

Montane/Subalpine/Alpine

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
FC	Landscape level modification
FC	Stand structure modification
RE	Motorized terrestrial
FC	Silviculture
FC	Roads
FC	Riparian disturbance/modification
ME	Mine site
RE	Resort development
RE	Non-motorized terrestrial

4.2. Aquatic Realm

Table 6. Key Threat Summaries for Aquatic Ecological Subunits in the Kettle/Granby Sub-Basin.

Interior Dry/ Moist /Wet

Streams

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
FO	Roads
CC	Hydrograph changes
AG	Water demand
GR	Riparian disturbance/modification
FO	Riparian disturbance/modification
FO	Landscape level modification
AG	Cultivation
TC	Highways
NS	Non-native species
Additional Significant Threats	
Threat Code	**Threat Activity**
DE	Habitat conversion
DE	Water demand
AG	Fertilization
ME	Discharges
RE	Motorized terrestrial
FO	Silviculture

Rivers

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
AG	Water Demand
GR	Riparian disturbance/modification
FO	Riparian disturbance/modification
AG	Cultivation
FO	Landscape level modification
CC	Hydrograph changes
DE	Habitat conversion
DE	Water demand
TC	Highways
Additional Significant Threats	
Threat Code	**Threat Activity**
HA	Recreational Harvest
NS	Non-native species
AG	Fertilization
DE	Sewage disposal
IN	Water discharge
FO	Roads

Rivers Con't

Additional Significant Threats	
Threat Code	**Threat Activity**
TC	Railways
FO	Silviculture

Lakes

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
CC	Hydrograph changes
AG	Water demand
RE	Motorized aquatic
DE	Water demand
DE	Habitat conversion
GR	Riparian disturbance/modification
AG	Cultivation/Fertilization
NS	Non-native species
HA	Recreational harvest
Additional Significant Threats	
Threat Code	**Threat Activity**
FO	Riparian disturbance/modification
FO	Landscape level modification
FO	Roads
AG	Fertilization
DE	Sewage disposal
RE	Resort development
FO	Silviculture

Montane/Subalpine/Alpine

Streams

Main Threats	
Threat Code	Threat Activity
CC	Climate change
CC	Hydrograph changes
FO	Roads
FO	Riparian disturbance/modification
FO	Landscape level modification
GR	Riparian disturbance/modification
NS	Non-native species
RE	Motorized terrestrial
DE	Water demand
FO	Silviculture

Lakes

Main Threats	
Threat Code	Threat Activity
CC	Climate change
CC	Hydrograph changes
FO	Riparian disturbance/modification
FO	Landscape level modification
FO	Roads
GR	Riparian disturbance/modification
NS	Non-native species

Rivers

Main Threats	
Threat Code	Threat Activity
CC	Climate change
CC	Hydrograph changes
FO	Riparian disturbance/modification
FO	Landscape level modification
FO	Roads
GR	Riparian disturbance/modification
NS	Non-native species
FO	Silviculture

Table 7. Key Threat Summaries for Aquatic Ecological Subunits in the Lower Columbia/Kootenay Sub-Basin.

Interior Dry/Moist/Wet

Streams

Threat Code	Threat Activity
Main Threats	
CC	Climate change
CC	Hydrograph changes
FO	Roads
FO	Riparian disturbance/modification
DA	Physical obstructions
FO	Landscape level modification
TC	Highways
DE	Habitat conversion
ME	Discharges
TC	Railways
RE	Motorized terrestrial
Additional Significant Threats	
DE	Water demand
AG/GR	Cultivation, Water Demand, Fertilization, etc.
NS	Non-native species
DA	Flow regulation
DA	Habitat conversion
FO	Silviculture

Rivers

Threat Code	Threat Activity
Main Threats	
CC	Climate change
DA	Flow regulation
DA	Habitat conversion
DA	Physical obstructions
CC	Hydrograph changes
NS	Non-native species
DE	Habitat conversion
AG/GR	Cultivation, Water Demand, Fertilization, etc.
TC	Highways
FO	Riparian disturbance/modification
HA	Recreational harvest
FO	Roads

Rivers Con't

Threat Code	Threat Activity
Additional Significant Threats	
FO	Landscape level modification
ME	Discharges
TC	Railways
DE	Sewage disposal
IN	Water discharge
RE	Motorized aquatic
TC	Pipelines
FO	Silviculture
DE	Water Demand

Lakes

Threat Code	Threat Activity
Main Threats	
CC	Climate change
NS	Non-native species
CC	Hydrograph changes
HA	Recreational harvest
DE	Habitat conversion
DA	Flow regulation
DA	Physical obstructions
FO	Riparian disturbance/modification
DE	Sewage disposal
RE	Motorized aquatic
DA	Habitat conversion
Additional Significant Threats	
FO	Roads
RE	Resort development
ME	Discharges
IN	Water discharge
FO	Landscape level modification
AG	Fertilization
FO	Silviculture

Reservoirs

Main Threats	
Threat Code	**Threat Activity**
DA	Flow regulation
DA	Physical obstructions
DA	Habitat conversion
CC	Climate change
NS	Non-native species
HA	Recreational harvest
CC	Hydrograph changes
RE	Motorized aquatic
DE	Habitat conversion

Additional Significant Threats	
Threat Code	**Threat Activity**
DE	Sewage disposal
IN	Water discharge
FO	Riparian disturbance/modification
FO	Landscape level modification

Montane/Subalpine/Alpine

Streams

Main Threats	
Threat Code	Threat Activity
CC	Climate change
CC	Hydrograph changes
FO	Roads
FO	Riparian disturbance/modification
FO	Landscape level modification
RE	Motorized terrestrial
NS	Non-native species
TC	Highways
FO	Silviculture

Rivers

Main Threats	
Threat Code	Threat Activity
CC	Climate change
CC	Hydrograph changes
NS	Non-native species
FO	Riparian disturbance/modification
FO	Roads
FO	Landscape level modification
RE	Motorized terrestrial
FO	Silviculture

Lakes

Main Threats	
Threat Code	Threat Activity
CC	Climate change
CC	Hydrograph changes
NS	Non-native species
CC	Hydrograph changes
FO	Riparian disturbance/modification
FO	Roads
FO	Silviculture

Table 8. Key Threat Summaries for Aquatic Ecological Subunits in the Upper Columbia Sub-Basin.

Interior Dry/Moist/Wet

Streams

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
FO	Roads
CC	Hydrograph changes
DA	Habitat conversion
DA	Flow regulation
FO	Riparian disturbance/modification
DA	Physical obstructions
FO	Landscape level modification
TC	Highways
TC	Railways
NS	Non-native species
Additional Significant Threats	
Threat Code	**Threat Activity**
DE	Habitat conversion
RE	Motorized terrestrial
RE	Non-motorized terrestrial
FO	Silviculture

Rivers

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
DA	Physical obstructions
TC	Highways
TC	Railways
CC	Hydrograph changes
FO	Roads
FO	Riparian disturbance/modification
FO	Landscape level modification
DE	Habitat conversion
NS	Non-native species
Additional Significant Threats	
Threat Code	**Threat Activity**
FO	Silviculture
DE	Sewage disposal

Lakes

Main Threats	
Threat Code	**Threat Activity**
CC	Climate change
CC	Hydrograph changes
FO	Riparian disturbance/modification
FO	Landscape level modification
FO	Roads
NS	Non-native species
RE	Resort development

Reservoirs

Main Threats	
Threat Code	**Threat Activity**
DA	Flow regulation
DA	Physical obstructions
DA	Habitat conversion
CC	Climate change
CC	Hydrograph changes
FO	Roads
FO	Riparian disturbance/modification
FO	Landscape level modification
NS	Non-native species
DE	Sewage disposal
RE	Motorized aquatic

Montane/Subalpine/Alpine

Streams

Main Threats	
Threat Code	Threat Activity
CC	Climate change
CC	Hydrograph changes
FO	Roads
FO	Riparian disturbance/modification
FO	Landscape level modification
TC	Highways
TC	Railways
DE	Habitat conversion
NS	Non-native species
RE	Non-motorized terrestrial
FO	Silviculture

Rivers

Main Threats	
Threat Code	Threat Activity
CC	Climate change
CC	Hydrograph changes
TC	Highways
TC	Railways
FO	Roads
FO	Riparian disturbance/modification
FO	Landscape level modification
DE	Habitat conversion
NS	Non-native species
FO	Silviculture

Lakes

Main Threats	
Threat Code	Threat Activity
CC	Climate change
CC	Hydrograph changes
FO	Riparian disturbance/modification
FO	Landscape level modification
FO	Roads
NS	Non-native species

5. Results II: Considering Climate Change in Restoration

Section 4 summarizes key threats for the terrestrial (Tables 3-5) and aquatic realms (Tables 6-8) of the Selkirk Resource District. Many of the threats are relatively well known and understood (e.g., the historic effects of fire suppression activities in NDT4 forest types). However, climate change is identified as a primary threat to all ecosystems, yet its potential effects are not well known or understood within the field of resource management or restoration (see Utzig and Holt 2009 for a preliminary analysis of potential effects at multiple scales in British Columbia). Climate change therefore adds a novel layer of information to be considered, which may have very large consequences. Globally and locally, climate change is expected to significantly alter existing ecosystems distribution and function, therefore climate change must be considered when planning restoration activities. Rather than attempt to deal with climate change in detail in the Results tables below, we provide an overview of how climate change may affect restoration priorities, and summarise some current information on climate change for local ecosystems that may be relevant into the coming years and decades. Since there are many uncertainties and no single implication of climate change, a list of potential implications for restoration is provided.

5.1. Climate Change and Restoration Goals

Restoration practitioners have been discussing how to engage in setting restoration targets and thresholds for many years. A consensus emerged over the last few decades that, in general, using historic information on ecosystem structure and processes to guide restoration targets had utility, and this concept has lead to much discussion about the specifics of applying concepts such as ‘historic range of variation’ (HRV) or ‘range of natural variability’ (RONV). The concept has never been to ‘restore back’ to a specific state of an ecosystem, but to recognize natural variability and to use this information as a guide to recognize potential future states of a system. Although concepts of RONV / HRV explicitly recognize a natural range, they do so in the context of a basically stable climate. Under climate change, this assumption no longer holds, and so a new approach to setting broad ecosystem goals much be considered (Harris et al. 2006).

Novel factors to consider should include:

- consideration of the future climate and potential future ecosystem relevant to a site, which may be well outside the typical historic ‘range of natural variation’ for that location;
- consideration of what factors are the focus of the restoration activities (historically restoration has focused on the ‘structure’ of ecosystems, but it may become more relevant to attempt to restore or maintain appropriate ‘processes’ such as natural disturbance regimes, hydrologic cycles etc. into the future);
- consideration of a projects contribution towards global atmospheric carbon mitigation as part of any land management decisions(i.e., assessing the potential carbon benefits of any particular project).

The literature on potential adaptation options to climate change is huge and growing rapidly. This is not a summary of that literature but it does identify some useful approaches that have been proposed for setting restoration targets (e.g., Millar 2007; Halofsky et al. 2011; Holt and Utzig 2012 In prep.) In Table 9, we highlight how different circumstances may influence how to approach setting restoration targets.

Table 9. Climate change responses and restoration implications.

Type of activity	Potential management in climate change context	Restoration implications
Resistance: slow the impacts of climate change	Manage for maintenance of current condition in areas of historic refugia, or where current values are very high (e.g. caribou habitat), and where rate of change can be slowed by resisting change (e.g., wet old growth forests) that may be maintained for long periods if not disturbed.	Identify areas where restoration activities can maintain or restore elements that resist change, that are critical habitat elements, or that may be historic refugia. Reduce effects of fires, insects, diseases, buffer key areas against disturbances, remove invasives, prevent spread of undesired species. These activities may be most likely to be effective in ecosystems least sensitive to climate change. The restoration goal is to maintain RONV, or current condition as traditionally employed in restoration activities.
Resilience: improve probability / capacity to maintain or return to functioning condition after disturbance	Manage for resilience – maintenance of stand and landscape level diversity – in areas where resistance is likely to be futile against predicted changes. Maintain habitat elements (e.g., stand structure, landscape connectivity) to highest degree possible to maintain species and allow species to move.	Similar to resistance, except to ensure key elements that promote resilience are identified and restored. This may differ for different ecosystems, populations and contexts. For example, it may include explicitly identifying key invasive species that may reduce natural functioning (and that may be promoted in a climate change context). Most rapid rate of change associated with new climate change is likely in recently disturbed areas, so use of aggressive techniques to maintain values may be most effective at this point (e.g., restocking with species important for functioning, e.g. genotypes resistant to an increasing disease threat). Restoration goal is to maintain high end of RONV for key attributes that promote resilience.
Transition: manage to promote shift to most likely future state	Actively manage for transition in areas where probability of regime shift is high, and where implications of the shift are large (e.g., large catastrophic fires in areas with high values).	Restoration goal is not based on RONV, but on transitioning to future likely state with least loss of values. May include intentional species shifts, removal of structure to avoid catastrophic fire, explicit 'resetting' of ecosystem trajectory post disturbance, actively manage to promote connectivity (at multiple scales) to promote natural transitions and reduce loss of species across broad landscapes.
Mitigation	All management decisions should consider implications to mitigation of climate change.	Rehabilitation / reforestation of degraded forest ecosystems to promote carbon sequestration rates and maintenance of carbon in biomass. Consider potential conflicting trajectories between this goal and restoring to some relatively 'stable' ecosystem.

* RONV = (historic) range of natural variability

One of the most difficult elements of decision-making within a climate change context is in responding appropriately to the variety of uncertainties that are embodied in the various predictions of future conditions (climate) and their implications for ecosystems. These 'uncertain times' mean that all decisions should be considered within a management structure that promotes diversity, does not have a 'one size fits all' approach, and considers the risks associated with different options. The use of a 'no regrets' framework for management decisions has been widely promoted and applies to restoration decision-making as well as to general land management. A 'no regrets' approach promotes making of decisions that 'even if the worst case change scenario does not happen, the decision will not have been a poor one'.

Finally, the current trajectories for climate change are heading the globe into the realm of 'dangerous' climate change (IPCC 2005), hence an integration of climate mitigation opportunities into all decision-making should become standard practice. Mitigation opportunities in the context of restoration decisions can include:

- maintaining stand conditions in order to reduce losses of carbon to the atmosphere (this could include reducing stand densities to reduce long-term fire threat under either a transition strategy or a resilience strategy, or maintaining original stand conditions under a resistance strategy); and/or
- restoration / (re) afforestration of degraded or non-forested areas (this could include reforesting degraded or unused agricultural land, degraded forest land (e.g., areas of fumekill, riparian restoration, etc).

5.2. Predicted Climate Change for the Selkirk Resource District

Work is currently underway to look at some of the potential implications of climate change for the West Kootenays (Utzig and Holt 2011, In prep. and www.kootenayresilience.org), and for the province as a whole (Holt and Kehm in preparation). There is a high, but not complete overlap of study areas between these two Kootenay projects. The climate resilience project was funded by the province (FFESC[1]) to investigate climate change predictions for this region, and to assess how it may alter forest management decision-making processes. As one part of that work, David Roberts (University of Alberta; Roberts and Hamann 2012) has provided climate envelope modeling results for the province, which have then been fine-tuned for the Kootenay study area (Utzig and Holt 2011). This work takes predicted future climate envelopes, and attempts to 'match them' to the closest climate envelope currently existing anywhere in Western North America. The model then attaches the vegetation associated to that current climate envelope to the future location. Associating a particular climate combination with its currently associated vegetation provides a good way of projecting the type of ecosystem that is currently known to be associated with a particular type of climate. However, it does not suggest that that particular vegetation combination will in fact exist in a certain place in future. The difference between fundamental and realized niches, plus many other limiting factors (appropriate soils, migration potential and rate for different species, intra-and inter specific competition) will all affect how particular vegetation will develop in the future. Additional details (e.g., climate change scenario modeled, and other limitations and implications of this work) can be found at www.kootenayresilience.org.

In addition, an analysis has been taken to look at how future climates may influence fire regimes in the West Kootenays for the same study area (Utzig, Boulanger and Holt 2011).

Given the limitations, the following general predictions are made for the West Kootenay region.

Kettle / Granby Dry – Interior Dry[2]

In most low elevation areas in this sub-basin, climate envelopes are projected to shift from the typical open forested ecosystems of today to those more typical of grassland / steppe ecosystems. Increasing average temperatures and reduced moisture (particularly in summer months), create less suitable conditions for tree cover. In addition, predictions of significantly increased fire frequency are likely (the Kootenay fire analysis work did not cover this sub-basin but the results are likely to apply). Fire regime is likely to be the dominant factor creating a shift from forested to non-forested ecosystems, with the potential for large-scale regime shift post-fire events. The current pattern of increased fire risk in ingrown stands (due to fire suppression

[1] Future Forest Ecosystems Science Council

[2] Note that the more detailed information from the Kootenay region does not extend into the Kettle / Granby and results for this area are taken from the broader provincial scale information.

activities) will be exacerbated under the projected future climate. There may be a shift towards more drought tolerant species, and those more suited to resist fire. Cedar and other fire intolerant species may be lost from localized sites where they currently exist.

On wet sites within this zone, forested ecosystems may remain for a longer period, depending on the source of moisture. Riparian or wetland systems will likely become more limited than currently, as water tables drop.

Invasive species may become more prevalent as fires cause regime shift, depending on the ability of native species to colonize rapidly altered areas.

Kettle / Granby – Interior Moist/Wet and Montane/Subalpine/Alpine
In the more moist areas found at middle and higher elevations in this sub-basin, a shift to warmer conditions is expected. Moisture predictions are more uncertain, with potentially wetter conditions in winter (less snow and warmer temperatures) and drier in summer. It is difficult to predict outcomes for forest type since we don't know whether moisture tolerance thresholds will be crossed for these forest types. The area is likely to incur higher fire frequencies due to warmer and drier summer conditions, particularly in areas of higher fuel loads with drying ecosystems at lower elevations, from which fire can spread. An increase in invasive species is likely, especially if regeneration by native species after disturbance events is moisture limited.

Lower Columbia / Kootenay – Interior Dry
In the driest portion of this zone, climate envelopes are projected to shift from those typical of drier cedar / hemlock / fir forests to those more typical of grassland / shrub steppe. On current moister and cooler site series within this sub-basin, there is a projected shift from cedar-hemlock forests to those dominated by Douglas fir and grand fir. Increasing temperatures overall, and decreasing moisture in summer are projected to increase fire risk which, in combination with currently high fuel densities in many areas (e.g. West Arm of Kootenay Lake), may result in a rapid and catastrophic transition from current to future ecosystems. Invasive plant species may be a significant threat if the drying is sufficient to surpass moisture tolerance for native species. Habitats typical of wetter, older stands will become at significant risk under the future climate scenarios (e.g., caribou habitat).

Lower Columbia / Kootenay – Interior Moist/Wet
Warming temperatures, combined with variable snowpack and decreasing moisture in summer months are predicted to shift zonal sites from cedar - hemlock dominated forests towards Douglas fir and subalpine fir. Warming and drying predictions are sufficient that localized grassland climates / ecosystems are predicted for valley bottoms around Trout Lake. Wettest sites within this zone may have sufficient moisture to retain the dominant cedar / hemlock tree species, but at the landscape level, are still likely to be affected by increased fire regime. Much of the zone may undergo significant shift in natural disturbance regime from typical gap dynamics in cedar / hemlock forests to a significant increase in fire frequency. Loss of old growth conditions (already pushed outside of the historic natural range by harvesting) is likely to increase with increasing fire regime.

Lower Columbia / Kootenay – Montane/Subalpine/Alpine
Predictions suggest upper elevations may shift initially towards drier ESSF ecosystems, but over time (by the 2080s) a shift to conditions more typical of coastal systems is expected. This would be attributed to potentially higher snowpack (at least initially as winter precipitation increases and before temperatures have increased) and overall warmer temperatures in winter. Predictions about suitability for individual tree species is uncertain in future. Warmer conditions

may potentially increase stand-level mortality due to hemlock looper and spruce bark beetle (transition from two to one year life cycle). Landscape level increases in fire risk may affect all areas, but particularly those in drier valley bottoms below.

Upper Columbia[3] – Interior Dry
From the more general predictions, the dry areas at the north end of the Rocky Mountain Trench shift to warmer drier climate envelopes with likely increases in fire frequency (though the Kootenay Resilience fire analysis did not include this area). Moisture stress may limit tree growth on driest sites with a shift to grassland / steppe climate envelopes. Wet sites, where moisture remains, may retain existing tree species.

Upper Columbia – Interior Moist/Wet
General predictions for this zone suggest a shift towards a warmer and possibly wetter system that resembles coastal systems. For mesic and wet sites, moisture remains sufficient to maintain current tree species, though there may be a shift away from cedar-hemlock on drier sites. There is potential for an increase in fire regime in these zones (though analysis did not include this part of the study area).

Upper Columbia – Montane/Subalpine/Alpine
There is potential for a reduction in the extent of subalpine / alpine areas as warmer temperatures promote growth of trees at higher elevations. Predictions are significantly influenced by the interplay between precipitation and temperature, changing timing and depth of snowpack, and soil conditions affecting colonization by vegetation in areas currently unvegetated.

6. Results III: Identification of Key Ecosystems of Concern, Key Attributes Affected and Potential Restoration Activities

In the Results I Section above, the key ‘threats’ or ‘stressors’ to ecosystems in the SRD are identified. The ecological impacts associated with different stressors vary widely, depending on their geographic and temporal extent, the severity of the activity, and the particular ecosystem being impacted. In this study area, there is a high correlation between different activities occurring in different parts of the land base. For example, the valley bottoms in the southern portion of the area have the most consistent history of human development, the densest human population, and the broadest range of stressors affecting them. They also tend to be ecologically most diverse, so potential impacts tend to be both cumulative effects of multiple activities, and of ecological significance because of the diverse values present.

This section summarizes impact information (1) by type of threat activity, and (2) by sub-basin and ecological unit.

Threat Activity Summary :
Table 10 lists threat activities and identifies for each type of ‘threat’:

- the general types of impacts caused (descriptions of general impacts are adapted from Holt et al. 2003);
- the specific sub-basins and ecological units that are primarily affected by this threat activity (descriptions of the key ecosystems and habitat types generally relate to groups

[3] Detailed projections are not available for the Upper Columbia zone from the Kootenay Resilience project, but more general predictions available from a provincial level project, using the same dataset and approach (Holt unpublished).

of site series, and particular descriptions will differ in each sub-basin; i.e. a dry forest type in the Lower Kettle sub-basin is different from one in the Upper Columbia sub-basin);

- the key ecosystem attributes affected;
- the key restoration techniques that may be applicable.

Sub-Basin Summary:

- o The cumulative effects of each threat activity from Section 1 are summarized, combined with results from the threat activity roll-up (Table 10), and used to identify the top threats and impacts for each sub-basin (Section 7).

Table 10. Key Ecosystems of Concern, their Attributes affected by Threat Impacts and applicable Restoration Techniques (* adapted from Holt et al. 2003).

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
AG -Cultivation	Cultivation is associated with: • Land clearing and land surface draining; Conversion to non-native habitat; • Site degradation; • Loss of unique habitat types; (wetland/ riparian etc); extent of loss varies by type of agriculture.	Kettle/ Granby – Interior Dry; Lower Columbia/ Kootenay – Interior Dry • Grasslands and Shrub-steppe • Dry forests [intermediate/ wet] • Non-forested wetlands • Cottonwood forests • Riparian • Stream • Rivers	• Near complete loss of functioning ecosystems and isolation of remaining habitat features (e.g., riparian systems isolated from upland habitats). • Loss/displacement of many species and reduced habitat suitability for others through simplification, edge effects with impacts on parasitism/predation. • Surface erosion and stream sedimentation in some locations due to reduced water holding capacity and irrigation. • Varying magnitude of effects across ecosystems but universal impacts in bottomland systems within ALR. • Removal of riparian vegetation, loss of large woody debris recruitment, shading, nutrient input. • Loss of side channels and channel complexity due to infilling, channelization and diking • Loss of natural floodplain processes	• Revegetation (especially riparian/wetland) • Flow naturalization • Channel morphology reconstruction (excavation, dredging, substrate addition) • Construction of aquatic structures • Fish passage/Barrier removal • Off channel habitat creation/enhancement • Floodplain reconnection • Soil bioengineering • Slope/Bank stabilization • Reconnection of isolated habitats • Nest structures • Invasive plant control • Wildlife tree creation/retention • Timing windows
AG – Fertilization	Crop fertilization potentially leading to: • run-off of chemicals into other receiving habitats and potential impacts to community composition.	Kettle/ Granby – Interior Dry Lower Columbia / Kootenay – Interior Dry • Non-forested Wetlands • Stream • Rivers	• Changes in aquatic community structure, species composition, abundance and diversity. • Use of fertilizers most common in open habitats, but run-off into streams, wetlands, lakes, rivers and can lead to lake eutrophication	• Revegetation (riparian buffers help reduce water contamination) • Fertilizer/pesticide alternatives (manual removal, planting more complex vegetation

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
AG – Fertilization Con'		• Lakes	where agriculture is intensive.	communities, use of cover crops, seasonal rotation) • Timing windows (for application) • Invasive plant control • Water conservation and control (to prevent nutrient losses and control run-off).
AG – Water Demand	Removal of extensive or minor amounts of water from aquatic systems results in: • Loss or modification of riparian/ wetland area • Causes changes in habitat distribution and associated species when severe.	Kettle / Granby – Interior Dry; Lower Columbia / Kootenay – Interior Dry • Riparian • Wetlands • Stream • Rivers • Lakes •	• Affects riparian areas and various aquatic ecosystems through modified flow regimes. • Lower low flows and reduced water yield. • Can be severe in drier areas or on smaller systems leading to complete dewatering and removal of habitat. • Habitat isolation/ reduced habitat connectivity. • Lethal to fish and detrimental to water quality (e.g. temperature, oxygen). • Cascading impacts on biodiversity downstream.	• Water conservation and control (to prevent nutrient losses, control usage and run-off). • Irrigation management • Timing windows (for water usage)
CC- Climate Change (see more detailed descriptions of potential changes in Results Section II).	Predicted to result in following changes: • Hotter and drier conditions in summer; • Warmer and wetter in winter • Greater uncertainty around precipitation, with possible increased severity of events • Longer fire season;	Kettle / Granby – All zones Lower Columbia / Kootenay – All zones Upper Columbia – All zones • Grasslands and Shrub-steppe • Dry forests • Intermediate forests • Wet forests • Forested wetlands	• For all forested zones - increased disturbance from wildfire and loss or change in the current dominant tree species, except for wettest biogeoclimatic zones, and local sites maintained by groundwater source (i.e., a subset of wet forests). • In driest / southern systems – at low elevation - habitat conversion with	• Consideration of local climate futures may alter traditional 'goals' for restoration activities. See Discussion in Section II above. • In addition, climate change will exacerbate some of the impacts associated

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
CC- Climate Change Con't	• Changes to natural disturbance regimes – increase in fire frequency / severity; increase in insect / disease agents due to increased moisture stress and suitable conditions shifting • Increased lightning probability; • Longer ice-free period and modified snowpack melt. • Increase in number of frost-free days; also less predictable frost regimes	• Non-forested wetlands • Cottonwood forests • Avalanche features • High elevation meadows • Riparian • Streams • Rivers • Lakes • Reservoirs	extensive increase in grassland climate zone area (by 2080). Unknown impacts on individual plant and animal species but changes in species composition predicted; likely increase in generalists and invasive species and a loss or displacement of species for which drought/temperature thresholds are exceeded. • In more northerly, wetter, lower elevations sections of the sub-basins, a shift from Cw-Hw forests to those dominated more by Fd-Bg. • Climate change can interact with many other factors: e.g. climate-change induced loss of suitable habitat (73% for whitebark pine by 2070) coupled with blister rust and mountain pine beetle infestation pose a triple threat for this species. Similarly, paper birch has significant risk of mortality as a result of a combination of climate, bronze birch borer and birch leaf miner. • Loss or reduced size of wetland and riparian habitats, especially ephemeral/vernal pools due to drying. • Variable impact on cottonwood systems depending on their water source, but likely a reduced extent due to lower water tables and moisture stress. • Higher stream temperatures leading	with traditional threats and will help to prioritize certain systems (see summary section below).

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
CC- Climate Change Con't			to loss of cold water-dependent species (e.g., tailed frog, salmonids). • Disturbed life-history timing and dynamics for many aquatic and terrestrial species. • Longer ice-free period and modified snowpack melt may affect the availability and distribution of avalanche features (chutes and run-out zones).	
CC – Hydrograph Changes	• Changes to stream hydrographs are the result of changes snowmelt and precipitation patterns attributed to warmer temperatures.	Kettle/ Granby – All zones Lower Columbia / Kootenay – All zones Upper Columbia – All zones • Streams • Rivers • Lakes • Reservoirs	• Aquatic impacts expected include lower lake levels, earlier and higher peak flows, and lower low flows which may be inadequate for sustaining aquatic habitat requirements. • Lower water flows may affect the ability to fill reservoirs and maintain water levels that were designed to mitigate operation of the dams. • Impacts on fish populations and other aquatic species expected (due to habitat loss, reduced habitat suitability, possible increases in stream temperature, etc.); • Cascading effects on other species (shifts in life history timing and dynamics).	• See discussion in Results II.
DA – Flow Regulation	Flow regulation results in: • Seasonally modified hydrograph with a general dampening of natural seasonal flooding cycles; • Low flows, lower peak flows, and non-natural flow dynamics,	Lower Columbia / Kootenay – Interior Dry/Moist/Wet Upper Columbia – Interior Moist Wet • Forested wetlands • Non-forested wetlands • Cottonwood forests	• Flow regulation reduces downstream habitat availability and suitability, particularly of cottonwood forests and wetlands (which require seasonal flooding cycles and groundwater recharge). • These habitat types show shifts in	• Modified flow regulation • Floodplain reconnection • Revegetation • Slope/bank stabilization • Wetland creation/enhancement • Nest structures

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
DA – Flow Regulation Con't	which affects community structure and function; • Rapid changes to downstream water levels leads to fish stranding and macro-invertebrate die-offs.	• Riparian • Streams • Rivers • Lakes (Lower Columbia/Kootenay) • Reservoirs	vegetation community structure and function and ingress of other woody perennials, with impacts to dependent species (including many listed species). • Flow regulation leads to changes in aquatic community structure (e.g. from loss of sturgeon), changes in stream temperature regimes, modified sediment regimes, associated changes in channel bed structures, as well as modified nutrient dynamics. • Altered hydrology influencing river hydraulics including hydraulic depth and water velocity, which influence fish movement and spawning migration timing. • In situations with off-site power generation, water loss and changes to downstream aquatic habitat availability and suitability impacts macro-invertebrates and fish populations, with cascading effects on other dependent species. • Reduced primary and secondary productivity at the edges of the reservoir due to fluctuations in water levels. • Access and use of tributary streams can be affected by flooding and dewatering causing stranding, blockages from stranded debris, and loss of habitat. • Floodplain disconnection.	• Species relocations • Recontouring (to prevent fish stranding)

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
DA – Habitat Conversion	• Impacts of permanent inundation include loss or degradation of floodplain, wetland, littoral, riparian, riverine habitats and lakes. • Flooding associated with dam construction has varying impacts on rivers and lakes converted into reservoirs depending on location and uniqueness of the previous habitat.	Lower Columbia / Kootenay – Interior Dry; Interior Moist Wet Upper Columbia – Interior Moist Wet • Forested wetlands • Non-forested wetlands • Cottonwood forests • Gravel bar • Intermediate / wet forests (depending on location) • Riparian • Streams • Rivers • Lakes • Reservoirs Note – specific impacts on ecosystems by individuals dams has been analyzed, and varies significantly– see unpublished report by MacKillop et al. (2008).	• Loss and degradation of native shoreline vegetation and habitats. • Species with highest habitat impacts were wetlands and riparian specialists.(amphibians, birds, bats, aerial insectivores). • Reduced suitability of shoreline habitat for feeding and breeding amphibians, reptiles, birds and mammals. • Reservoirs act as barriers to movement for terrestrial species limiting seasonal migration, genetic exchange, prey-predator relationship, dispersal and population recovery. • Decline in productivity due to daily and seasonal water fluctuations, persistent shoreline erosion and sedimentation. • Loss of riverine, small-medium sized lake habitat affecting hydrological regimes, geomorphic processes, floodplain processes, natural disturbance regimes, trophic dynamics, nutrient cycling. • Loss of riverine habitat affecting life history stages of fish species. • Loss of side channel complexes. • Dams act as barriers causing habitat/population fragmentation (e.g. white sturgeon, rainbow trout) • Loss of low gradient habitat tributary stream habitat within the reservoir footprint.	• Revegetation (Riparian including drawdown zones) • Flow naturalization • Nutrient addition • Spawning channels • Hatchery program • Construction of aquatic structures • Reconnection of isolated habitats • Slope/Bank stabilization • Soil bioengineering • Nest structures • Off channel habitat creation/enhancement • Floodplain reconnection

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
DA- Physical Obstruction	Physical barrier for water storage, flood control and power generation obstructs upstream and downstream movements causing: • changes to nutrient regime upstream and downstream of the dam; • Cessation of fish biomass movement upstream, and cascading impacts on wildlife populations and habitat use throughout entire terrestrial habitat upstream.	Lower Columbia / Kootenay – Interior Dry; Interior Moist Wet Upper Columbia – Interior Moist Wet • Riparian (loss of upstream salmon runs and nutrient input) • Streams • Rivers • Lakes • Reservoirs	• Entrainment and reduced passage of organisms through the dam and lost access to key habitats for various species, particularly for anadromous fish. • Reduced nutrient passage through the dam and impaired nutrient cycling in local area. • Dissolved gas super-saturation leading to potential mortality and health impacts for fish. • Changes to temperature regimes, turbidity, loss of sediment flushing flows will impact fish and other biota by affecting habitat suitability and processes such as predation, competition, etc.	• Fish passage/barrier removal • Reconnection of isolated habitats (fish ladders) • Spillway modification (reduction in TGP) • Exclusions (netting to reduce entrainment) • Flow naturalization • Nutrient addition • Spawning channels • Hatchery program • Construction of aquatic structures • Channel morphology reconstruction (excavation, dredging, gravel addition)
DE Habitat Conversion	The conversion of native habitats to developed or built states (e.g., residential, cottage, dock development, etc,) results in: • habitat loss, degradation, and reduced function, especially within riparian and littoral zones; • wildlife disturbance, displacement and loss of connectivity.	Kettle/ Granby – Interior Dry Lower Columbia / Kootenay – Interior Dry (Interior Moist Wet) Upper Columbia – Interior Moist Wet (localized) • All forests (relatively localized) • Non-forested wetlands • Cottonwood forests • Riparian • Streams • Rivers • Lakes	• Impacts of converting lakeshore, riverine, wetland, and riparian habitats to "developed" or built environments include significant and permanent habitat loss, impairment of function, and degradation through. • Loss of riparian vegetation and disruption of riparian habitat. • Removal and disturbance of native vegetation; and introduction of non-native species. • Disruption of migration and movement corridors, particularly in winter range habitat. • Loss of shoreline and littoral	• Revegetation • Flow naturalization • Spawning channels • Hatchery program • Construction of aquatic structures • Reconnection of isolated habitats • Slope/Bank stabilization • Soil bioengineering • Nest structures • Invasive plant control • Channel morphology reconstruction (excavation, dredging, substrate addition)

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
DE Habitat Conversion Con't			breeding and feeding habitat or reduced suitability for dependent fish and wildlife populations, with cascading effects. • Wildlife disturbance and displacement from people, dogs, cats. • Disruption of fish habitat, movement, predator/prey relationships with construction of structures along the shoreline such as docks, retaining walls, jetties, armouring of banks. • Loss of nutrient input, LWD input and allochthonous material. • Habitat modification, by removing rocks from beach that are required for rearing. • material) • Introduction of deleterious substances through surface runoff and storm drains.	• Off channel habitat creation/enhancement • Floodplain reconnection • Wildlife tree creation/retention • Fish passage/Barrier removal • Native seed collection and dispersal
DE- Sewage Disposal	Potential for impact on sensitive aquatic/ terrestrial species in areas of high density rural development, and in areas with a high density of rare species.	Lower Columbia/Kootenay Sub-Basin Interior Dry Moist Wet Upper Columbia – Interior Moist Wet (localized); Montane/Subalpine/Alpine (localized) • Lakes • Rivers (localized) • Reservoirs (localized)	• Sewage disposal (including waste water treatment facilities) causes water contamination and creates nutrient issues as a result of eutrophication. This can lead to changes in species composition and abundance, especially for benthic invertebrate and periphyton communities. • Can impact sensitive ecosystems or areas with a density of listed species.	• Water treatment
DE-Water Demand	Removal of extensive or minor amounts of water from aquatic systems results in:	Kettle / Granby – Interior Dry Moist Wet; Streams: also Montane/Subalpine/alpine	• Affects riparian areas and various aquatic ecosystems through modified flow regimes.	• Water conservation and control (to prevent nutrient losses, control

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
DE-Water Demand Con't	• Loss or modification of riparian/ wetland area Causes changes in habitat distribution and associated species when severe.	Lower Columbia / Kootenay – (Interior Dry (localized)) • Riparian • Wetlands • Stream • Rivers • Lakes	• Lower low flows and reduced water yield. • Can be severe in drier areas or on smaller systems leading to complete dewatering and removal of habitat. • Habitat isolation/ reduced habitat connectivity. • Lethal to fish and detrimental to water quality (e.g. temperature, oxygen). • Cascading impacts on biodiversity downstream.	usage and run-off). • Irrigation management • Timing windows (for water usage)
FO- Fire Suppression	Fire suppression to protect mature forest land base results in: • Impacts to landscape pattern, reduced amount of 'natural' early seral forest, and overall habitat availability and quality in fire-maintained ecosystems; • Level of impact depends on a) natural fire frequency/severity, and b) success of suppression activities.	Kettle/ Granby – Interior Dry (Interior-Moist Wet) Lower Columbia / Kootenay - Interior Dry (Interior-Moist Wet) Upper Columbia – Interior Dry • Grasslands and Shrub-steppe • Dry forests • Intermediate forests • High elevation meadows	• Reduction in native grassland and shrubland ecosystem area through tree encroachment. • For all forested zones - increased area of dry forests and change in pattern of seral stages across landscape. Increase in mature forest area and changes to forest structure, resulting in denser, overstocked stands with increased moisture stress and higher incidence of insects and diseases. • Decrease in burned unsalvaged forest required by selected dependent species including species at risk (e.g., Lewis' and Black-backed Woodpeckers). • Loss and degradation of critical habitat and biodiversity for grassland, shrubland and open forest-dependent species; loss of forage and greater incidence of invasive species.	• Prescribed burning • Brushing and thinning • Wildlife tree retention • Invasive plant control

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
FO- Fire Suppression Con't			• Note interplay with climate change effects; increasing fire frequency and reduced effectiveness of fire suppression over time. • Low intensity fire helps to maintain dry subalpine meadows by reducing tree invasion.	
FO:- Landscape Level Modification	Affects harvesting rate and pattern over broad landscape resulting in: • Modifications to natural landscape patterns, with general reduction in size and number of remaining mature and old forest patches, combined with lack of connectivity corridors.	Kettle/ Granby – All zones Lower Columbia / Kootenay – All zones Upper Columbia – All zones • Dry forests • Intermediate forests • Wet forests • Riparian • Streams • Rivers • Lakes	• In all forested zones, loss and fragmentation of mature and older forests, and shift from natural seral stage distribution. • Biodiversity impacts include loss of connectivity, loss and alteration of habitat for older forest associated species, and creation of edge effects with impacts on parasitism/predation rates, as well as reproduction and survivorship. • Where harvest rate is rapid or large areas harvested, can get changes to hydrographs (higher peak flows, altered timing of flows. sedimentation and/or bank instability).	• Revegetation • Reconnection of isolated habitats • Slope/Bank stabilization • Nest structures • Invasive plant control • Wildlife tree creation/retention • CWD creation/retention • Flow naturalization • Channel morphology reconstruction (excavation, dredging, substrate addition) • Construction of aquatic structures • Fish passage/Barrier removal • Timing windows
FO – Roads	The majority of the road systems in this region are associated with forest extraction. Historically, many were built through sensitive riparian areas in valley bottoms where road impacts have been significant.	Kettle/ Granby – All zones Lower Columbia / Kootenay – All zones Upper Columbia – All zones • Dry forests • Intermediate forests • Wet forests • Riparian	• Extensive network of access promotes spread of non-native species which alters plant and animal community structure. • Direct wildlife mortality and increased disturbance. • Native ecosystem habitat loss and degradation.	• Revegetation (especially riparian/wetland) • Slope/Bank stabilization • Soil bioengineering • Soil amendments • Soil loosening • Invasive plant control • Sediment control

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
FO – Roads Con't	Road building and road use are known to cause: • Direct mortality and wildlife disturbance; • Habitat fragmentation and degradation, invasive weed spread, loss of connectivity where roads act as barriers for some wildlife (e.g., grizzly bear); • Access to sensitive or remote areas for people and predators. • The extent of local impacts depends on road density, use and sensitivity of the local resource. • Effects on aquatic • Cause barriers Although it is difficult to separate the effect of 'other' roads (e.g. mining roads), these are considered under their associated categories. Forestry roads are highlighted due to their prevalence on the landscape.	• Streams • Rivers	• Changes to connectivity, edge effects with barriers to sensitive species, increased access to other species, altered predator-prey dynamics and increased human-wildlife encounters and hunting/poaching. • Main access roads and skid trails cause loss of habitat, compaction, direct sedimentation on unstable slopes and erosion of road surfaces; where severe sedimentation with induced channel instability can result in long term degradation of aquatic habitats. • Roads modify hydrologic dynamics – from concentrated drainage and often exacerbated by networks of skid trails and high overall road densities, with loss of high-productivity sites, particularly in riparian areas. • Many remaining impacts from historic development of roadways in riparian ecosystems. Disruption of amphibian and turtle migration patterns. • Increased angling opportunities. • Increase for potential for introduction of non native species. • Restricted fish passage caused by road infrastructure such as culverts and bridges, impeding upstream fish migrations. • Reduced riparian vegetation where	• Wildlife crossings • Predator control • Deactivation • Reconnection of isolated habitats • Flow naturalization • Fish passage/Barrier removal • Construction of aquatic structures • Channel morphology reconstruction (excavation, dredging, substrate addition) • Off channel habitat creation/enhancement

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
FO – Roads Con't			roads parallel streams. • Increase in water temperature through loss of shade or conversion of groundwater to surface water. • Channel encroachment causing changes in flow dynamics. • Potential for landslides or debris flows initiated at roads. • Increase potential for erosion and sedimentation into streams, causing a decrease in water quality. • Where sedimentation is severe, induced channel instability can result causing long term degradation of aquatic habitats.	
FO- Riparian Disturbance Modification	Riparian vegetation removal results in: • Structure lost from riparian systems, causing direct loss of habitat, and cascading impacts on aspects of riparian system; • Forested and non-forested wetlands, lakes and rivers with inadequate protection; level of impact depends on practices followed, plus local species dependent on riparian habitat.	Kettle/ Granby – All zones Lower Columbia / Kootenay – All zones Upper Columbia – All zones • Non-forested wetlands • Forested wetlands • Cottonwood forests • Riparian • Streams • Rivers • Lakes	• Loss of riparian vegetation results in a loss and degradation of high value habitat for biodiversity, listed species, keystone species (grizzly bear), as well as a general decline in riparian function. • May result in higher water temperatures, loss of nutrient inputs (leaf litter, CWD input) and lower productivity. • Loss of large woody debris recruitment. • Reduced bank stability and lower water quality. • Increased sedimentation and bedload causing infilling of fish habitat. • Decreased channel stability and degraded littoral areas. • Possible impacts to fish and	• Revegetation (riparian) • Reconnection of isolated habitats • Slope/Bank stabilization • Soil bioengineering • Nest structures • Invasive plant control • Channel morphology reconstruction (excavation, dredging, gravel addition) • Wildlife tree creation/retention • CWD creation/retention • Fish passage/Barrier removal • Flow naturalization • Construction of aquatic structures • Timing windows

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
FO- Riparian Disturbance Modification Con't			amphibians and cascading effects to other biodiversity. • Changes in aquatic community structure, species composition, abundance and diversity.	
FO- Silviculture	• Activities associated with incremental silviculture (e.g., mechanical site prep., stumping, tree planting, fertilization, brushing, pruning, juvenile spacing and pesticide application, etc.) are varied and therefore have a range of impacts on ecosystems, depending on which activities are applied and how broadly and intensively silviculture is implemented across the landscape. • Silviculture is intended to accelerate the early stages of succession and conversion to a closed conifer-dominated stand	Kettle/ Granby – All zones (localized) Lower Columbia / Kootenay – All zones (localized) Upper Columbia – All zones (localized) • Dry forests • Intermediate forests • Riparian • Streams (Montane/Subalpine/ Alpine) • Rivers (Montane/Subalpine/Alpine) • Lakes (Montane/Subalpine/Alpine)	• In all forests, some activities (e.g., stumping) have significant negative long term impacts on biodiversity (soil mycorrhizae), whereas others (e.g., pruning/ spacing) may have positive impacts on many ecosystem components; difficult to generalize. • Application of pesticides to remove unwanted vegetation and reduce competition may lead to water contamination or mortality of non-target vegetation. • Tends to result in forest simplification and loss of unique structural attributes (e.g., wildlife trees) due to safety requirements associated with activities. • Some species dependent on early seral habitats impacted, while selected mid to later seral-dependent species may benefit; very species-specific. • Impacts of herbicides such as glyphosate on amphibians. • Use of fertilization may cause eutrophication of adjacent aquatic habitat. • Use of pesticide may result in contamination of water bodies.	• Revegetation (riparian buffers will help reduce water contamination) • Soil amendments • Soil loosening • Pesticide alternatives (manual removal, brush mats, planting more complex vegetation communities) • Timing windows • Invasive plant control • Slope/Bank stabilization • Wildlife tree creation/retention • Reconnection of isolated habitats • CWD creation/retention • Wetland creation/enhancement

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
FO - Stand Structure Modification	Harvest resulting in: • Loss of key stand structural attributes (e.g., wildlife trees, coarse woody debris, veteran trees, etc); • Variability in management regimes create range of localized effects but greater impacts where operability is high and silviculture systems diverge markedly from natural disturbance processes; • Exacerbated by local effects such as blowdown, salvage harvesting and firewood cutting.	Kettle/ Granby – All zones Lower Columbia / Kootenay – All zones Upper Columbia – All zones • Dry forests • Intermediate forests • Wet forests • Riparian •	• In all types, loss of older forest structural attributes such as large live and dead trees with specific features (cavities, loose bark, brooms, dens, chimney trees, etc.), large/hollow woody debris, and riparian stand structure. • Reduces within stand variability, patchiness and habitat complexity for many species. • At least 80 species dependent on wildlife trees and CWD for life requisites (breeding, feeding, denning, roosting, etc.); many are listed species that require specific stand structure attributes for population maintenance. • Loss of LWD input from riparian into streams and rivers reducing habitat diversity.	• Revegetation • CWD creation/retention • Wildlife tree creation/retention • Reconnection of isolated habitats • Nest structures • Invasive plant control • Timing windows
GR –Riparian / Wetland Disturbance	Grazing can result in: • Trampling of riparian vegetation and breeding habitat for terrestrial/ riparian species; • Loss of some vegetation types, plant community changes and introduction of invasive species; • Compaction, erosion, reduced vigour; • Fecal contamination.	Kettle/ Granby – All zones Lower Columbia / Kootenay – Interior Dry (minor in Interior Moist-Wet) • Grasslands and Shrub-steppe • Dry forests • Intermediate forests • Wet forests • Cottonwood forests • Forested wetlands • Non-forested wetlands • Riparian • Streams • Rivers • Lakes	• Local effects dependent on level of grazing, but potential impacts on all forested and non-forested ecosystems as they overlap with grazing tenures. • Key attributes affected include loss or damage to native vegetation, introduction of invasive species, plus direct fecal contamination. • Direct mortality and habitat degradation of riparian and wetland species. • Loss of riparian vegetation and degradation of riparian habitats and their functions.	• Riparian/wetland revegetation • Exclusions (Fencing) • Reconnection of isolated habitats • Slope/Bank stabilization • Nest structures • Invasive plant control • Soil loosening • Soil bioengineering • Flow naturalization • Spawning channels • Hatchery program • Construction of aquatic structures

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
GR –Riparian / Wetland Disturbance Con't			• Degradation of wetland and aquatic habitats through fecal contamination, eutrophication, loss of pools, degraded littoral areas, sedimentation, erosion, reduced bank and channel stability, compaction, faster run-off, etc. • Habitat loss (decline in deciduous and especially cottonwood recruitment due to heavy browsing).	• Channel morphology reconstruction (excavation, dredging, substrate addition) • Timing windows • Greater enforcement
GR - Vegetation Modification	• Livestock grazing impacts on native vegetation depend on grazing pressure; overgrazing results in loss of cover and erosion (due to soil compaction, reduced infiltration and increased run-off). • Practices to increase forage for cattle have a negative impact on native grassland species. • Species conversion in these areas, coupled with lack of fire, reduces ecosystem vigour.	Kettle/ Granby – All zones Lower Columbia / Kootenay – Interior dry • Grasslands and Shrub-steppe • Dry forests (Intermediate forests)	• Significant loss in native species distribution and abundance and species conversions with introduction and spread of invasive species. • In heavily grazed areas, loss of cover and erosion (due to soil compaction, reduced infiltration and increased run-off), particularly in formerly native grasslands. • Lower species loss and impact in forest ecosystems, but locally significant in some areas. • Habitat loss and reduced habitat suitability for other wildlife dependent on open grasslands, shrublands and forests with native plant associations.	• Revegetation • Reconnection of isolated habitats • Invasive plant control • Nest structures • Wildlife tree creation/retention • Exclusions (Fencing) • Timing windows • Soil loosening • Soil amendments • Native seed collection and dispersal • Greater enforcement
HA – Recreational Harvest	• Legal harvest of fish and wildlife populations for recreational purposes (e.g., sport fishery, trophy hunting) can result in native population declines in some areas, and shifts in species composition compared	Kettle/ Granby – Interior Dry/Moist/Wet (localized) Lower Columbia / Kootenay – Interior Dry/Moist/Wet • Lakes	Recreational fishing leads to changes in community structure including: • Species depletion. • Extirpations of native prey species (e.g., amphibians). • Extinctions due to by-catch. • Enhanced competitive edge of other	• Legislation/regulation changes • Greater enforcement

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
HA – Recreational Harvest Con't	to natural distributions.	• RiversReservoirs (Interior Dry/Moist/Wet)	species. • Poaching in rivers within restricted fishing windows (e.g. slocan river, salmo river).	
ME - Discharge	Solid and liquid waste/ discharge from mining activities (including adits, placer, tailings)	Lower Columbia/Kootenay Interior Dry/Moist/Wet • Streams •	• Deterioration of water quality in waterbodies. • Changes in biotic community structure, species composition, abundance and diversity. • Toxicity levels depend on the discharge volumes and content of discharge. • May lead to persistent contamination.	• Water treatment
ME – Mine Site	Includes establishment of new mines, reclamation of existing facilities and issues related to decommissioning and clean-up of historic mines. Impacts include: • Habitat loss and degradation due to land clearing and excavation; • Effects on water supply • Construction of roads/trails for exploration and mine development;	Kettle/ Granby – Interior Moist Wet (Montane-Subalpine-Alpine) Lower Columbia / Kootenay – Interior Moist Wet (Montane-Subalpine-Alpine) Upper Columbia – Interior Moist Wet (Montane-Subalpine-Alpine) • High elevation meadows • Avalanche zones • All forests (localized) • Forested wetlands • Non-forested wetlands • Riparian •	For all habitat types, mines result in: • Direct habitat loss and degradation; • Wildlife disturbance, displacement and mortality. • Spread of invasive species due to increased access. • Sedimentation from roads, excavation, land clearing. •	• Revegetation • Water treatment • Deactivation (trails/roads) • Exclusions (fencing for tailings) • Soil bioengineering • Reconnection of isolated habitats • Slope/Bank stabilization • Invasive plant control • Nest structures • Exclusion (bat hibernacula gates) • Native seed collection and dispersal • Soil loosening • Soil amendment •
NS - Non-Native Species	Invasive species are associated with: • Shift in species composition	Kettle/ Granby – Interior Dry; Interior Moist Wet (Montane-Subalpine-Alpine)	• Native grassland, shrubland and dry forest plant species diversity diminished / altered with associated	• Invasive plant control • Revegetation (including shade species planting)

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
NS - Non-Native Species Con't	and plant community structure; • Competition changes potentially resulting in native species decline.	Lower Columbia / Kootenay – Interior Dry; Interior Moist Wet (Montane-Subalpine-Alpine) Upper Columbia – Interior Moist Wet; Interior Dry (Montane-Subalpine-Alpine) • Grasslands and Shrub-steppe • Dry forests • Intermediate forests (more localized) • Non-forested wetlands • Cottonwood forests • Riparian • Streams • Rivers • Lakes • Reservoirs	changes to productivity and resistance to fire effects. • Changes to habitat structure and functions of key species impaired by encroachment of invasive spp. • Reduced habitat suitability for breeding wildlife. • Reduced forage (for wildlife and domestic species) with potential toxic effects. • Ingress of woody species into wetland and riparian areas previously dominated by grasses, in combination with loss of frequent flooding regimes. • Loss of structure and habitat simplification in riparian zones, resulting in bank erosion and sedimentation impacts. • Displacement of native species by aquatic alien species, with decreased habitat suitability for fish populations and cascading effects on other spp. • Increased competition with native fish species for resources such as food and habitat. • Displacement of native fish species. • Hybridization of native stocks (e.g. Westslope cutthroat trout and rainbow trout). • Increased predation by non native fish species. • Aquatic invasive plant species causing deterioration of habitat,	• Native seed collection and dispersal • Hatchery program • Wetland creation/ enhancement

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
NS - Non-Native Species Con't			decreased water quality, increased organic matter and reduced oxygen in wetlands, lakes and streams. (e.g. Eurasian milfoil,dydimo).	
RE – Resort Development and Operation	Clearing, construction and disturbance associated with resort (e.g., golf courses, skiing facilities, fishing lodges, backcountry lodges, etc.) development and operation results in: • habitat loss and conversion in remote or natural areas; • increased access and wildlife disturbance.	Granby / Kettle – Interior Dry Lower Columbia / Kootenay – Interior Dry; Interior Moist Wet (Montane-Subalpine-Alpine) Upper Columbia – Interior Dry; Interior Moist Wet (Montane-Subalpine-Alpine) • Grasslands and Shrub-steppe • Dry forests • Intermediate forests • Wet forests • Forested wetlands • Non-forested wetlands • Riparian • Lakes	• Potential for greatest impacts in wetlands and riparian areas due to direct habitat loss and modification (e.g., nutrient problems from sewage in streams, wetlands, etc.) • Ongoing maintenance activities may be associated with impacts (i.e., herbicide and other chemical use on golf courses and contamination risks to nearby streams; tree slashing and felling of hazard trees on ski hills leading to reduced stand structure, etc.). • greater access into remote or natural areas, resulting in wildlife disturbance, displacement, and human-wildlife encounters, as well as problems with attractants (e.g., food, waste). • effects on local fish and wildlife populations (through fishing, hunting, poaching).	• Revegetation (especially riparian) • Pesticide alternatives (manual removal, planting more complex vegetation communities) • Wildlife tree creation/retention • Reconnection of isolated habitats (wildlife corridors) • Invasive plant control • Slope/Bank stabilization • Nest structures • Wildlife tree creation/retention • Wastewater treatment • Fish passage/Barrier removal • Flow naturalization • Construction of aquatic structures • Channel morphology reconstruction (excavation, dredging, substrate addition) • Wetland creation/enhancement • Timing windows

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
RE- Motorized Aquatic	Use of motorized boats results in: • Wildlife disturbance and displacement; • Spread of invasive species.	Kettle/ Granby – Interior Dry/Moist/Wet Lower Columbia / Kootenay – Interior Dry/Moist/Wet Upper Columbia – Interior Moist Wet • Non-forested wetlands • • Lakes • Reservoirs	• Major impacts are on lakes, reservoirs and rivers where boating can disrupt successful breeding and feeding for some waterfowl, shorebirds or aquatic mammals, leading to elevated stress, reduced reproductive success and increased mortality for some species (including listed species such as western grebe). • Other impacts include shoreline erosion, spread of invasive species and associated changes to community structure; through the spread of non-native species. • Release of contaminants into the water such as fuels, reducing water quality.	• Revegetation (especially riparian/wetland) • Exclusions (fencing) • Slope/Bank stabilization • Soil bioengineering • Invasive plant control • Timing windows • Wastewater treatment
RE- Motorized Terrestrial	Includes ATV, snowmobile, dirt bike, 4 x4, helicopter, etc. use in sometimes uninhabited and remote areas with impacts including: • trampling of vegetation, rutting, compaction; • intro and spread of non-native species; • wildlife disturbance, displacement and mortality.	Kettle / Granby – All zones Lower Columbia / Kootenay – All zones Upper Columbia – All zones • Grasslands and Shrub-steppe • Non-forested wetlands • High elevation meadows • Riparian • Streams	• Wetlands, streams and riparian zones are impacted by mud-bogging. Instream use of ATVs results in significant sedimentation, erosion, loss of wetland/riparian vegetation, spread of aquatic invasive species, and degradation of sensitive habitat with various impacts to dependent species (i.e., fish, amphibians, invertebrates, and aquatic birds, mammals and reptiles). • Impacts to grassland habitats can also be severe and include vegetation loss and degradation, spread of invasive species, rutting, compaction, reduced productivity,	• Revegetation (especially riparian/wetland) • Exclusions (Fencing) • Stream crossing construction (bridge) • Slope/Bank stabilization • Invasive plant control • Deactivation (trails/roads) • Reconnection of isolated habitats • Channel morphology reconstruction (excavation, dredging, substrate addition) • Flow naturalization • Construction of aquatic structures

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
RE- Motorized Terrestrial Con't			loss of function, as well as disturbance and mortality impacts to dependent species. • Alpine and subalpine meadows are particularly vulnerable due to shallow soils, short growing season and sensitive herbaceous plant communities. • Disruption of streams at crossings, increased erosion, release of sediments and decrease in water quality.	• Wetland creation/enhancement • Timing windows
RE-Non-motorized Terrestrial	Non motorized activities (e.g., heli-skiing, backcountry touring, skiing, mountain-biking, hiking, camping, rock climbing, etc.) can result in: • trampling of sensitive vegetation; • potential disturbance of wildlife.	Kettle/ Granby – Montane-Subalpine-Alpine Lower Columbia / Kootenay – Montane-Subalpine-Alpine Upper Columbia – Montane-Subalpine-Alpine • Dry, intermediate and wet subalpine forests including whitebark pine forests • High elevation meadows	• Impacts most apparent in alpine and subalpine sites with moist, shallow soils, short growing season and sensitive herbaceous plant communities. • Impacts vary with sensitivity of ecosystem and intensity of use. • Impacts include increased wildlife disturbance, displacement, and human-wildlife encounters (e.g. caribou).	• Revegetation • Exclusions (Fencing) • Deactivation (trails/roads) • Invasive plant control • Timing windows
TC – Highways	Encompasses highway construction and use as well as modification of hydrologic features, impacts include: • habitat fragmentation • wildlife disturbance (e.g. road avoidance) • increased human exploitation (FO roads) • wildlife mortality • barriers to fish and wildlife movement	Kettle/ Granby – Interior Dry Lower Columbia / Kootenay – Interior Dry; Interior Moist Wet; Aquatic: Montane/Subalpine/Alpine Upper Columbia – Interior Moist Wet; Aquatic: Montane/Subalpine/Alpine • Forested wetlands • Non-forested wetlands • Riparian • Streams • Rivers	• In all ecosystem types, highway construction and use will result in direct habitat loss, degradation, and spread of invasive species. • Wildlife using the vegetation management zone will experience ongoing disturbance and habitat impacts. • Roadkill mortality is significant for most taxa and especially for listed species. Impacts tend to be highest in riparian and wetland habitats due	• Revegetation (especially riparian/wetland) • Invasive plant control • Wildlife crossings • Exclusions (Fencing) • Reconnection of isolated habitats • Stream crossing construction • Slope/Bank stabilization • Soil bioengineering • Sediment control

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
TC – Highways Con't	• • degradation of aquatic habitat quality • intro and spread of invasive species; • chemical applications for vegetation maintenance		to habitat simplification, reduction in riparian function, sedimentation, channel instability, and water contamination, as well as high wildlife impacts. • Highways are a barrier to movement for wide-ranging species (e.g. grizzly bear). Barriers can disrupt social structures, cause population fragmentation and isolation. • Some historic impacts still visible in population dynamics (e.g. the population break for bears between Kaslo and New Denver). Unknown long term effects elsewhere. • Disruption of social structure has occurred within National Parks where female grizzlies are much less likely to cross roads than males. • Disruption of processes that maintain regional populations due to movement barriers. Dispersal among local populations is important for maintaining gene flow, supplementing small or declining populations, and re-colonizing local populations lost to extinction events. • Storm water discharges, alterations in stream hydrology, and sedimentation affect the aquatic community, structure and function. • Restricted fish passage due to road infrastructure (culverts/bridges) impeding upstream fish migrations and reducing habitat connectivity.	• Fish passage/Barrier removal • Flow naturalization • Spawning channels • Hatchery program • Construction of aquatic structures • Channel morphology reconstruction (excavation, dredging, substrate addition) • Off channel habitat creation/enhancement • Floodplain reconnection • Timing windows

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
TC – Railways	Railways create/maintain linear corridors resulting in: • direct habitat loss; • habitat fragmentation • wildlife disturbance (e.g. railway avoidance) • wildlife mortality • barriers to fish and wildlife movement • degradation of aquatic habitat quality • intro and spread of invasive species; chemical applications for vegetation maintenance and preservation of railway ties are a source of contamination	Kettle/ Granby – Interior Dry Lower Columbia / Kootenay – Interior Dry; Interior Moist Wet Upper Columbia – Interior Moist Wet Aquatic: Montane/Subalpine/Alpine • Forested wetlands • Non-forested wetlands • Riparian • Streams • Rivers	• Direct habitat loss, degradation, and spread of invasive species. • Wildlife using the vegetation management zone will experience ongoing disturbance and habitat impacts. • Roadkill mortality is significant for most taxa and especially for listed species. • Impacts tend to be highest in riparian and wetland habitats due to habitat simplification, reduction in riparian function, sedimentation, channel instability, and water contamination, as well as high wildlife impacts. • Highways are a barrier to movement for wide-ranging species (e.g. grizzly bear). Barriers can disrupt social structures, cause population fragmentation and isolation. • Some historic impacts still visible in population dynamics (e.g. the population break for bears between Kaslo and New Denver). Unknown long term effects elsewhere. • Disruption of social structure has occurred where female grizzlies are much less likely to cross roads than males. • Disruption of processes that maintain regional populations due to movement barriers. Dispersal among local populations is important for maintaining gene flow,	• Revegetation (especially riparian/wetland) • Invasive plant control • Wildlife crossings • Stream crossing construction • Sediment control • Fish passage/Barrier removal • Exclusions (Fencing) • Reconnection of isolated habitats • Slope/Bank stabilization • Flow naturalization • Spawning channels • Hatchery program • Construction of aquatic structures • Channel morphology reconstruction (excavation, dredging, gravel addition) • Off channel habitat creation/enhancement • Floodplain reconnection • Timing windows

Threats	General Impacts*	Key Ecosystems Affected by Impacts within Sub-Basin & Ecological Unit	Specific Key Ecosystem Attributes Affected	Potential Ecosystem Restoration Techniques
TC – Railways Con't			supplementing small or declining populations, and re-colonizing local populations lost to extinction events. • Storm water discharges, alterations in stream hydrology, and sedimentation affect the aquatic community, structure and function. • Restricted fish passage caused by road infrastructure such as culverts and bridges, impeding upstream fish migrations and reducing habitat connectivity.	

7. Cumulative Sub-Basin Threat Summaries

In the following sections, we summarize the output from the ranked terrestrial and aquatic threats for different geographic sub-basin and ecological unit combinations (from Tables 3 – 8), as well as the general threat impacts and specific attributes affected for key ecosystems (Table 10).

In the case of some threats, the ecosystem itself is expected to respond in a particular way to a specific threat. For example, some systems are predicted to be moving towards a regime shift under climate change because they are located close to moisture tolerance threshold for key tree species. Other threats are highlighted because they are located in a particular location that has been subject to a variety of cumulative effects over a longer time period (e.g., areas of early settlement and development). There is often interaction between various threats which has tended to result in higher levels of impact at lower elevations and in the southern areas of the SRD. Since this effort is focused on identifying areas of greatest concern, threats at the higher elevations were not ranked within different ecological units (i.e., dry, moist wet). This was largely because threats (except perhaps for climate change) generally seemed to apply across ecosystem types, which were affected more by geographic location than moisture regime. In addition, emphasis in the summaries below was placed on ecosystems most affected by cumulative threats.

7.1. Kettle/Granby Sub-Basin

7.1.1. Terrestrial

<u>Kettle/Granby – Interior Dry</u>

Key ecosystems of concern include grasslands and dry forests, wetlands (all types), and cottonwood ecosystems.

Open forests and grasslands are impacted by a combination of almost all the top threats affecting this sub-basin, in particular climate change, non-native species, fire suppression, grazing impacts and direct habitat loss due to agriculture and private land development. These combined threats tend to interact and result in cumulative impacts that lead to complete habitat conversion and/or significant degradation of remaining habitat. Specific attributes affected by these combined threats include the loss of entire dry ecosystems, shifts in native understory species composition in grassland and dry forest sites, loss of older/larger stand structural attributes within forested areas, reductions in landscape connectivity and a resulting isolation of residual habitat patches. The current effects of fire suppression (i.e., progressive forest ingrowth and encroachment) may be counteracted by the effects of climate change. This is because the 'grassland' climate envelope is predicted to increase, and moisture stress may directly reduce the ability of trees to colonize grassland and open forest areas. In addition, fire frequency is expected to increase significantly and potentially cause rapid habitat shifts (from forested to non-forested). This would potentially exacerbate impacts linked to changes in understory species and increase the likelihood of colonization by non-native species.

Forested and non-forested wetlands are affected by most of the top threats, in particular climate change, agriculture, livestock grazing, private land development, and non-native species. Key attributes affected include loss of the entire system (due to conversion or drying), contamination and/or change in species composition due to livestock impacts or invasion by non-native species.

Although limited in extent, cottonwood ecosystems are impacted by a number of the top threats, including climate change (effect dependent on level of impact to water source), development activities (primarily on private land), non-native species, and agricultural conversion. Key impacts include complete loss of cottonwood riparian bottomland because of conversion to other land uses, change in species composition (loss of regenerating cottonwood coupled with changes in other understory species) as a result of drying and non-native species invasions.

Kettle/Granby – Interior Moist/Wet and Montane/Subalpine/Alpine

Key ecosystems of concern include all forested ecosystems and localized riparian and wetland habitats.

The Moist/Wet and the High Elevation zones within the Kettle/ Granby sub-basin show similar trends. In both zones, a combination of climate change, forest management and associated roads, fire suppression and grazing have a cumulative impact on the functioning of forest ecosystems (dry, moist and wet sites).

Forested Ecosystems - Forested ecosystems have been impacted at landscape and stand-level scales, resulting in the loss of connectivity, naturally-occurring older forest stands as well as larger/older stand structural attributes. The effects of fire suppression are generally not as intense as those in drier ecosystems of this sub-basin, however there has been a loss of naturally-occurring early seral forest, with some level of forest ingrowth on drier sites, plus a probable loss of un-salvaged burnt mature forest when compared to a natural system[4]. Road networks and forest management activities affect the local and tenuous grizzly bear population in this sub-basin, while connectivity to adjacent local grizzly populations is severely curtailed.

Riparian and Wetland Ecosystems - Grazing and forestry activities throughout non-forested and forested ecosystems of the sub-basin affect smaller riparian and wetland habitats, though likely in a localized fashion, and may exacerbate invasive species issues, particularly close to road systems. Key riparian attributes affected include native vegetation abundance and diversity, bank stability, water temperature and quality, nutrient input and productivity, and native fish and amphibian populations, with cascading effects on other biodiversity components.

7.1.2. Aquatic

Kettle/Granby – Interior Dry/Moist/Wet

Key aquatic ecosystems of concern in this sub-basin include streams, rivers and lakes.

The combination of climate change, agriculture, livestock grazing, forest management (historic and current), urban/rural development, transportation corridors, recreational fishing and non-native species introductions are expected to be a significant agent of change into the future. One of the main threats to aquatic habitats within this sub-basin has been identified as the increased pressures of water demand compounded with low precipitation rates, causing extreme low flows and high water temperatures during the summer months. Low seasonal flows and high seasonal temperatures within streams and rivers are detrimental to aquatic life. This area is differentiated from the two other areas within the SRD due to the absence of major dams.

[4] Based on general trends for this zone, rather than analysis of forest cover patterns for this localised area.

Streams – Water demand from agriculture and urban/rural development is a key concern for this sub-basin. Water diversion points in low order streams can be found throughout the sub-basin. The pressure of water demand confounded by historical practices of riparian logging or clearing, which have resulted in losses of woody debris recruitment within streams, and a decrease of woody debris input into larger rivers downstream, and within nursery tributaries, have had a net negative impact on fisheries habitat (Epp and Andrusak 2011). In addition, logging, agricultural and grazing disturbances including channelization/dyking and riparian removal or alteration has also resulted in low supply of riparian large woody debris. Removal of riparian functions can accelerate stream bank erosion and such activities can greatly affect natural geomorphology to the degree that there are significant losses of fish habitat (Slaney and Zaldokas 1997).

Rivers – Water demand, compounded by climate change, agriculture, grazing, forest management and urban/rural development disturbances, is not only a threat for streams but for river ecosystems. The mainstem of the Kettle River has experienced flow declines in the summer and increases in water temperatures reaching a daily maximum of 24°C (Epp and Andrusak 2011). High temperature exposure has had a cumulative negative effect resulting in fish mortality and reductions in abundance, especially in trout populations. This problem is further exacerbated by historical practices of riparian logging or clearing, which have resulted in losses of woody accumulations along river banks and at apexes of side-channels. Recreational fishing has added additional pressures on trout populations that are stressed from low flows, high temperatures, reduced riparian cover and large woody debris, and minimal deep pools for rearing and overwintering.

Lakes – The largest lake in this sub-basin is Christina Lake, and recreation, development, non-native species and water demand pressures here are most prevalent. Smaller lakes within the sub-basin are affected by forestry practices, agriculture/grazing, and non-native species. Climate change will generally have the effect of increasing water temperatures and decreasing water levels, which will affect cold water fish species such as salmonids. A decrease in precipitation would also decrease flows in small tributaries to small lakes that trout depend on for spawning.

<u>Kettle/Granby – Montane/Subalpine/Alpine</u>

Similar to low elevation areas, the aquatic key ecosystems of concern are streams, rivers and lakes.

Forest management impacts, compounded with climate change, non-native species and localized grazing have affected all aquatic ecosystems of concern in higher elevations. The main impact from grazing livestock is riparian disturbance and modification primarily in the Montane Spruce BEC zone. Forestry impacts in this sub-basin are similar to low elevation impacts where roads, landscape level hydrology changes and riparian/aquatic disturbances have altered aquatic ecosystems. Non-native species impacts are increasing with the expansion of invasives and recreational fish stocking.

7.2. Lower Columbia/Kootenay Sub-Basin

7.2.1. Terrestrial

<u>Lower Columbia/Kootenay – Interior Dry</u>

Key ecosystems of concern in this sub-basin include dry forests, wetland, cottonwood and other riparian ecosystems.

The combination of urban/rural development, fire suppression, forest management (historic and current) and dams have had significant cumulative effects on ecosystems, and climate change is expected to be a significant agent of change into the future.

Dry Forest Ecosystems - Very dry forests in the southernmost portion of this sub-basin are unique (particularly in the Lower Arrow Lake [IDFun], Lower Columbia and Pend d'Oreille Valleys [ICHxw]) and significant habitat loss has occurred as a result of fire suppression (loss of natural early seral habitats), reservoir flooding, dam construction, as well as recreational development. Substantial portions of these ecosystems have been lost, converted from their native state, or severely degraded as a result of flooding, smelter-related sulphur dioxide emissions, invasion and proliferation of non-native species and ingrowth of woody species through fire suppression. Key attributes affected include loss of whole ecosystems, changes to species composition and function, forest ingrowth, proliferation of invasive species and associated impacts to biodiversity. Open grassland, shrubland and forest habitats within these zones provide habitat for a range of listed species (e.g., various invertebrates, herptiles, birds) and isolation (loss of connectivity) of habitat patches is a concern for some species.

Dry forests and their associated open forest stand structure and dependent species have been significantly reduced as a result of fire suppression (ingrowth), historic harvesting (loss of large stand structures), dam construction and reservoir flooding. This has led to a loss of habitat as well as degradation from general development in valley bottom corridors. Key attributes affected include loss of whole ecosystems, loss of open forest stand structure, loss of older seral attributes, loss of connectivity of mature forest, changes to understory plant species composition and spread of non-native species.

Note that the above very dry and dry forests are quite similar but the habitat elements they support are somewhat different and warrant distinguishing very dry from dry. Furthermore, climate change is likely to shift at least the very dry forests into a grassland climate envelope more rapidly than the dry forests.

Cottonwood, Riparian and Wetland Ecosystems - These have been significantly diminished in this zone. Complete habitat loss has occurred through the variety of cumulative impacts (dam construction, reservoir flooding, riparian development) coupled with degradation due to loss of natural flooding regimes. In remaining systems, ingrowth from shrubs (native and non-native), plus lack of regenerating cottonwood stands has had a significant influence on this 'keystone' habitat type. Key attributes affected include loss of mature and regenerating cottonwood trees and associated native understory community, and loss of processes (e.g. maintenance of hydrologic regime and particular community structure) associated with the flooding regime.

<u>Lower Columbia/Kootenay – Interior Moist/Wet</u>
Key ecosystems of concern are forested ecosystems (dry, intermediate and wet sites), cottonwood forests, riparian habitat, and forest and non-forested wetland ecosystems.

This sub-basin is affected by a range of activities with cumulative impacts including climate change, forestry, habitat loss through dam construction and reservoir flooding, as well as development – particularly in the valley bottom.

Forested Ecosystems - In all forested ecosystems of this unit, landscape and stand level forest management have resulted in a loss of older forest patches, connectivity and stand structural attributes. These effects are relatively low in intensity, but extensive in nature, thereby affecting the distribution of many wildlife species (i.e., populations of ungulates, predators, wildlife tree users, with cascading effects in these ecosystems). Within the forested zone, dry forest sites are of particular concern in relation to climate change since trees on these sites may become significantly moisture limited and go through a regime shift to non-forested systems. The spread of invasive species would likely be exacerbated in this case.

All sites within the wettest ICH zones are of significant concern, given the extensive loss of the predominant old seral stage forest cover that existed prior to the onset of harvesting. Relatively few large patches of old and ancient forest remain and old forest attributes and connectivity have been significantly affected. Impacts have occurred in almost all of the lower elevation valley bottoms within these zones, and priority areas to maintain or restore include Trout Lake, Lardeau, Camborne area, North Kootenay Lake, Incomappleaux Valley and adjacent to Arrow Reservoir. Key species affected by these habitat impacts include mountain caribou populations and mature/old forest obligates (e.g, northern goshawk).

Cottonwood, Riparian and Wetland Ecosystems – Dam construction and reservoir flooding in the 'Arrow corridor' resulted in the loss of a significant area of forested and non-forested wetlands, cottonwood bottomland, and intermediate forest ecosystems. In addition, historic logging impacts on large riparian systems (e.g., on the Slocan and Salmo Rivers) have resulted in significant habitat loss (on land and in the aquatic portion) including cottonwood ecosystems and associated flooding regimes (in some areas), as well as large woody debris. Smaller riparian systems are affected to a lesser degree by forest management activities, but cumulative effects may exist in some areas of significant harvest. Key attributes affected include loss of cottonwood bottomland and other intermittently flooded forested riparian ecosystems, loss of natural riparian shoreline structure and function, and large stand structures on larger riparian systems.

<u>Lower Columbia/Kootenay – Montane/Subalpine/Alpine</u>

Key ecosystems of concern include forested ecosystems (all sites), whitebark pine ecosystems, and high elevation grasslands, wetlands and riparian areas (localized). This zone is affected by fewer activities, with key threats being climate change, forest management (fragmentation at landscape and stand level, and linked to riparian disturbance and associated roads), recreation (motorised and non-motorised), as well as historic and an increasing rate of current mine site development.

All Forested Ecosystems - The extensive nature of the impacts in this zone tend to affect all forest types, and key attributes affected include landscape connectivity, older forest stands and associated stand structural attributes (veteran trees, large wildlife trees and woody debris). Within this forested zone, whitebark pine ecosystems are of particular concern due to a suite of threats (i.e., blister rust, mountain pine beetle, fire suppression, climate change and forest harvesting).

Note that whitebark pine ecosystems have been extensively studied in local areas surrounding the Kootenay Sub-basin, however, maps of existing or vulnerable populations of whitebark pine are not available in the SRD (B. Wilson pers. comm.). However, various mapping projects are underway that will identify potential locations for restoration activities – these maps should be available in the next few years (contact B. Wilson for emerging details).

The extensive road network throughout this zone has led to substantial landscape fragmentation and associated decline in ecosystem function, further exacerbated by pervasive motorised access, recreational uses and associated disturbance. Key attributes affected include landscape level connectivity and degradation of habitat values for sensitive species (e.g., caribou, grizzly bear, mountain goat) with specific requirements (calving areas, denning sites, escape terrain, etc.).

Riparian and Wetland Ecosystems – The overall impacts on riparian and wetland systems in this zone are less than at lower elevations, however extensive historic harvesting and road building have likely affected stream reach integrity (i.e., composition, structure and function, water temperature, bank stability). Recreation has also resulted in localized impacts to high elevation wetlands through rutting, compaction, sedimentation, erosion, and reduced function.

Shrub Steppe / Open Forest Ecosystems / High Elevation Meadows – Recreational activities cause trampling and compaction in open meadows, with fragile/rare plant associations being key attributes affected.

Mine sites (historic and current) have the potential to impact all high elevation ecosystems (e.g., forest, riparian, wetland, grassland) depending on where they are situated. In particular, leaching from tailings may affect water quality and cause localized contamination.

7.2.2. Aquatic

<u>Lower Columbia/Kootenay – Interior Dry/Moist/Wet</u>

All aquatic ecosystem of concern are considered high priority in this sub-basin including streams, rivers, lakes and reservoirs.

Climate change, urban/rural development, forest management (historic and current), dams, transportation corridors, mining (historic and current) and non-native species introductions are key cumulative threats to this sub-basin.

Dam impacts are significant in this sub-basin, affecting all aquatic ecosystems of concern. The stream and river losses have all occurred at lower elevations (<1000 m), and larger low gradient rivers have been disproportionately affected (Thorley 2008). Shallow water habitat loss from dams was estimated at approximately 2 km^2 for the Lower Columbia River (Mackillop 2008); this loss has had significant effects on breeding, rearing and feeding of invertebrates, fish, aquatic birds and mammals.

Streams – Forest management impacts from roads, riparian disturbances and hydrology changes have had extensive effects across the landscape on stream ecosystems. Highways and railways have created barriers to fish movement, altered hydrological function and increased sedimentation of streams. With increased development pressures, water demand and riparian disturbances have also increased. These impacts have been compounded by the effects of dam construction. Losses of low elevation 1st and 2nd order streams total 42 km for the Duncan Reservoir. For the Arrow Lakes, 30 km of 1st -2nd order streams and 47 km of 3rd-5th order streams/rivers were lost (this includes the Upper Arrow Lake which is found in the Upper Columbia Sub-basin).

Rivers – The lotic habitat types most affected by dam construction are not only the most productive but preliminary analysis of a fish inventory database suggests that they are also the richest in terms of the number of native fish species (Thorley 2008). Higher order, lower elevation and lower gradient reaches also tend to have higher fish standing crops as well as larger individuals. A loss of 46 km of 6th - 7th order rivers occurred in the Duncan Reservoir. Along Arrow Lakes, 110 km of the mainstem Columbia and 14 km of 6th-7th order rivers were lost (this includes the Upper Arrow Lake which is found in the Upper Columbia Sub-basin). It is likely that the inundated spawning areas included much of the better quality habitat since alluvial fans and low gradient reaches ideal for kokanee spawning were typically in the lower reaches that were lost (Arndt 2009).

The main ongoing impacts from dams are from flow regulation and creation of physical obstructions for aquatic communities. Fluctuating non natural flow dynamics leads to changes in aquatic community structure, stream temperature regimes, modified sediment regimes, associated changes in channel bed structures, as well as modified nutrient dynamics. Physical obstructions have caused entrainment and reduced passage of organisms denying access to key habitats for various species, particularly for anadromous fish species.

Climate change, forestry practices (e.g., roads and riparian disturbances), recreational fishing, non-native species and urban/rural riparian habitat conversion are applying additional pressures on a system that has been extensively affected by hydroelectric power generation.

Lakes – Although dam construction has resulted in a net increase in 'lake' habitat of over 600 km^2, the increases have not been uniformly distributed among lentic habitat types. In the entire Columbia Basin, the area of medium-sized lakes has actually declined by 29 % (40 km^2) as medium lakes have been inundated by the newly created reservoirs. Thirteen percent (13 km^2) of low to moderate elevation small lakes have also been inundated (Thorley 2008).

On the Duncan Reservoir, 26 km^2 of lake were lost from dam impacts. Construction of the Keenleyside Dam inundated the Upper and Lower Arrow Lakes, which had a combined surface area of 350 km^2, producing Arrow Lakes Reservoir the largest lake in the sub-basin with a surface area of 476 km^2 (this also includes the Upper Arrow Lake which is found in the Upper Columbia Sub-basin).

As lakes offer numerous recreational opportunities, impacts have been increasing from non-native species, riparian habitat conversion, littoral zone modifications, sewage disposal, fishing and increased boat usage and infrastructure. As development pressures increase in this sub-basin, so will the impacts. Climate change will further exacerbate impacts by having the effect of increasing water temperatures, which are less suitable for salmonid species and more suitable for other non native fish species, such as cyprinids.

Reservoirs – The construction of dams has caused historical impacts to lotic and lentic environments by transforming them into reservoirs. Historical impacts are mentioned in the stream, river and lake ecosystems of concern sections. In addition to historical impacts, reservoirs experience on-going impacts due to dam management. Non-natural fluctuating water levels from flow regulation cause loss and degradation of native shoreline vegetation and reduced habitat suitability for feeding and breeding fish, amphibians, reptiles, birds and mammals. Reservoirs have experienced a decline in productivity due to daily and seasonal water fluctuations, persistent shoreline erosion, sedimentation changes, and an altered nutrient regime upstream and downstream of the dam. The magnitude of fish entrainment impacts has not been quantified but is speculated to cause significant mortality. Additional pressures on fish populations include recreational fishing, non native species and recreational boat use. Climate change will reduce the ability to maintain reservoirs at their maximum capacity, affecting littoral habitats to a greater degree.

Lower Columbia/Kootenay – Montane/Subalpine/Alpine

The high elevation aquatic key ecosystems of concern are streams, rivers and lakes.

Forest management, climate change and non-native species are the main impacts for all aquatic ecosystems of concern in higher elevations. Forestry impacts from roads, landscape level hydrology changes, riparian/aquatic disturbances and to a lesser extent silviculture practices (e.g., pesticides) have altered high elevation aquatic ecosystems and caused cascading impacts downstream. Non-native species impacts are increasing with the expansion of invasive algae such as didymo (*Didymospenia geminate*) in streams and recreational fish stocking in lakes. In addition to the main impacts, all terrain vehicles continue to be a concern due to sedimentation, erosion, loss of wetland/riparian vegetation, spread of aquatic invasive species, and degradation of sensitive habitat with various impacts to dependent species (e.g., fish, amphibians, and invertebrates). A resurgence of mining exploration has been prevalent in this sub-basin and could result in additional future impacts.

7.3. Upper Columbia Sub-Basin

7.3.1. Terrestrial

Upper Columbia – Interior Dry

Key ecosystems of concern include grasslands and dry forest sites, wetland and cottonwood ecosystems.

Grasslands and Dry Forests – These are currently affected by a combination of almost all the top threats operating in this sub-basin - climate change, non-native species, fire suppression, stand structure modification through forest management and direct habitat loss due to agriculture and private land development. These threats tend to interact and result in cumulative impacts to these key ecosystems of concern. Key attributes affected by the combination of threats include changes to native understory species composition, tree ingrowth and encroachment in open forest or grassland systems, respectively, loss of large stand structural attributes in forested zones. Climate change may counteract the effects of fire suppression by increasing the total area of this zone within a ‘grassland’ climate envelope. Warming and drying will likely result in the loss of mature forest within this zone, as fire frequency increases.

Wetland and Cottonwood Ecosystems – This sub-basin has an intact wetland system of extremely high importance along the Columbia River. Historic development of sections of this system had significant impacts, though the wetlands are significantly restored today. Changes to the flooding regime have negatively impacted cottonwood regeneration, and on-going effects of development adjacent to many riparian systems (lakeshore, river, wetlands) have resulted in habitat loss, degradation and disturbance to dependent wildlife populations.

Upper Columbia – Interior Moist/Wet

Key ecosystems of concern include forested and non-forested wetlands, cottonwood forests, and all forest ecosystems (dry, intermediate and wet sites).

Forested and Non-forested Wetlands and Cottonwood Ecosystems – As a result of Revelstoke dam construction and reservoir flooding, extensive non-forested and forested wetlands, wet forests, and cottonwood riparian forests were lost with key attributes affected including extensive floodplains, gravel bars, mature cottonwood trees, as well as loss of valley bottom connectivity.

All Forest Ecosystems (dry, intermediate, wet) – Extensive natural old growth in this sub-basin has been converted to younger seral forest through forest harvesting and road-building, thereby significantly altering the seral stage distribution across the landscape, and the availability of old seral attributes at the stand level. An over abundance of early seral habitat has promoted a shift in the prey abundance of ungulates, negatively affecting mountain caribou populations. In addition, motorised recreation within these forest zones has significant local impacts on animal use and movement. Additional key attributes lost include connectivity of mature forest ecosystems due to fragmentation from harvesting, road systems, and motorised recreation trails.

Climate change is expected to have a significant impact, even in these wet forest types, with drier sites predicted to shift from Cedar-Hemlock to Douglas-fir dominated forests.

Upper Columbia – Montane-Subalpine-Alpine

Key ecosystems of concern include forested ecosystems (all sites), whitebark pine ecosystems, high elevation grasslands (localized), and wetland and riparian habitats.

Key threats affecting these ecosystems include climate change, forestry (resulting in landscape and stand level effects as well as riparian and road impacts), recreation (motorised and non-motorised), as well as historic and recent mine site development.

All Forested Ecosystems – The extensive nature of impacts in this zone tend to influence all forest types and the key attributes affected include older forest stands and associated stand structural attributes (veteran trees, wildlife trees large woody debris, etc.), as well as fragmentation and disturbance of remaining forests from logging, extensive roads, and recreational use. Whitebark pine ecosystems are of particular concern due to the combination of threats impacting them (blister rust, mountain pine beetle, fire suppression, and climate change). [Contact B. Wilson regarding specific areas with potential for restoration of whitebark pine]. Local impacts to sensitive species (caribou, grizzly bear, mountain goat) are also an issue.

Riparian and Wetland Ecosystems – Overall impacts to riparian and wetland systems in this zone are less than at lower elevations, however extensive historic harvesting and road building have likely affected stream reach integrity (i.e., composition, structure and function, water temperature, bank stability). Recreation has also resulted in localized impacts to high elevation wetlands through rutting, compaction, sedimentation, erosion, and reduced function. Mine sites (historic and current) have the potential to impact all high elevation ecosystems (e.g., forest, riparian, wetland, grassland) depending on where they are situated. In particular, leaching from tailings may affect water quality and result in localized wetland or riparian contamination.

Grassland Ecosystems / High Elevation Meadows – Recreational activities cause trampling and compaction in open meadows, with fragile/rare plant associations being key attributes affected.

7.3.2. Aquatic

Upper Columbia – Interior Dry/Moist/Wet

Key aquatic ecosystems of concern in this sub-basin are streams, rivers, lakes and reservoirs.

The Upper Columbia includes a small area of Interior Dry ecological unit, located in the vicinity of Golden along the valley bottom. The major aquatic impacts to this area are largely related to recreational activities such as all terrain vehicle use, transportation corridors (highways, roads and railways), and urban/rural development. Creeks that drain into the Columbia River system have the highest impact and are of primary concern. Riparian vegetation removal/damage, sedimentation, erosion, and degradation of sensitive habitat have had various impacts to dependent species in the area (i.e., fish, amphibians, invertebrates, aquatic birds and mammals).

Streams –The combination of climate change, dams, forest management (historic and current), transportation corridors, non-native species and to a lesser extent urban/rural development are expected to have significant cumulative effects. Modifications to streams have occurred as a result of dam flow regulations, forestry practices and transportation corridors. Direct habitat loss of low elevation streams is largely the result of Mica and Revelstoke Dam construction, where 122 km 1st and 2nd order streams and 128 km for streams/rivers of 3rd-5th order have been lost (Thorley 2008). Shallow water habitat loss from dams was approximately 6 km^2 for the Upper Columbia (Mackillop 2008).

Rivers – Similar to streams, significant impacts to rivers have occurred as a result of dam flow regulations, forestry practices, and transportation corridors. In addition, urban/rural development and non-native species are of concern. The aquatic habitat losses post dam construction have been substantial, 625 km of 6th order and greater rivers have been lost in Kinbasket Reservoir and Revelstoke Reach alone. Loss of the Columbia River from Bush Arm to Mica Dam was 93%. The construction of the Revelstoke Dam has resulted in the inundation of 100% of the Columbia River now known as Revelstoke Reach, a 142 km long section.

The main ongoing impacts from dams are from flow regulation and creation of physical obstructions for aquatic communities. Fluctuating non natural flow dynamics leads to changes in aquatic community structure, changes in stream temperature regimes, modified sediment regimes, associated changes in channel bed structures, as well as modified nutrient dynamics. Physical obstructions have caused entrainment and reduced passage of organisms denying access to key habitats for various species, particularly for anadromous fish. Water licenses have been issued for a number of streams and rivers throughout this area for hydro production which could lead to additional pressures to aquatic ecosystems.

Lakes – Five small and medium lakes with a combined surface area of 24 km^2 and 5.55 km^2 of shallow water habitat have been lost due to dam construction in the Upper Columbia. Construction of the Keenleyside Dam inundated the Upper and Lower Arrow Lakes, which had a combined surface area of 350 km^2, producing Arrow Lakes Reservoir the largest lake in the sub-basin with a surface area of 476 km^2 (this includes the Lower Arrow Lake which is found in the Lower Columbia/Kootenay Sub-basin).

Very few low elevation lakes exist within the Upper Columbia Sub-basin, largely due to dam construction. Impacts to these lakes are primarily from forestry practices and non-native species.

Reservoirs –The construction of dams has caused historical impacts to lotic and lentic environments transforming them into reservoirs. Historical impacts are mentioned in the stream, river and lake ecosystems of concern sections. In addition to historical impacts reservoirs experience on-going impacts due to dam management. Upper Arrow Lakes and Kinbasket Reservoir experience non-natural fluctuating water levels from flow regulation causing loss and degradation of native shoreline vegetation and habitats and reduced suitability for feeding and breeding fish, amphibians, reptiles, birds and mammals. Kinbasket Reservoir minimum and maximum licensed water levels are 707.1m and 754.4m respectively. Water levels can therefore fluctuate 47.3m in annual operations (BC Hydro 2011). In comparison Upper Arrow Lakes water levels are allowed to fluctuate 20.1m (420.0m minimum - 440.1m maximum). Although typical operations do not fluctuate to this extent Kinbasket Reservoir does experience far greater water level changes. From daily and seasonal water fluctuations these reservoirs have experienced a decline in productivity due to, persistent shoreline erosion, sedimentation changes, and an altered nutrient regime upstream and downstream of the dam. The magnitude of fish entrainment impacts has not been quantified, but is speculated to cause significant mortality. Additional pressures on fish populations include recreational fishing, non native species and recreation boat use.

<u>Upper Columbia – Montane/Subalpine/Alpine</u>

The high elevation aquatic key ecosystems of concern are streams, rivers and lakes.

The high elevation aquatic ecosystems in the Upper Columbia Sub-basin are primarily affected by forest management, climate change, non-native species and recreational use (e.g., ATV, hiking, skiing). Forestry impacts from roads, landscape level hydrology changes, riparian/aquatic disturbances and to a lesser extent silviculture practices (e.g., pesticides) have altered high elevation aquatic ecosystems and caused cascading impacts downstream. Climate change will further exacerbate these impacts by affecting water temperatures and flows, which will provide a competitive advantage to non-native fish species.

In addition, the spread of non-native algae species such as didymo (*Didymospenia geminate*) will expand as recreationists get access to more remote areas. In addition to the main impacts, with increasing access into the high elevations, all terrain vehicles will be a concern due to sedimentation, erosion, loss of wetland/riparian vegetation, spread of aquatic invasive species, and degradation of sensitive habitat with various impacts to dependent species (e.g., fish, amphibians, and invertebrates). Impacts from recreational use, such as all terrain vehicles and hiking, is most apparent in alpine and subalpine sites with moist, shallow soils, short growing season and sensitive herbaceous plant communities.

As highways and railways pass through these higher elevation areas, they cause barriers to movement, alterations in stream hydrology and sedimentation, thereby affecting aquatic community structure and function. Impacts tend to be highest in riparian and wetland habitats due to habitat simplification, reduction in riparian function, sedimentation, channel instability and water contamination.

8. Ecosystem Restoration Techniques

Ecosystem restoration techniques were identified in Table 10 to address the key threats and impacts to the SRD. The restoration techniques broadly describe ways to restore ecosystems of concern and associated descriptions are found in Appendix 3. Restoration techniques are important components of an overall ecosystem restoration approach, as they may serve to repair or re-introduce degraded or missing parts in a "broken" system. However, it is important to acknowledge that single stand alone techniques may not restore underlying ecosystem function, structure and processes. Simultaneous implementation of a mosaic of restoration techniques coupled with resumption of the underlying driving processes (e.g., fire in NDT4 ecosystems, seasonal flooding regimes in cottonwood bottomland forests) will be required to fully achieve restoration on an ecosystem scale.

Since restoration techniques are often used simultaneously to address impeding impacts, it is difficult to prioritize these techniques for a sub-basin. Likewise, ecosystems of concern in different areas are impacted with varying severity. Similar reasoning applies to addressing cost and effectiveness of restoration techniques at this scale. Not only will each ecosystem of concern have varying severities of impacts, the logistics for restoration activities will also vary depending on site-specific factors (e.g., access to the area, proximity to restoration resources, type of equipment needed), which can cause significant variations in cost. The effectiveness of a specific restoration technique will also vary, depending on a range of environmental variables in an ecosystem of concern.

It is recommended that specific ecosystem restoration projects determine the suite of threats and associated impacts that affect their target area (e.g., watershed, ecosystem or habitat type) and then identify the priorities for restoration for that target based on cost and potential effectiveness.

9. Summary and Knowledge Gaps

In the sub-basin summaries above (Results Section III), we highlight the key ecosystems of concern *within each of the geographic sub-basins* used to stratify the study area. However, there remains overall regional priority areas that can be identified based on historic and current cumulative effects.

In general, the lowest elevation areas of the southern regions of the Selkirk Resource District have been most heavily impacted and this also tends to coincide with the driest / warmest regions. These areas have the longest history of development activities, and have also been impacted by the broadest suite of impacting activities, hence these areas have the highest overall restoration priority within the SRD. In addition, whitebark pine ecosystems at high elevations have been systematically impacted across British Columbia, and such impacts are projected to worsen, therefore the latter are also a priority.

No attempt was made to focus on restoration of selected single species (e.g., rare and endangered) habitats that are closely linked to the ecosystems of concern highlighted here. This was mainly due to the additional detail required, which exceeded the project scope and funds available. Identifying key (e.g., listed) animal and plant species or a suite of listed/sensitive species all of which share the same ecosystem of concern may be a way to further prioritize specific projects within broader ecosystems of concern.

In addition to these general priorities, the landscape level effects of forest management have had two particular significant effects: (1) in wetter ICH variants, harvesting is significantly different from the natural disturbance regime, and it results in a significant loss of old growth forests at the landscape level, and (2) in the driest forested ecosystems in the region, fire suppression has similarly caused a significant landscape level shift in natural processes. Restoration of ecosystems or species-specific habitats in these zones should be prioritized.

Aquatic habitats that have been most impacted are also located in areas of highest population density and development and are affected by a variety of activities. One of the most significant impacts is the construction of dams for power generation and water storage. These were often constructed in remote areas, where flooded lakes, rivers and streams previously supported an abundance and diversity of habitat for aquatic and riparian life. As long as these dams are in operation and natural processes are suspended (e.g., seasonal flow and flooding regimes, fish passage, nutrient cycling, etc.), options to alleviate cascading impacts are very limited. Some operating regimes can partially mitigate some impacts of dam operations, however, the window within which they operate is dictated by transboundary agreements, and changes to these would be outside the scope of this plan. Restoration techniques can however be applied to reservoirs to assist in the creation of more productive habitat that was historically lost. Examples of such techniques include establishment of large woody debris structures in shallow waters and decompaction of old development sites that were flooded. A useful planning process would entail delineating the larger watershed groups within the three geographic sub-basins of the SDR and identifying their key threats and aquatic values. A ranking system to prioritize watersheds and the reaches within them, as well as the applicable restoration options, could then be developed.

The predicted climate change information can be applied and used to modify:

- Wetland systems – these will likely become increasingly stressed through SRD and highest emphasis for restoration should be placed on systems where long term maintenance is likely (e.g., wetlands with a relatively predicable water source);
- Streams / rivers – those already stressed by low flows either because they are already located in dry areas or experience high water demands should be prioritized;
- Riparian systems – especially in southern regions of the study area, these may become increasingly stressed due to moisture reduction, particularly during summer (restoration of vegetation that promotes maintenance of wetland processes should be a high priority where possible);
- Drier forested ecosystems – in southern zones and on dry sites in the mid and north of the region, consider potential future transition from forested to non-forested ecosystems (identify areas where the transition agent [e.g., fire] may cause significant resource losses [such as important wildlife habitat]and look for opportunities to buffer or otherwise reduce fire probability in high priority areas);.
- All ecosystems – consider genetic diversity, and whether current provenance approaches are appropriate (also consider non-local species);
- Movement corridors – identify known potential movement corridors and manage to promote resilience;
- Identify crucial habitat for key species today – and assess whether appropriate for a 'resistance' strategy;
- Consider target sites where future species may move – restore or maintain habitat and habitat structures in target areas ;
- Build in resilience – consider a wider range of species than may have been applicable historically (e.g. consider promoting a move to more fire resistant tree species in areas where this has traditionally not been a goal).

Knowledge gaps are numerous and include gaps under the following headers:

Threat Identification

- The work presented here is built on existing studies, and local knowledge of existing local threats. For this project, we have applied this information at a more fine-scale of resolution than it was originally generated for. Specific local threats may therefore be different than identified here and exceptions to the general patterns identified here should be expected.

- The threats are primarily the results of historic and current human activities (with the exception of climate change). However, a number of other activities are changing their effects on the landscape at this time. For example, there is significant tenure for development of independent power projects in this region (e.g., both run-of-river and wind generation projects). Both of these, as they are developed, will begin to shift priorities identified here. Most of the comments with regard to mining are focused on the effects of historic mining activities, however significant mining development is planned at this time and this could become a larger impact in future.

Attributes of Concern

- The attributes of concern are identified at a general scale, based on typical impacts of various activities. In designing specific restoration projects, site-specific information should be used to identify locally relevant attributes of concern and integrate these into cohesive restoration prescriptions..

Climate Predictions

- Large uncertainties are associated with different aspects of the climate change information (e.g., what will future greenhouse gas emissions be and how specifically will this affect climate? What vegetation / ecosystem responses will occur?). However, it is generally accepted that the uncertainties should not be used as an excuse for not incorporating climate information into decision-making. An analysis of a wide variety of climate models and future emissions scenarios all result in similar trends in future temperature for British Columbia. The primary factor changing is the rate and overall magnitude at which the change occurs (though future moisture information has less clear trends in direction across a range of models and is considered to be less reliable). Therefore, incorporating ideas regarding a warming (and summer drying) future climate is a necessary part of planning, even though there remain uncertainties about what will actually occur.

Efficacy of Restoration Activities

- The effectiveness of some restoration activities are better known than others, and particularly in a climate change context, there are more uncertainties with respect to the overall effectiveness of restoration activities.
- In this circumstance, it is especially important to develop clear restoration goals and objectives, detailed prescriptions and workplans, as well as well-defined schedules and measurement endpoints for effectiveness monitoring and adaptive management.
- Based on the findings from project monitoring, periodic review and modification of SRD restoration program activities will be necessary, and development of an overarching program-level restoration monitoring plan to evaluate restoration effectiveness and to set program priorities is recommended.

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Appendix 1. A Ratings Table for Use in the Compilation of Assessment Tables for Each Realm (From Holt et al. 2003).

	Topic	5	4	3	2	1
P	**Persistence of Threat**	Current, and definitely increasing in future	Current and likely to continue, and some chance of an increase in future; or not current, but likely to be very significant in the future	Current, but uncertainty about future, may continue, but may decrease in future; or not current, but some possibility of future significance	Definitely diminishing in future	Past only, threat ceased
Ev	**Evidence**	Strong, undisputed evidence	Strong evidence, but some contrary views	Moderate evidence, but some contrary views	Weak evidence but no contrary views, or moderate with significant contradictory information	Very weak or little evidence; little certainty; or highly contradictory information
DC	**Degree of Change**	Sufficient change to eliminate key functions of an ecosystem process or habitat element, or eliminate a whole ecosystem	Significant change to a key process, ecosystem or habitat element, such that its functioning is severely compromised	Changes that result in significantly reduced functioning to an ecosystem process, ecosystem or habitat element	Changes that result in reduced functioning of an ecosystem process, ecosystem or habitat element in some locations	Minor change to an ecosystem process, particular ecosystem or habitat element, functioning not effected
Ex	**Extent**	Pervasive impacts throughout the applicable area	Numerous moderate to large locations	A few moderate to large locations or numerous well-distributed small locations	A few small or isolated locations within the applicable area	A single isolated location within the applicable area
R	**Reversibility**	Impacts are non-reversible within a century	Impacts can recover naturally within a century or quicker with extensive investment	Impacts take many decades (~5-10) to recover and require moderate investment	Impacts recover naturally in a few decades (~<5) and require minimal investment	Impacts recover naturally in a short period
KS	**Keystone species***	A major factor leading to the significant decline of keystone species – due to direct killing or elimination of critical habitat	Effects keystone species in a significant way, over extensive areas, either directly or via habitat modification	Effects keystone species in a significant way over limited area, or in a moderate way over a large area	Effects keystone species in a limited way over large areas, or in a moderate way over a small area	Effects keystone species, but only in a marginal way in a small percentage of its applicable range

Appendix 1. (Cont'd)

	Topic	5	4	3	2	1
FS	**Focal species***	A major factor leading to the significant decline of focal species – due to direct killing or elimination of critical habitat	Effects focal species in a significant way, over extensive areas, either directly or via habitat modification	Effects focal species in a significant way over limited area, or in a moderate way over a large area	Effects focal species in a limited way over large areas, or in a moderate way over a small area	Effects focal species, but only in a marginal way in a small percentage of its applicable range
RS	**Rare species***	A major factor leading to the listing of rare species – due to direct killing or elimination of critical habitat	Effects rare species in a significant way, over extensive areas, either directly or via habitat modification	Effects rare species in a significant way over limited area, or in a moderate way over a large area	Effects rare species in a limited way over large areas, or in a moderate way over a small area	Effects rare species, but only in a marginal way in a small percentage of its applicable range
What		Comments on the specifics of the impacts, what activities, what processes, functions, ecosystems, spp. are impacted.				

- Keystone species are those having a larger ecological impact than that suggested by their biomass.
- Focal species is a generic term for any species considered of particular interest in an area.
- Rare species are those designated as rare or threatened under the BC Conservation Data Centre rating system or COSEWIC

Appendix 2. Rating Key for Ranking Threats and Impacts (From Holt et al. 2003).

Threat/ Impact Characteristic	Rating Criteria					Comments
Magnitude						An index based on a summation of the degree of change and reversibility of those changes at various ecological levels.
Type of Change	Processes/ Functions	Whole Ecosystems	Habitat Elements	Individual Species Keystone Rare Focal	Genes	Impacts at various ecological levels are additive (changes at higher levels often have cascading impacts).
Degree of Change	Elimination of key process, habitat element, or whole ecosystem	Severely reduced function of key process, ecosystem or habitat element	Significantly reduced function of process, ecosystem or habitat element	Reduced function of process, ecosystem or habitat element in some locations	Minor changes to process, ecosystem or habitat element, function not effected	Degree of change accounted for 50% of the score at each of the ecological levels. At the species/gene level, max. degree of change accounted for 100%.
	High Ranking (5)	←======================================→			**Low Ranking (1)**	Ratings (1 – 5) from Assessment Tables.
Reversibility of Change	Recovery is not possible within a century	Natural recovery almost a century or quicker with extensive investment	Recovery takes decades (~5-10), even with moderate investment	Natural recovery in a few decades (~<5) with minimal investment	Natural recovery in a short period	Reversibility of change accounts for 50% of the score at each of the ecological levels (except species).
Extent						An index based on the % occurrence within geographic/ecological units, and local distribution within each of those.
Local Distribution	Pervasive throughout applicable area	Numerous moderate to large locations	Few moderate to large locations or numerous well-distributed small locations	Few small or isolated locations within the applicable area	Single isolated location within the applicable area	The local distribution of impacts throughout individual ecological units within individual geographic areas.
RANKING CLASSES	**Very High**	**High**	**Moderate**	**Low**	**Not Known to Occur**	

Appendix 3. Restoration Technique Descriptions

Restoration Techniques	Descriptions
Aquatic	
Channel morphology reconstruction (excavation, dredging, substrate addition)	Stream channel reconstruction including restoration of natural channel characteristics (pool riffle sequences, meander bends) to channelized and modified streams and rivers.
Construction of aquatic structures	Structures installed to increase habitat complexity, protect river banks, provide grade control. Includes: large woody debris, boulder clusters, deflectors/weirs.
Fish passage/Barrier removal	Removal of pipes, culverts, weirs, dams or any blockages impeding fish passage.
Floodplain reconnection	The use of heavy equipment to reestablish and create floodplain surfaces at appropriate elevations to hydrologically connect to main channels. Improves deposition of fine sediments, riparian vegetation recruitment and hydroperiods.
Flow naturalization	Restoring natural flow patterns.
Hatchery program	Rearing of native fish for release into natural environment to aid in species recovery.
Modified flow regulation	Flow management programs including variable flow releases to restore more normative flow conditions for critical life stages such as increased flows for sturgeon migration and spawning.
Nutrient addition	Lake and stream fertilization.
Off channel habitat creation/enhancement	Off-channel habitats include: overflow, groundwater and wall-based side channels, freshwater sloughs, alcoves, ponds, wetlands, overwintering pools, protective alcoves, channel pond complexes and other permanently or seasonally flooded areas important for rearing juvenile salmonids.
Recontouring (to prevent fish stranding)	The use of heavy equipment to recontour surfaces in areas where high rates of fish stranding occur.
Revegetation	Planting native vegetation including grasses, forbes, sedges, rushes, shrubs and trees. Includes bed preparation, seeding, transplanting, and maintenance.
Sediment control	Road rehabilitation, outsloping and cross ditching.
Slope/Bank stabilization	Stabilization of eroding banks including steep slopes and streambanks using hard engineering solutions. Includes: riprap, gabion walls, retaining walls, recontouring, slope roughening, terracing, check dams, drainage control, geosynthetic material applications.
Soil bioengineering	The use of live plant materials in combination with natural and synthetic support materials for slope stabilization, streambank stabilization, revegetation and erosion control. Includes: brush layers, brush mattresses, wattle fences, live pole drains, live staking and joint planting.
Spawning channels	Recreation of channels specific for spawning of fish species.
Spillway modification	To reduce total gas pressure (TGP).
Stream crossing construction	Includes bridges and boardwalks to prevent motorized and non-motorized damage.
Stream relocation	Creation/redirection of stream habitat in an area not affected by mining activities.
Timing windows	Conducting instream work during periods of least risk to fish. Timing windows for effective usage of water, pesticides, etc.
Wastewater treatment	Numerous wastewater treatment technologies exist including retention basins, filtrations, diffusers, reagents, etc.
Water conservation and control	Techniques used to prevent nutrient losses, control usage, run-off.
Wetland creation/enhancement	Includes wetland restoration (reestablishment of impacted wetland to a previously existing condition prior to

	disturbance), enhancement (maintenance and management of existing wetlands for a particular value and/or restoring degraded wetlands to higher quality sites) and creation (establishment of an artificial wetland where it never existed historically).
Terrestrial	
Chemical alternatives (manual removal, planting more complex vegetation communities)	Fertilizer/pesticide alternatives (manual removal, planting more complex vegetation communities, use of cover crops, seasonal rotation).
CWD creation/retention	Includes felling large trees to create wildlife habitat and mechanical modification of logs/stumps to create hollows, cavities, runways, dens, etc.
Deactivation (roads/trails)	Recontouring old roads, revegetation, culvert removal, bridge removal, ditching, cross ditching, water bars, gully management.
Exclusions	Includes fencing, road closures, placement of boulders or logs, fish-netting to reduce dam entrainment. Bat gates involve the installation of a pre-fabricated gate to block access to a valuable roost site (often a mine adit or cave).
Invasive plant control	Includes biological control, mechanical control (cutting, mowing, discing), hand removal, overseeding, herbicide use.
Legislation/regulation changes	Changes in regulations and laws to reduce impacts that will aid in ecosystem restoration.
Native seed collection and dispersal	Includes mechanical and manual harvesting, seed traps, etc.
Nest structures	Includes installation of nest boxes and nesting platforms for various birds, reptiles and bats.
Predator control	Culling of wildlife to reduce impacts on sensitive prey.
Prescribed burning	Using a variety of intensities and duration of fire to restore a natural process. Includes backing fire, strip head fire, flanking fire, point source/grid ignition fire, ring fire, aerial ignition.
Reconnection of isolated habitats (connectivity)	Improving habitat value by reconnecting habitats. Includes: wildlife corridor retention and establishment.
Soil amendments	Mycorrhizae, biosolids, organic matter, compost, nutrients, etc.
Soil loosening	Techniques include tilling, turning, drilling, subsoiling.
Thinning, brushing and pruning	Includes the removal of vegetation through brushing, harvesting, limbing and herbicide use.
Timing windows	Conducting work during periods of least risk to affected species or habitats. Chemical application and irrigation timing to prevent runoff, leaching and drift. Avoiding tillage, grazing and harvesting during wet periods. Also includes closures and restrictions on timing for recreational activities.
Wildlife crossings	A crossing above or below an obstruction (road, railway) that allows passage of wildlife.
Wildlife tree creation/retention	Techniques include fungal inoculation, cavity construction, snag planting, stub creation (high cut stumps when harvesting), tree topping, tree girdling, other mechanical techniques to create slits, cracks, hollows, etc. and rtree retention.